Lecture Notes in Networks and Systems 1130

Irina Samoylenko
Toshpulot Rajabov *Editors*

Innovations in Sustainable Agricultural Systems, Volume 1

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Editors

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Preface

This volume contains the proceedings of International Conference on Innovations in Sustainable Agricultural Systems held by Stavropol State Agrarian University (Russia) and Samarkand State University named after Sharof Rashidov (Uzbekistan) on 4–5 March, 2024. The papers are focused on four main sections: sustainable development of agricultural production, intelligent agricultural techniques, tools, and systems, sustainability in veterinary practice, and economic, ecological and social systems for human development.

The sustainable development of agricultural systems focuses on ensuring that agriculture practices are environmentally friendly, socially responsible, and economically viable for long-term success. It involves implementing sustainable practices such as conservation agriculture, crop rotation, integrated pest management, and organic farming to minimize negative impacts on the environment, while improving soil health, biodiversity, and water conservation. By adopting sustainable agricultural systems, farmers can increase their resilience to climate change, reduce greenhouse gas emissions, and promote sustainable food production. It also takes into consideration the social aspects of agriculture, including fair labor practices, community engagement, and ensuring access to healthy and affordable food for all.

Farm sustainability constitutes the practice of maintaining and improving the long-term health of a farm while simultaneously ensuring the economic viability of the operation. This involves implementing practices that promote soil health, reduce water consumption, minimize chemical inputs, and support biodiversity on the farm. One important aspect of farm sustainability is food quality and safety. Farmers need to ensure that the food they produce is of high quality and safe for consumers to eat. This involves following proper food safety protocols, such as good agricultural practices, proper handling and storage of produce, and regular testing for contaminants. Additionally, farmers may choose to implement practices such as organic farming to reduce chemical residues in their produce.

The integration of digital, automatic, intelligent, and robotic systems in the agro-industrial complex has revolutionized the way farming operations are conducted, leading to increased efficiency, productivity, and sustainability. These advanced technologies have transformed traditional agricultural practices into smart and data-driven processes that optimize resource utilization, reduce waste, and improve overall outcomes. Digital technologies such as precision agriculture, remote sensing, and Geographic Information Systems (GIS) allow farmers to collect and analyze real-time data on soil quality, weather conditions, crop health, and yield estimates. These data enable farmers to make informed decisions regarding planting, irrigation, fertilization, and pest control, leading to more precise and effective management practices.

One key aspect of agricultural social sustainability is ensuring that farmers and farm workers are treated fairly and have access to resources and services that enable them to thrive. This includes providing fair wages, safe working conditions, and opportunities for education and skills development. Socially sustainable agricultural systems also prioritize diversity and inclusivity, ensuring that marginalized groups have equal access to resources and opportunities within the agricultural sector. Additionally, farmers should receive fair prices for their products, have access to affordable credit and insurance, and are able to adopt cost-effective and efficient farming practices.

Overall, the book presents innovative approaches that consider environmental, social, and economic factors in agricultural practices.

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About the Editors

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Sustainable Development of Agricultural Production

Colorimetric Selection, User Authentication, Identification and Access Control at Agricultural Enterprises

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Abstract. The large volume of information flows in agricultural systems requires systematizing information resources for storing, processing, receiving and transmitting digital information. The massive information cloud carries confidential information about the entirety of agricultural processes, such as planting and harvesting various crops, cultivating land, logistics, geolocation, placement of buildings for livestock farming, financing of agricultural enterprises and others. Currently, there is a large number of information attacks on the resources of an agro-industrial complex in the digital space. Therefore, the need for information security concerns this area as well. This study is driven by the need to protect information and to control access to these resources. In this regard, there is a problem of access control and protection against unauthorized actions. Since the access control implies user authentication and identification, we propose to consider the use of colorimetric selection and the formation of a color atlas or map to address these issues. On this basis of a structural algorithmic selection scheme we propose an assessment of color quality and color selection digitalization. According to the results of the empirical analysis, a colorimetric matrix for color selection is suggested.

Keywords: Authentication · identification · selection · colorimetry · access control · information security

1 Introduction

Agriculture is one of the key industries in global economies. A well-established food supply system affects every person on Earth. Since in the modern world all branches of the national economy are subject to computerization and globalization, agriculture is no exception. At the moment, information, telecommunications and navigation technologies are actively used in agribusiness, as well as software and hardware that ensure the operation of systems like precision farming and automatic control of production processes. It makes possible to gain unauthorized access to personal data and documents containing confidential information. The active development of the Internet of Things (IoT) involves the use of modern technologies for smart irrigation and lighting systems,

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for automating farms and monitoring the condition of livestock, for optimizing product supply chains and compiling digital maps using unmanned aerial vehicles, and much more. All this leads to the fact that the problem of information security is reaching a new level. Existing systems are usually based on authentication or biometric identification, and within the framework of this study it is proposed to use colorimetric selection to ensure a higher level of information security.

It has already been proposed to form a digital atlas for encoding digital information [7]. A number of scientific papers are devoted to the synthesis of the color gamut, but the simultaneous use of colorimetric selection, authentication and identification has not yet been applied. The comparative analysis of the available research results showed the possibility of introducing colorimetric selection in the field of information security and in the agribusiness in particular. Therefore, the purpose of this article is to improve the algorithmization and digitalization of color solutions [8], which increases resistance to unauthorized actions and the efficiency of decision-making on the admission of users to the information resources of the agro-industrial complex.

2 Materials and Methods

At agricultural enterprises, the problem of computer and network information security is considered comprehensively. From the point of view of information protection, the human-machine system is based on user authentication. Existing methods of using a login and password have a number of significant drawbacks that reduce the effectiveness and accuracy of authentication and identification. To eliminate these disadvantages, it is proposed to consider colorimetric selection based on the optical properties of the material (color, hue, reflectivity, etc.). Colorimetric selection decomposes the primary colors into components, and the combination of the main color and its shades creates a composite image [1]. The composite image can be adjusted by the proportions of the base colors, which are determined by the color coordinates, as all other values are mathematically calculated based on them. Since the flow of color radiation is reflected and absorbed, it is necessary to take into account the coefficients of reflection, transmission, and absorption, which are measured by spectrophotometers [2]. In order to improve the resistance of identification features based on biometric characteristics, it is proposed to consider the possibility of creating a color map for personal identification and access control to the segments of information resources (Fig. 1).

From Fig. 1, it can be seen that the main element is colorimetric selection. Based on this, a structural-algorithmic scheme has been developed (Fig. 2).

The coloristic shaper plays the main role in the chromaticity selection. This process involves transferring the color from the color cloud to the chromaticity picker device. The formation of chromaticity requires certain assumptions in order to maintain its quality. To ensure the quality of chromaticity, the following concepts are proposed for consideration (Fig. 3).

The chromaticity picker device selects the presented chroma F_{chr} and luma F_l signals and selects the chromaticity using the D_k decoders and the intermediate frequency filter (IFF) (Fig. 4).

To digitalize the chromaticity selection, it is proposed to use information technology in the PAINT editor (Fig. 5).

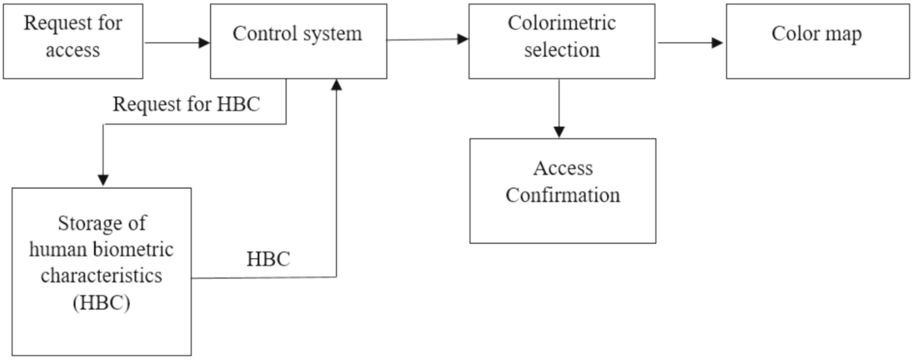


Fig. 1. Creating a colormap

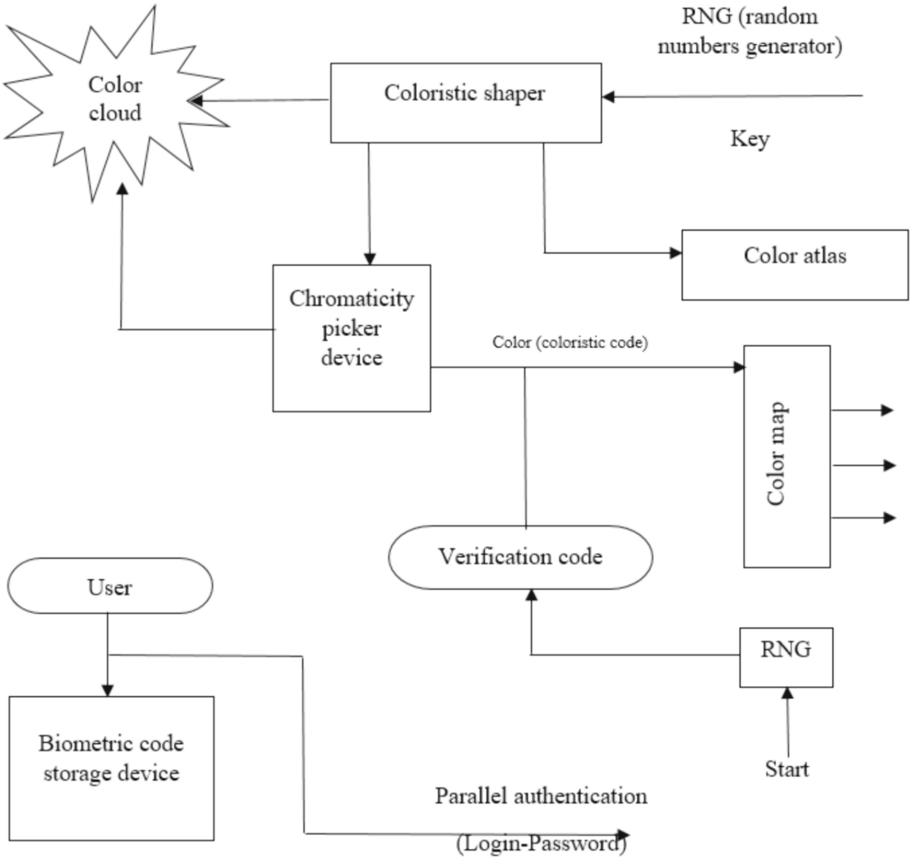
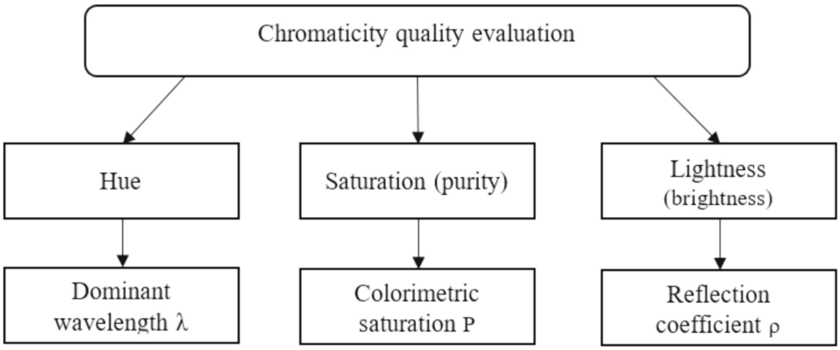


Fig. 2. A structural-algorithmic scheme of colorimetric selection



Characteristic	λ_i	P	ρ
Calculation formula	From the chromaticity table	$P = \frac{B_\lambda}{B_\lambda + B} * 100\%$ B_λ– *brightness of pure color* *B – brightness of mixture*	$\rho = \frac{F_{\text{отр}}}{F_{\text{пад}}} * 100\%$ $F_{отр}$ – *reflected flow* $F_{пад}$ – *incident flow*

Fig. 3. Chromaticity quality evaluation

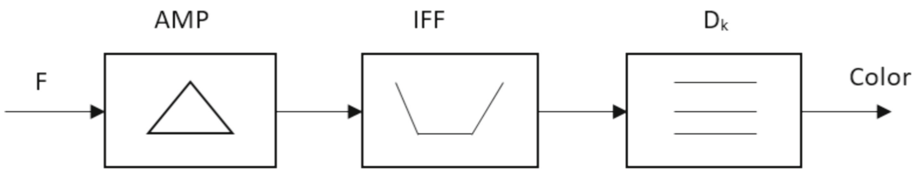


Fig. 4. Block diagram of the chromaticity picker device

In addition, the chromaticity picker forms a color and converts it into a digital series (coloristic code), which, in order to check for errors and authenticity, is supplemented with a verification code (for example, the sum of the parity and the odd). The verification code is launched using a random number generator (RNG). This contributes to the accuracy of encoding and minimizing errors (characterized by the error probability P_{err}).

Chromaticity selection is carried out by providing the user with a biometric characteristic, which is stored digitally in the biometric code storage device (BCSD) and activated by the user with parallel authentication (Login-Password). Login-Password is issued to the user by the administration of the enterprise, and can also be transmitted in cryptographic form via telecommunication channels of various physical nature, as well as complex physical principles [3].

The biometric code storage device stores and processes biometric characteristics converted into code sequences and is used for parallel authentication (identification) of the user, which makes it possible to significantly reduce the number of errors and false actions [4].

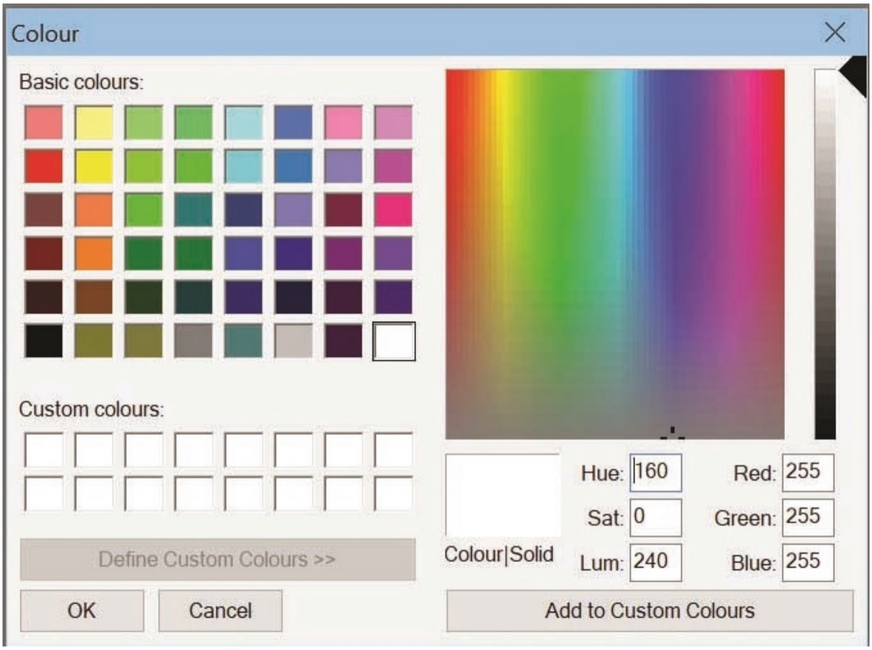


Fig. 5. Digitalization of chromaticity selection

Based on the presented colors from the color atlas, the color map shaper synthesizes the distribution of chromaticity (coloristics) on digital or paper media in the form of a matrix after the selection of chromaticity (Fig. 6).

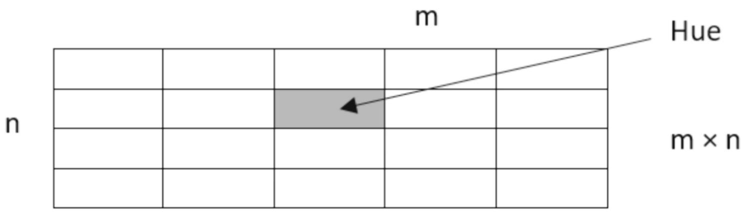
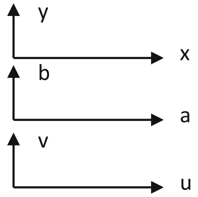


Fig. 6. Coloristic matrix of chromaticity selection

From Fig. 6 it is possible to make a conclusion about the application of a reference space in color selection, which can be expressed in generally accepted forms approved by the International Commission on Illumination (CIE):

$$\begin{cases} CIE_{xy} \\ CIE_{axb} \\ CIE_{uv} \end{cases} \tag{1}$$



Where CIE_{xy} is a direct representation of the original functions of the main three colors,

CIEaxb are transformations during the colorimetric selection,

CIEuv is correction of imbalance during the colorimetric selection.

This reference space in color selection (1) has a sample of "standard coloristic observation" in a subset of all visible colors that are defined by CIE. Chromaticity selection sets priorities in the display of colors.

3 Results

To assess the quality of biometric characteristics (HBC) of the colorimetric code (CC), it is proposed to use the percentage of errors in controlling access to information [5], which has the following form (Fig. 7):

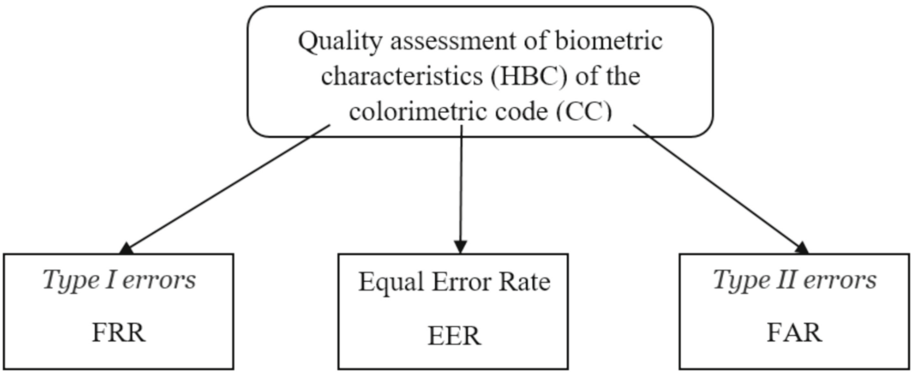


Fig. 7. Quality assessment of biometric characteristics (BHC) of the colorimetric code (CC)

It can be seen from Fig. 7 that the following parameters are distinguished:

FRR is a probability of mistaking "friend" for "foe".

FAR is a probability of mistaking "foe" for "friend".

EER – Equal Error Rates, equal possibility of FRR and FAR errors.

When conducting research, a comparison system was used. If the obtained values of the system are equal, or are better in at least one indicator, then such a system is recognized as better than the others. Since the digital code with a code length L = up to 1000 bits is stored in the database for each human biometric characteristic, the

Table 1. FRR and FAR values

№	Method	Requirement	Result		
		FRR	FAR	FRR	FAR
1	Digital encoding of BHC (DE BHC)				
	0,025–0,01	10–3 – 10–6	0,025	10–4	
2	Digital colorimetric encoding (DCE BHC)	0,025–0,01	10^{-3} – 10^{-6}	0,025	10–3

colorimetry has a digital code $L_{kk} > L$ which increases the length of the code. However, this L_{kk} has shown a decrease in the FRR and FAR values presented in Table 1.

From the obtained values it can be seen that digital colorimetric encoding of biometric characteristics has an advantage over digital encoding in terms of FAR parameter. Based on the obtained results, it is recommended to use the proposed selection technique (digital colorimetric encoding of human biometric characteristics) in agricultural enterprises.

4 Discussion

The analysis of the structural-algorithmic scheme of colorimetric selection shows that the generated reference color parameters, color representation parameters, and the functioning of the area of their comparison require the proof of their correlation.

Due to the fact that the phenomena under study have correlations and a set of individual parameters [6], the indicator of the strength of association between the reference and declared parameters must satisfy the following basic requirements:

1. The value of the degree of confidence between them tends to 0 if there is no direct correlation between color phenomena;
2. In the presence of a functional relationship between the confidences, the degree of confidence tends to 1;
3. In the presence of a correlation, the coefficient of their correlation is a proper fraction and the greater the absolute value, the better the correlation coefficient between the parameters [11].

Taking into account all the above, the best characteristic of the strength of association for evaluating statistical studies of the use of a biometric identification system is the Fechner coefficient (K_F). The K_F is calculated as the ratio of the difference between the number of matches and the number of mismatches of deviations of individual biometric values to their sum:

$$K_F = \frac{n_a - n_b}{n_a + n_b} \tag{2}$$

where n_a is the number of matches of biometric chromaticity parameters;

n_b is the number of mismatches between the declared biometric chromaticity parameters.

The calculated Fechner coefficient (K_F) according to the obtained research data is:

1. K_F (low level) = + 0,5;
2. K_F (medium level) = + 0,7;
3. K_F (high level) = + 0,75;

The average value: $K_{\text{of the level of matches}} = + 0,59$.

The resulting average value of the $K_{\text{of the level of matches}} = + 0,59$ indicates (> 0.5) a strong consistency in the statistical research. This means that there is a direct correlation between the above-mentioned attributes [12]. This allows us to conclude that the solution of the problem set in the scientific paper is correct. Therefore, colorimetric selection, along with authentication and identification, can be used in agro-industrial enterprises.

5 Conclusion

The advantages of the proposed colorimetric selection algorithm are that such protection provides a greater effect compared to other systems [9]. This characterizes a high level of security of the software-hardware implementation, as it is not possible to simultaneously lose, steal, or counterfeit all possible color cards and passwords. It is worth noting that the use of digital technologies in colorimetric selection opens up new possibilities in this scientific field. One of the promising directions is the use of artificial intelligence and machine learning to analyze color characteristics and automate the selection process.

Information security and access control to information resources are important aspects of information security in the field of agriculture and beyond. Without proper security measures, information can be compromised, leading to serious consequences such as data leakage, financial losses, and disruption of company operations. To protect information, it is necessary to use various methods, such as data encryption, access control in combination with colorimetric selection. In general, information security and access control are important tasks for any organization, as they help ensure data security and prevent potential threats. This is a promising direction for the development in any field of activity. The applied coloristics requires a high level of resolution and an increase in L. This increases code redundancy, but improves resistance to any kind of exposure [10], which gives an advantage over other identification systems. Thus, it can be concluded that the goal of this article has been achieved, as there is indeed an improvement in the algorithmization and digitilization of color solutions, which increases resistance to unauthorized actions and speeds up the decision-making on user access to the corporate information resources in the agribusiness sector.

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Mineral Fertilization System for Sustainable Apple Production in Southern Russia

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Abstract. Sustainable fruit production plays a crucial role in ecosystem preservation. However, farmers are facing challenges in achieving economic yield due to the frequent occurrence of abiotic stressors and weather anomalies associated with climate change. The research is aimed at determining the optimal doses of mineral fertilizers (NPK) when growing various varieties in compacted apple plantations in southern regions of Russia to ensure the sustainable development of the agroecosystem of the garden. The research was carried out under the conditions of field experience set in 2022–2024 in an irrigated intensive apple orchard, laid in 2016 on the territory of the Kuban educational and experimental farm of the Kuban State Agrarian University (Krasnodar). The soil of the experimental site is leached chernozem. The trees are arranged according to the scheme 4.0 x 1.0 m (2500 trees/ha). The scheme of the experiment included the study of the following doses of fertilizers: 1 – control (production background recommended for traditional plantations – 1666 trees/ha: $N_{130}P_{130}K_{130}$); 2 - production background + $N_{40}P_{40}K_{40}$; 3 - production background + $N_{60}P_{60}K_{60}$; 4 - production background + $N_{80}P_{80}K_{80}$. In order to ensure the sustainable functioning of compacted apple plantations, a differentiated approach is needed to select the optimal dose of mineral fertilizers using the intensity of tree growth of the varieties. Apple varieties, characterized by restrained tree growth, are the most responsive to an increase in the level of mineral nutrition. At the same time, when using high-growth varieties, doses of mineral fertilizers should be minimized.

Keywords: apple tree · compacted plantings · mineral fertilizers · doses · economic yield · sustainable fruiting

1 Introduction

Sustainable production of fruits, which are an important source of vitamins and biologically active substances, is one of the priorities of the agro-industrial complex of Russia. However, its solution is hampered by the rather frequent manifestation of various abiotic stressors and weather anomalies associated with the emerging trend of climate change [14, 17]. In particular, in the south of Russia in recent years, there has been a significant increase (in comparison with the climatic norm) in the average decadal air temperature during the autumn-winter period [4]. In order to mitigate the negative impact of abiotic

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factors on fruit plants and ensure stable fruiting at a sufficiently high level, it seems advisable to implement an adaptive gardening strategy based on a more differentiated use of the adaptive potential of cultivated plant varieties and man-made factors [11, 26]. Based on this concept, the development of varietal farming techniques is required for the sustainable functioning of perennial fruit plantations (garden agrocenosis). One of its main elements is the fertilization of the garden – a powerful factor in increasing the yield of fruit crops [18, 22]. The further intensification of the horticulture industry and the activation of the laying of compacted plantations dictates the need for some adjustment of the recommended fertilizer system, especially against the background of changing climatic characteristics.

In this regard, the aim of the research was to determine the optimal doses of mineral fertilizers (NPK) for sustainable production of various apple trees in compacted plantations against the background of local climate change in the southern regions of Russia.

2 Materials and Methods

The research was carried out in laboratory and field experiments (2022–2024) in an irrigated intensive type garden in 2016, located on the territory of the Kuban educational and experimental farm of the Kuban State Agrarian University (Krasnodar city). The soil of the experimental site is leached chernozem, the soil availability of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) is average.

Fertilizers Ammophos, Carbamide and Kalimag were used in the experiment.

The object of research is apple varieties of winter consumption on dwarf rootstock M9, cultivated according to the 4.0×1.0 m scheme. Row spacing was kept under tinning, the trunk strip was under herbicidal steam. The method of forming the crown of trees is a slender spindle.

The subject of research is the dose of fertilizer.

The scheme of the experiment included the study of the following options: apple variety – Golden Delicious, Kuban Crimson (factor A); fertilizer dose (factor B); 1 – control (production background (PB) recommended for traditional plantations – 1666 trees/ha: $N_{130}P_{130}K_{130}$); 2 - production background + $N_{40}P_{40}K_{40}$; 3 - production background + $N_{60}P_{60}K_{60}$; 4 - production background + $N_{80}P_{80}K_{80}$. The repeatability of the experiments is threefold, 4 plants are registered in the repeat.

Fertilization was carried out in autumn in the trunk strip to a depth of 15 - 18 cm at a distance of 0.5 m from the tree trunk. The agrotechnics in the experimental plantations corresponded to the recommended one [24].

Records and observations were carried out according to generally accepted methods [19], the stages of organogenesis of the apple tree – according to Isaeva [10]. The analysis of the obtained results was carried out using the methods of mathematical statistics [6, 16].

3 Results

As the experiment showed, the maximum hydration of leaf tissues in the Golden Delicious apple variety was recorded in the variant where the recommended level of mineral nutrition was increased by 1.5 doses, and in the Kuban Crimson variety – only by one dose (Fig. 1). When using increased doses of NPK, the hydration of leaf tissues is significantly lower than in the control.

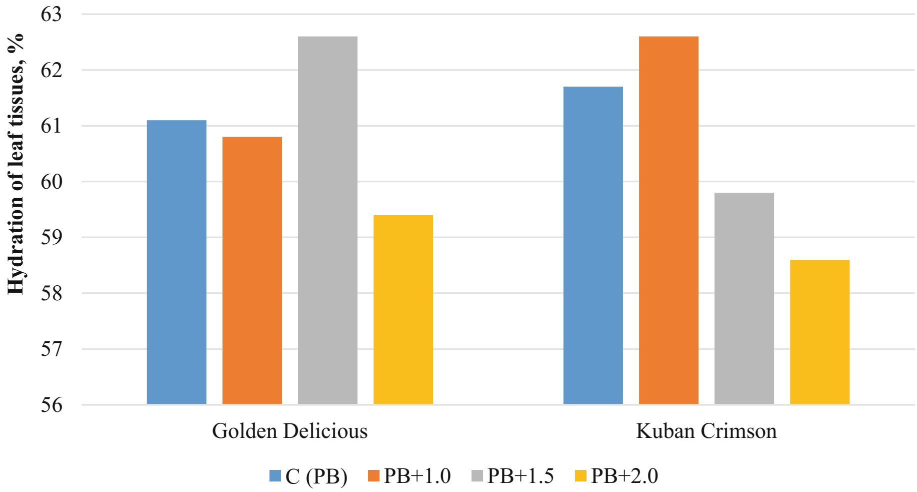

Fig. 1. Hydration of the tissues of the leaves of the Golden Delicious and Kuban Crimson apple varieties, depending on the dose of fertilizers (July 2023)

It is noteworthy that an increase in the level of mineral nutrition by 1.5 – 2.0 doses provides a significant (by 22 – 88%) increase in the net photosynthetic productivity (NPP) of apple plants of the two studied varieties (Fig. 2). Moreover, the most prominent differences with the control were recorded in the Golden Delicious variety.

According to the results of our experiments, an increase in the considered physiological parameters of the plant organism – the hydration of leaf tissues and NPP, associated with an increase in the dose of mineral fertilizers, is associated with a change in plant growth indicators (Table 1).

An increase in the level of mineral nutrition of apple trees compared to the recommended 1.0 - 2.0 doses leads to a natural increase in the diameter of the tree trunk and the length of annual shoots. Moreover, when using a high dose of mineral fertilizers, the average length of the annual shoot of the Golden Delicious apple tree increases by 1.6 times compared to the control value, and in the Kuban Crimson variety – by 1.9 times reaching 61 cm. In addition, with an increase in the level of mineral nutrition by 1.0 - 2.0 doses, the Kuban Crimson variety recorded intensive formation of shoots of the second growth wave. It is appropriate to note that, taking into account the diameter of the tree trunk, the Kuban Crimson variety is characterized by more intensive growth compared to the Golden Delicious variety.

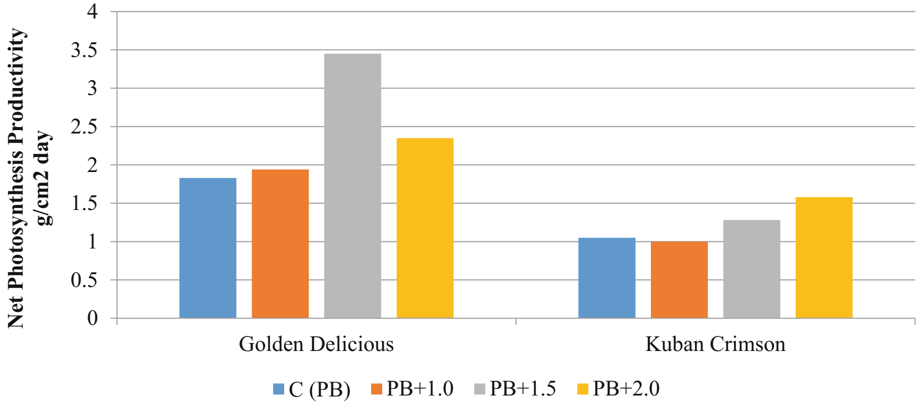

Fig. 2. The net photosynthesis productivity of apple trees of Golden Delicious and Kuban Crimson varieties, depending on the dose of mineral fertilizers (July – August 2023)

Table 1. Growth rates of Golden Delicious and Kuban Crimson apple trees depending on the dose of mineral fertilizers (October 2023)

NPK level	Golden Delicious			Kuban Crimson		
	diameter of the stem, cm	the average length of the annual shoot, cm	the average length of the shoots of the second growth wave, cm	diameter of the stem, cm	the average length of the annual shoot, cm	the average length of the shoots of the second growth wave, cm
Control (PB)	4.8	25.2	0	6.1	31.5	0
PB + 1.0	4.9	25.7	0	6.0	42.3	11
PB + 1.5	5.2	27.6	0	6.1	48.4	14
PB + 2.0	5.5	39.9	0	6.1	61.4	17
NSR_{05}	-	1.1	-	-	3.2	-

Mineral fertilizers have a noticeable effect on the indicators of the generative activity of apple plants (Table 2). However, the nature and degree of this influence largely depend on the biological characteristics of the cultivated variety. Thus, with an increase in the nutrition level by 1.5 doses, the economic yield of the Golden Delicious variety increases by 1.5 times in comparison with the control value. Further increase in the dose of fertilizers does not lead to an adequate result. At the same time, the maximum fruit yield in the experiment for the Kuban Crimson variety was noted in the control version.

Increasing the dose of mineral fertilizers when growing this variety does not lead to the desired results. It should be noted that in the control variant, the economic yield of the Kuban Crimson apple variety is 1.7 times higher than that of the Golden Delicious variety.

Table 2. Indicators of the generative activity of apple trees of two varieties, depending on the dose of mineral fertilizers

NPK level	Golden Delicious			Kuban Crimson		
	Household yield kg/tree (average for 2022–2023)	Development of generative kidneys: stages of organogenesis, % (01/15/2024)		Household yield kg/tree (average for 2022–2023)	Development of generative kidneys: stages of organogenesis, % (01/15/2024)	
		IV	V		IV	V
Control (PB)	15.0	0	50.0	25.0	0	20.0
PB + 1.0	20.3	0	37.5	24.2	0	19.5
PB + 1.5	22.5	0	16.6	23.8	0	18.4
PB + 2.0	18.7	8.3	0	22.9	7.0	10.0

$NSR_{05} = 1.8$ to compare the private averages of the economic yield.

According to our data, increasing the dose of mineral fertilizers weakens the laying of generative buds in Golden Delicious and Kuban Crimson varieties, and inhibits their development (passing through the stages of organogenesis). To the greatest extent, these processes are expressed with an increase in the level of nutrition by two doses.

4 Discussion

The rational use of nutrients in the form of fertilizers is the most important condition for increasing the yield of the agrocenosis of the garden [22]. It is logical to assume that in order to effectively realize the potential productivity of fruit plants in compacted plantations (2500 trees/ha), an increase in the dose of mineral fertilizers will be required in comparison with the recommended level adopted in gardens of traditional design (1666 trees/ha). In this regard, with the development of intensive technologies for growing fruit crops, the development of a sound fertilizer system for perennial plantations is of particular importance [13, 23]. Meanwhile, the maximum efficiency of using mineral fertilizers can be achieved only with the optimal course of the photosynthesis process and sufficient supply of plants with water [3, 9].

Based on the data obtained, an increase in the NPP index in the studied apple varieties with an increase in the dose of mineral fertilizers is associated with a significant decrease (in comparison with the control) in the hydration of leaf tissues. This fact may be associated with an increase in the intensity of plant transpiration and its productivity against the background of the intensity of the thermal factor with an increase in the dose of NPK [15, 20, 23]. At the same time, when determining the optimal dose of fertilizers, it is necessary to take into account not only the content, but also the nature of the distribution of plastic substances synthesized by the plant between vegetative growth and generative development. According to the results of the experiment, the peculiarities of the distribution of plastic substances between the processes of growth and fruiting of a plant organism largely depend on the biological characteristics of the pomological varieties used, or rather on their characteristics: "the intensity of plant growth". The Kuban Crimson apple variety, characterized by a high intensity of tree growth, forms the maximum economic yield in the control version of the experiment. Attempts to increase it by increasing the dose of mineral fertilizers during compaction of plantings lead to negative results. Excessive doses of fertilizers contribute to a sharp activation of plant growth processes exceeding the regulatory level, which inevitably leads to a weakening of the bookmark and a violation of the development of generative buds, which determine the possibility of realizing potential productivity in the next season [7, 8, 19, 21]. The effect of excess fertilizers on plants is especially negative in the conditions of the prolonged growing season that has been manifested in recent years. At the same time, an increase in the recommended level of mineral nutrition by 1.5 doses ensures an increase in the economic yield of the Golden Delicious apple tree in comparison with the control value by 50%. A further increase in the dose of mineral fertilizers does not lead to an adequate result. Based on the presented data, a differentiated approach is required to determine the optimal level of mineral nutrition, taking into account the genotypic characteristics of the variety used.

The genetic aspect of the mineral (including nitrogen) nutrition of plants and plant organisms is described in some detail in the special scientific literature [2, 12, 25]. Moreover, recent studies have proven the presence of special signaling devices in plant organisms, as well as the possibility of launching complex mechanisms that control the level of nitrogen intake [1, 5, 25]. The results of these studies and the results obtained by us indicate the need to adjust the recommended doses of mineral fertilizers, taking into account the responsiveness of perennial fruit plants to the nutritional level. It seems to us that an increase in the dose of mineral fertilizers, even in compacted apple plantations, is permissible only when cultivating varieties characterized by restrained growth (for example, for the Golden Delicious variety on leached chernozems, the optimal dose is $N_{190}P_{190}K_{190}$). On the contrary, when using varieties characterized by a fairly high intensity of tree growth processes, the dose of mineral fertilizers should not exceed the level recommended for gardens of traditional designs (for the Kuban Crimson variety on leached chernozems - $N_{130}P_{130}K_{130}$). If these conditions are met, stable fruiting of apple trees will be achieved with yields in adjacent years at the level of 56.3 – 62.5 t/ha.

5 Conclusion

To ensure the sustainable functioning of compacted apple plantations (2500 trees/ha), a differentiated approach to the selection of the optimal dose of mineral fertilizers (NPK) is necessary, taking into account the genotypic characteristics of the varieties used. Apple varieties characterized by restrained tree growth (for example, the Golden Delicious variety) are the most responsive to an increase in the level of mineral nutrition. With an increase in the level of mineral nutrition, in comparison with the recommended for gardens of traditional design, the economic yield of this variety can be increased by 50%. At the same time, when using varieties characterized by a fairly high intensity of tree growth processes (for example, the Kuban Crimson variety), the dose of NPK should not exceed the level recommended for traditional gardens (the number of trees per unit area of the garden is 1666). If this rule is observed, even under conditions of elevated air temperatures in the autumn-winter period, stable fruiting of apple trees with yields in adjacent years at the level of 56.3 – 62.5 t/ha will be achieved.

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The Development of the Machine Design for Hose Systems to Transport and apply Organic Fertilizers with Simultaneous Seeding of Siderites

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Abstract. The work discusses the options to use technologies for applying liquid organic fertilizers (LOF), their impact on crop yields and the environment. A design option is proposed for a combined machine for subsoil application of liquid organic fertilizers with simultaneous seeding of green manure crops. In view of the fact that enterprises of agricultural mechanical engineering in Russia and foreign countries do not produce combined units of this type, an option has been proposed to develop a combined unit based on the subsoiler by the machine-building plant "Potok" equipped with a pipe system for subsoil application of liquid organic fertilizers and an electro-pneumatic seeder of the "Turbo Jet Super" type mounted on its frame. Brief technical characteristics of the above machines and strengthening calculations of the most important connections are also given.

Keywords: combined unit · green manure · liquid organic fertilizers · hose systems

1 Introduction

The application of organic fertilizers when used various methods significantly affects both the result of obtaining the final harvest and the environment [1]. The following factors are the reason to choose one or another technology to apply organic fertilizers:

- specialization, size and location of the livestock enterprise;
- possibility to irrigate taking into account the availability of irrigation water;
- areas and characteristics of the sown areas;
- crop place in crop rotation;
- production conditions of the farm.

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The above-named factors are taken into account by ensuring the efficient use of financial and human resources, as well as minimizing the negative impact on the environment when applied liquid organic fertilizers. Modern technologies of LOF application include both surface, sub-soil and band, complete, local application. The classification of method to apply LOF is shown in Figure 1. Surface application of LOF by spraying provides high productivity of the unit, but at the same time does not provide the required uniformity of distribution of materials over the surface (no more than 25%). Large losses of nitrogen are also possible with surface application [2]. The use of this method does not allow for synchronous growth and development of the sown crop, and therefore, does not provide high yields. Even placement of fertilizers by plowing does not improve the uniformity of distribution of LOF over the field area [3].

With sub-soil application of LOF, the loss of biogenic elements from fertilizers can be reduced by approximately 7-10 times by eliminating surface runoff and losses of ammonia nitrogen into the atmosphere. Also, this method has less negative impact on the environment and increases the uniformity of fertilizer distribution over the field area [4, 5].

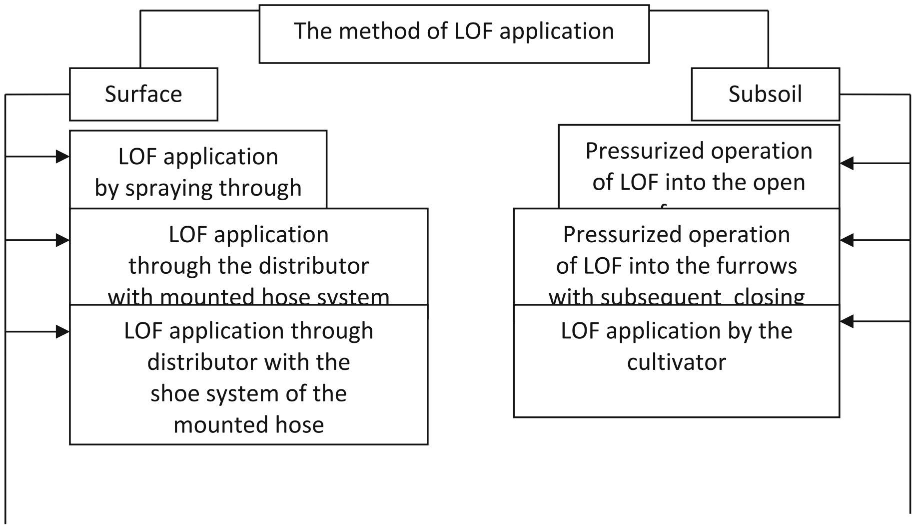

Fig. 1. The classification of method to apply LOF

2 Materials and Methods

In USA and Canada during the recent years, the research has already shown that with the rational use of siderites - green manure - it is possible to significantly enhance the productivity of crop rotations and to increase their saturation by stable crops without reducing soil fertility [6]. The sharing of LOF and green manure to increase soil fertility will allow achieving maximum effect when used a combined unit that integrates the operations of sub-soil application of LOF and seeding [7–9]. To choose the optimal manufacturing scheme of the unit, it is necessary to analyze the design of machines for seeding siderites. Currently, combined machines for sub-soil application of LOF and seeding of green manure are equipped with two separate machines - a subsoiler equipped with a hose system and a seeder mounted on it.

The pneumatic seeder "Turbo Jet Super" (Fig. 2) is equipped with a metering device with 6 outlet pipes, 8 seeding plates and bins of various capacities with an engraved scale in liters, a hermetic cap with a lock, a regulated bottom valve, an agitator, a window to control the operation of the drill shaft, a standard drill shaft and a one-velocity motor of the drill shaft with an electric drive. The seeder is supplied with two control units depending on function. The control unit is "Professional". Seeding depends on tractor speed, stepless rearrangement of the frequency, motor revolution of the drill shaft (installation of the seeding rate), current switch to the control board, turbine switch, a sensor of regulated seeding, an inspection sensor of performance control of the drill shaft, LED of performance control of the turbine.

Fig. 2. Pneumatic seeder "Turbo Jet Super"

With the help of the "Sider" control unit, the seeding rate will not depend on the speed of the tractor. This control unit automatically performs and calculates all specified functions. It provides an operator with the following information: tractor traverse speed in km/h, actual seeding rate in kg/ha, an area of the sown area, it regulates seeding using pick-off signal of the lift. Seeding rate does not depend on traverse speed. The block can be connected to a satellite positioning system (GPS) and is equipped with speed control radar, track switching mechanism.

Since some seeds of green manure crops do not have high looseness, it makes sense to equip the seeder hopper additionally with a device of the clog destructor.

To use combined machines in hose systems for applying LOF, additional equipment must be installed on them. Foreign manufacturers offer ready-made technical solutions for such machines. At present, it is difficult to purchase foreign machines. The Russian enterprises also produce and realize machines for hose systems to apply LOF. The example of such machine is a subsoil injector by the machine-building plant “Potok” (Fig. 3).

Fig. 3. Subsoil injector by the machine-building plant “Potok”

This machine has several options for tools, which allows to expand the limits of its use both on cultivated, carefully cut fields, as well as on a layer of perennial grasses and on fallow lands overgrown with trees and shrubs during their development. In this case, the manure will be distributed to a given depth up to 52 cm, and the zone of liquid manure application of one tool will be overlapped with the zone of application of the neighboring tool. In other words, after passing the subsoil injector by the machine-building plant “Potok” through the field, a continuous horizon containing applied liquid manure with a thickness of 10-15 cm is formed in the soil at a given depth without alternating cultivated (with added organic matter) and uncultivated (without organic matter) stripes. The soil located above this horizon is further crushed when passing the injector, which leads to the destruction of capillaries in it and preventing the evaporation of liquid manure from the surface. The exception is the operation on a layer of perennial grasses where to prevent the action on the plant rootage, flat-cutting wings are removed from the tools and mole plows are installed. It is necessary two men and less than one hour to reequip an injector under field conditions.

Most often on farms, the subsoil injector by the machine-building plant “Potok” is used with wide flat-cutting wings. The design of its tools allows it to work both on the overwetted soils and on overdried ones or on the frozen crusts up to 5 cm thick. When working under these conditions, the quality and uniformity of the liquid organic application do not deteriorate significantly.

3 Results and Discussion

Since the combined unit is designed on the basis of a chisel plow, it is necessary to determine the location of individual machine tools on the frame of the chisel plow, to select the method of their fastening and to perform the necessary strengthening calculations. The electro-pneumatic seeder "TP Turbo Jet Super" can be installed on a special platform of the chisel plow frame using threaded connections. To calculate the thread parameters, it is necessary to determine the forces acting in the connection (Fig. 4).

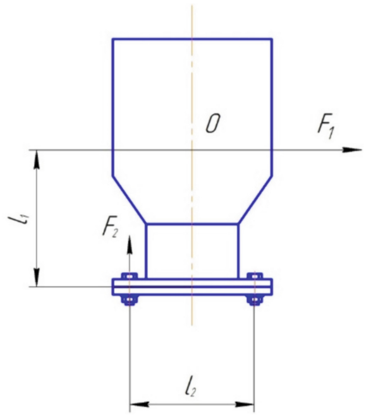

Fig. 4. Scheme to calculate threaded connections for fastening of the electro-pneumatic seeder

Let us first assume that the flanges of the seeder and the chisel plow are connected by eight bolts. When an axial load occurs, the bolt works in tension. A dangerous section is a section weakened by a thread. The cross-sectional area is approximately estimated by the internal diameter of the thread d_1. The strength condition for tensile stresses in the rod is:

$$\sigma = \frac{4F_2}{\pi d_1^2} \leq [\sigma]$$

where σ -the tensile stress, MPa;

F_2- the acting tensile force, kN;

d_1- the inner diameter of the thread

Force F_2 is determined by using the rule of moments:

$$F_1 \cdot l_1 = F_2 \cdot l_2$$

Force F_1 occurs when the unit begins to move and is determined from the expression:

$$F_1 = m \cdot a$$

where m - the weight of the seeder, kg;

a - the acceleration, m/s^2.

From here

$$F_2 = \frac{m \cdot a \cdot l_1}{l_2}$$

Then the minimum permissible bolt thread diameter is

$$d_1 = \sqrt{\frac{4 \cdot m \cdot a \cdot l_1}{l_2 \cdot \pi \cdot [\sigma]}}$$

The coverer (Fig. 5) is a tooth soil compactor which is jointly attached to the frame of the chisel plow at two points by means of pins. Two beams are attached to the roller frame by means of each six bolts. Under the circumstances, end pins operate on the cut and attaching bolts are at tension.

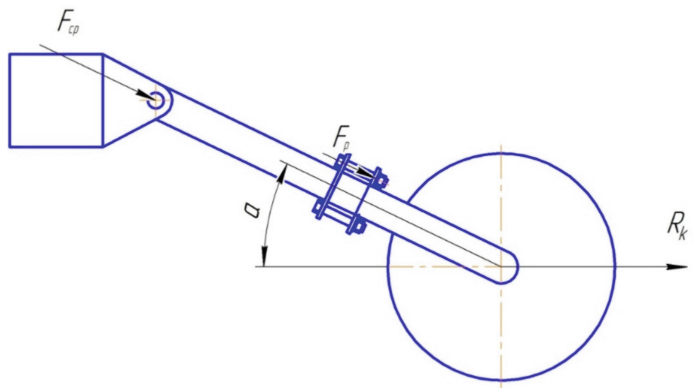

Fig. 5. Scheme to calculate fastening connections of the tooth soil compactor

The axial force acting in the connections is determined by the expression:

$$F = R_k \cdot cos\alpha$$

where R_k - the tool resistance, kN

α – the beam gradient angle, degrees.

Pin calculation is

1. To find the bending moment in the pin (kN * cm)

When supported by two eye ends with a bending moment applied in the middle of their effective length:

$$M_b = \frac{F \cdot l}{4}$$

where F- the transverse bending force acting on the pin, kN;

l- the effective length of the pin (the distance between the eye ends), which is specified, cm;

2. To determine the minimum moment of resistance of the pin cross section or axle, cm^3

$$W_r = \frac{M_b}{m \cdot 0.1R}$$

where m - the coefficient of the conditioned operation (is determined depending on the device);

R – the design resistance of round finished steel for axles and hinges, MPa. (For steel St.3 R=210 MPa)

3. To calculate the pin diameter, cm:

$d=\sqrt[3]{10W_r}$ or

$$d = \sqrt[3]{\frac{10R_k \cdot cos\alpha \cdot l}{0.4mR}}$$

4. Pin checking fingers for cut:

$$\frac{4F}{n_c \cdot \pi \cdot d^2} \le mR_{mid}$$

where n_c - a number of cuts of the pin or axis;

R_{mid} - the cut resistance for round finished steel (for steel St.3 R_{mid}=130 MPa). Calculation of threaded connections:

The bolts work in tension in attaching the soil compactor frame to the beam, at which the strength condition has the form

$$\frac{F_s}{n \cdot F_{net}} \le m \cdot R_p^{\sigma}$$

where F_s - the rated force of tension, kN

n -a number of bolts in connections,

F_{net} -the bolt area section (net) is determined depending on the diameter of the bolt rod;

m - the coefficient of the working conditions, m = 0.85;

R_p^{σ} - the design resistance of bolted connections in tension, MPa. (R_p^{σ} =210 MPa for steel St.3)

Tension calculated force in the given case is

$$F_s = R_k \cdot cos\alpha$$

To select a bolt of the required diameter, an area of cut of net bolt is determined F_{net}

$$F_{net} \ge \frac{F_s}{m \cdot R_p^{\sigma} \cdot n}.$$

After substituting the value F_s

$$F_{net} \ge \frac{R_k.cos\alpha}{m \cdot R_p^{\sigma} \cdot n}$$

4 Conclusions

To perform the technological operation of subsoil application of liquid organic fertilizers with simultaneous sowing of siderites, a combined tillage-seeding unit is recommended, containing a mounted tillage part consisting of a frame rested on supporting wheels, on which tools are mounted, including rippers with tubes for applying liquid manure; a compacting tooth roller installed behind the loosening tool, and a combined seeder, including a seed hopper, an electrically driven metering device, a fan and seed line with seed distributors. The seeder is installed on the mounted frame of the tillage machine; the metering device is divided into channels, the number of which is equal to the number of loosening tools.

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Changes in the Functional Groups of Wheat Flour Resulting from Treated Seeds with Ag Nanoparticles Using FTIR Spectroscopy

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Abstract. This research contributes with new solutions to support sustainable food production, food security and safety, and the production of high-quality food promoting human health and well-being. In This study, we used FTIR spectroscopy to evaluate the Changes in the functional groups of wheat flour resulting from treated seeds with Ag nanoparticles. FTIR Spectroscopy is a fast and reliable analytical method to identify functional compounds in wheat flour. The results of FTIR spectra indicated that the Cham A2 had the highest number of bands and most variation bands in the protein region compared to other samples. In contrast, Cham A3 had low bands in lipid and starch regions. Also, our study showed the different effects of silver nanoparticles with different dimensions and shapes on spectral indicators of wheat flour.

1 Introduction

Cereals are amongst the most grown food crops worldwide. Cereals are generally known as healthy basic foods containing proteins, carbohydrates, dietary fibers, and other bioactive components. We wish to understand the effects of nanoparticles on various functional groups and to understand and develop novel cereal foods as part of a sustainable diet (Alnaddaf. 2023d).

Wheat is one of the most crops cultivated by man (Golea et al. 2023) and is the main component of most diets in the world due to its nutritional benefits providing almost 20% of daily protein consumption. Also, it has agronomic adaptability and easy storage. In addition, it can produce a variety of foods having multiple uses including the production of gluten and starch (Wani et al. 2021).

Wheat is the only cereal that may form gluten during mixing. Therefore, it is considered unique among cereals. In addition to being a rich source of carbohydrates and other important components such as phytochemicals, vitamins, and minerals (Kaur et al. 2021).

Nanotechnology investigates the unique physicochemical characterization of nanoparticles (NPs) and their effects in various fields such as agriculture. AgNPs promote seed germination, and plant growth which are considered essential for the quality of crops (Khana et al. 2023). AgNPs can be incorporated with seed coats and help in

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water uptake inside seeds, promoting starch metabolism, protein content, seed germination, stimulating plant growth and metabolism compared to the control (Alnaddaf et al. 2023a, b). The plant responses to the AgNPs applications depend on many factors such as the composition, exposure time, particle size, types of plant species, and concentration (Sadak 2019).

Many methods were used to determine the quality of flour. The conventional methods involve chemical solvents, a lot of work and costly procedures (Golea et al. 2023). In contrast, new techniques depend on accurate, fast analysis for evaluating flour quality and using small amounts of sample such as FTIR (Fourier transform infrared spectroscopy) which uses infrared in ranges from 4000 cm^{-1} to 400 cm^{-1} (Ahmad et al. 2022). Also, it is characterized by speed, sensitivity, and versatility. It is also used to identify functional compounds of samples with an easy preparation protocol without any hazardous chemicals (Golea et al. 2023).

Few studies have examined the effect of NPs in flour produced from grains soaked with AgNPs before being grown. As a result, this study aimed to evaluate the changes in the functional groups of wheat flour resulting from treated seeds with Ag nanoparticles Using FTIR Spectroscopy.

2 Materials and Methods

2.1 Plant Materials

One durum wheat variety (Cham 7) was obtained from the General Commission for Scientific Agricultural Research (GCSAR), Syria.

Grains were soaked for 30 min in silver nanoparticles (AgNPs) bio-prepared from lemon juice with silver nitrate concentration (0.01) M and different mixing rates (Lemon: AgNPs) A1 (4:1) 27 nm, spherical shape – A2 (1:1) 47 nm spherical shape - A3 (1:4) 21.2 nm, Tube-shaped. Then, grain was cultivated at the Homs Agricultural Research Center in 2021. After harvesting, the grain wheat samples were dried and ground. In 2023, 4 samples of flour resulting from treating grains with AgNPs which have different dimensions and shapes.

2.2 FTIR Spectra of Wheat Flour

FTIR spectrum was performed using a (IRAffinity-1S-4100 SHIMADZU) from 4000 cm^{-1} to 400 cm^{-1} with a 4 cm^{-1} instrumental resolution. We analyzed in a lab at the science faculty, Albaath University.

3 Results and Discussion

Our results of FTIR indicated (table 1) the presence of different functional groups in most spectral regions in all samples. Two regions in the range of (1745–1870, 1500–1535) cm^{-1} can distinguish Cham A2. These are in agreement with other studies which indicated that the region between 1870 and 1500 cm^{-1} was selected as the classification model because this region distinguishes significant groups of the protein amide I and amide II (Nawrocka et al. 2017).

In the wavelength range between 3423 and 575 cm^{-1}, all the spectra obtained for the wheat samples analyzed had characteristic peaks. The number of bands was for Cham A1 (26) and Cham A3 (13) respectively. The highest number of it was 30 for Cham A2 compared to the control that had 19 bands. Cham A2 was distinguished with the most variation bands in protein region. In contrast, Cham A3 most of bands that had disappeared were in lipid and starch regions. This was in agreement with chemical analysis that the control 75.3% and Cham A2 80.7% wheat flours presented significantly higher values for Index gluten compared to Cham A3 52.6% and Cham A1 65.2% respectively (Alnaddaf. 2023d). Our research indicated that the moisture content was predicted based on 3416- 3600 cm^{-1} spectral range, this agrees with (Fanari et al. 2022), protein content 2200- 1400 cm^{-1} (corresponding to the functional group (CH) of protein) and 1772 cm^{-1} (corresponding to the functional group carboxyl C = O of lipid), starch (2800–3000, 3000- 3600 and 858- 575) cm^{-1} and FN (s) based on 1800–700 cm^{-1} spectral range. A similar study indicated that this region is associated with the presence of protein and starch (Golea et al. 2023; Georget & Belton, 2006), while UCDc based on the 1200–900 cm^{-1} spectral range (Pourfarzad et al. 2021), respectively.

Table 1. FTIR spectrum for samples of wheat flour

Control	Functional group	ChamA1	Functional group	ChamA2	Functional group	ChamA3	Functional group	bands belong to
3393	-OH stretching vibration	**3418–3990**	-OH stretching vibration	**3412–3279**	-OH stretching vibration	**3630–3423**	-OH stretching vibration	**moisture content**
2927	C-H stretching vibration of –CH and -CH2	2926	C-H stretching vibration of –CH and -CH2	2925	C-H stretching vibration of –CH and -CH2	2924	C-H stretching vibration of –CH and -CH2	strach
-		**2342**	CH bond in alkyl	**2345**	CH bond in alkyl	**2345**	CH bond in alkyl	**alkyl**
2154		2156		2155		-		
-		-		**1745–1870**		-		**(CH) of protein, carboxyl C = O, of lipid**
-		-		**1500–1535**	**N–H bending and C-N, C–C stretching**			**Amid II**

(*continued*)

Table 1. (*continued*)

Control	Functional group	ChamA1	Functional group	ChamA2	Functional group	ChamA3	Functional group	bands belong to
1457		**1419**		1458		1458		**Amid III**
1383	N–H bending and C-N stretching	**1375**	N–H bending and C-N stretching	1378	N–H bending and C-N stretching	-		**Amid III**
1242	N–H bending and C-N stretching	1241	N–H bending and C-N stretching	1240	N–H bending and C-N stretching	-		**Lipid and β-sheet structure**
930		929		930		-		**Lipid**
858	C–OH out of plane bending	860	C–OH out of plane bending	858	C–OH out of plane bending	858	C–OH out of plane bending	starch and FN
575–756	C–OH out of plane bending	578–762	C–OH out of plane bending	572–762	C–OH out of plane bending	-		**starch and FN**

4 Conclusion

FTIR analysis of wheat flour affirmed the presence of changes in functional groups for samples compared to the control. Also, many bands distinguish formed new reactions compared with the control. The results of our study showed the effect of silver nanoparticles which had different dimensions and shapes on some spectral indicators of wheat flour resulting from grains that were previously treated with these particles. Therefore researchers should examine the efficacy of AgNPs in plant growth on both quantity and quality sides. Also, further research work is needed to study the various impacts of eco-friendly and bio-based AgNPs on different plants and crops to overcome the problems related to the agriculture sector (Alnaddaf et al. 2023c).

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Winter Wheat Productivity in Various Soil and Climatic Zones of the Central Fore-Caucasus Under Climate Change

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Abstract. This article analyzes winter wheat productivity in various soil and climatic zones of the Central Fore-Caucasus in the context of climate change stages. Agro-climatic reference books and statistical reports served as the basis for identifying the correlation between cereal crops productivity, cultivated area and hydrothermal coefficient over a period from 1991 to 1998 and 1999 to 2022 in 4 soil and climatic zones. The correlation analysis allowed to build simulation models and to estimate winter wheat productivity from 2024 to 2029. The calculations of the hydrothermal coefficient (HTC) showed a slight deterioration of the territory humidification since the 2000s. There is a trend for HTC to decrease and for winter wheat productivity – to increase. In 2006, the intersection of trend lines resulted new conditions of cereal crop productivity. The correlation between cereal crops productivity, cultivated area and gross output is high and obvious (0.678416 and 0.947019, respectively). At the same time, the correlation between HTC and these indicators is weak and moderate. A further increase in the linear trend of crop productivity with a typical unpredictability for the certain soil and climatic zones is expected until the 30s of the XXI century. Estimates of winter crops productivity has revealed the possible growth in the first (from 33.06 to 35.81 kg/ha), the third (from 48.74 to 53.18 kg/ha) and the fourth (from 39.67 to 42.65 kg/ha) soil and climatic zones of the Central Fore-Caucasus. The decrease from 35.12 to 30.91 c/ha and the contradictions escalation between the crop cultivation adaptability to the climate change conditions and grain production are predicted only in the second zone.

Keywords: winter wheat · productivity · climate change · atmospheric humidification

1 Introduction

The scientists prove the planetary system natural evolution, where the global change dynamic processes of key cosmogeophysical conditions and Earth orbital characteristics regularly take pace. It is objectively necessary for the cyclic shifts and reconfigurations of mechanisms, forms and tasks of world life in the context of aims and principles of integr-rated galactic development. The beginning of the 80s of the XX century is characterized

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by a process of geographical displacement of the cyclones and anticyclones centers location by almost 20°, the axis oscillatory amplitude increase, the Earth angular rotation speed pre-threshold decrease, and others [1]. From 1901 to 2020, the global air temperature on the planet increased in average by 1.1 °C [2, 3]. The climatic changes, including an increase in the air temperature, the changes in precipitation dynamics affected many countries [4–7]. This geodynamics expanding scale leads to the changes and dysfunctions in the hydro-, atmo-, meteo- and biospheres development and affects all economic sectors growth, including agricultural systems [8, 9].

From 2000 to 2021, the major crops world cultivated area increased by 24% and reached up to 1.5 billion hectares. Cereal crops accounted for more than a half of all world cultivated area [10, 11]. A change in cultivated crops productivity is observed as well in the context of global climate change [12]. Thus, as a result of warming in Russia, there was an increase in winter wheat heat supply, its growing season duration and winter air temperatures (determining the conditions for winter wheat hibernation), a change in humidification conditions (an increase in precipitation during the cold season and a decrease in precipitation during the warm period). At the same time, the climate changes generate a tendency to decrease the cereal crops productivity on global average. The highest rates (2.2–2.6% in 10 years) refer to the cereal crops productivity in the south of Russia. Due to the current thermodynamics, Russia is expected to become one of the leading cereal exporters in the world market in the next 10 years [13–16]. In this regard, the climatic changes occurring in the territory of the Central Fore-Caucasus is of great interest.

The purpose of the paper is to analyze winter wheat productivity in various soil and climatic zones of the Central Fore-Caucasus in the context of climate change. Due to the fact that the planetary system cyclic transformation develops within the framework of the following stages: 1 – the beginning of the transient process (June 1908); 2 – activation of the transition process (from 1982–1983); 3 – the pre-intensive phase of the transient process (since 1991); 4 – the phase of intensive transition (August 1999 – the first third of the XXI century); 5 – the post-intensive phase of transition (until the middle of the XXI century.); 6 – completion of the cyclic transition (in the first third of the XXII century.) [1], we analyze the third and fourth stages only. The use and processing the statistical data in the program "Statistica" within the limits of selected stages made it possible to identify a problem area – the second soil and climatic zone, where the contradictions escalation between the crop cultivation adaptability and management processes in agriculture is expected, and negative dynamic of crop productivity appears as a result.

2 Materials and Methods

The agro-climatic reference books published by North-Caucasus Administration of Hydrometeorological Service referred to various periods are used in this article. The air temperatures and precipitation dynamics, the hydrothermal coefficient (HTC) by G.T. Selianinov are estimated on the basis of these sources [17]. The HTC indicator characterizes the atmospheric humidification of the territory. The analysis of statistical reporting of the Federal State Statistics Service Administration for the North-Caucasus Federal District from 1991 to 2022 helps us to identify the dynamics of winter wheat cultivated areas, gross output and crop productivity in the territory of the Central Fore-Caucasus.

The correlation dependence of crop productivity, cultivated areas and hydrothermal coefficient is determined in four soil and climatic zones of the Central Fore-Caucasus over the periods from 1991 to 1998 and 1999 to 2022, in general, and in each of these years, in particular. The correlation analysis of the indicators mentioned above contributes to building the simulation models and forecasting the winter wheat productivity in the context of zoning from 2024 to 2029.

2.1 Soil and Climatic Zoning of the Territory

Stavropol territory occupies 97% of the Central Fore-Caucasus territory. Its area is 66160 km^2. The climate is very diverse. It is extremely continental in the east (the annual amplitude of extreme air temperatures variation is up to 80 °C) with hot, dry summers and cold winters. It becomes milder in the west and towards the foothills [10]. The HTC varies in wide limits from 0.6 to 1.8 [17].

In the light of natural and economic conditions diversity in Stavropol territory, the regional farming systems were formed in the frameworks of 4 soil and climatic zones by the end of the 80s of the XX century (Fig. 1). The first soil and climatic zone is extremely dry with the area of 1716.7 thousand hectares. The HTC of 0.63–0.72 indicates an acute lack of humidification (Table 1). The zone is represented by light-brown soils. The second zone is dry. It is the largest one as it occupies 36.0% of the territory of the region. The dry zone is characterized by humidification regime more favorable compared to the previous one. The HTC amounts to 0.64–0.81. The third zone is of unsteady humidification. Its area is 1746.8 thousand hectares. HTC varies in the range of 0.98–1.09. Humidification is unstable. The average annual precipitation is 530–610 mm. The ordinary, leached and typical chernozems prevail the soil covering. The fourth zone is of sufficient humidification. The HTC is within the limit of 1.79. The annual precipitation is 480–605 mm. The leached and typical chernozems are widespread.

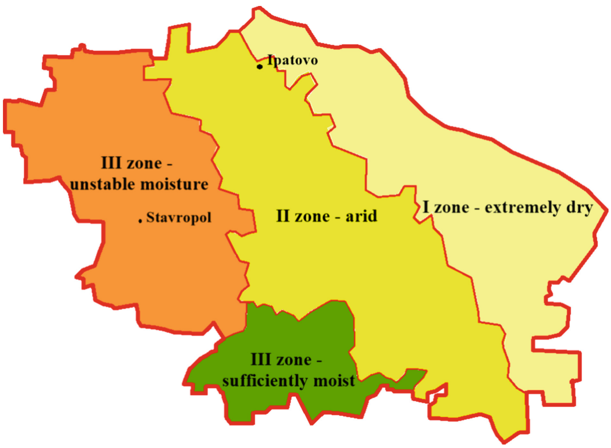

Fig. 1. Soil and climatic zoning of Stavropol territory

Table 1. Specification of soil and climatic zones of Stavropol territory

Marker	Soil and climatic zone			
	I -extremely dry	II - dry	III -unsteady humidification	IV -sufficient humidification
Square, thsd. ha	1716.7	2386.9	1746.8	655.9
Total of temperatures:				
> 5°C	3800–3900	3700–3900	3800–3950	3500–3600
> 10°C	3600	3500–3700	3000–3200	2660–2800
Duration of growing season, days:				
temperature > 5°C	175–180	178–182	180–195	180–190
temperature > 10°C	172	175–180	180–182	174–176
Minimum temperature in winter period, °C	- 36	- 36	- 32	- 32
Average annual total of precipitation, mm	380–430	380–470	530–610	480–605
HTC	0.63–0.72	0.64–0.81	0.98–1.09	1.79
Dominant soil type (% of zone square)	light-brown, brown (71,0)	brown, light-brown, dark-brown (78,0)	leached chernozems, typical chernozems, ordinary chernozems, southern chernozems, dark-brown chernozems (91,6)	leached chernozems, typical chernozems, ordinary chernozems (86)

Source: authors' development

Humidification is a limiting factor in successful crop production in Stavropol territory. Thus, the hydrothermal coefficient (HTC) is used as a humidification availability, facilitating a comparative assessment of such important factors as heat and humidity for cultivated plans growth.

HTC is determined as the ratio of the total of precipitation over a period with an average daily air temperature above 10 °C to the total of temperatures over the same period, reduced by 10 times. The calculation of the HTC is performed according to the formula (1):

$$\mathrm{HTC} = \frac{\sum P}{\sum t^{\circ}/10}, \tag{1}$$

where $\sum P$ – total of precipitation, mm;

$\sum t°$– total of temperatures, °C.

The main cultivated plant of the region is winter wheat. Its area was 1792.8 thousand hectares and productivity – 39.5 c/ha in 2022. The period of autumn vegetation of cereal crops has increased and overwintering conditions have improved in the current changing climatic conditions. These facts have provided a positive dynamics of winter wheat productivity.

3 Results

The current global climatic changes are reflected in Stavropol territory in the form of changes in precipitation amount in spatial and temporal distribution and temperature mode as well (especially in winter). Since the beginning of the XXI century, the winter lasts 55–65 days on average (from December 17–20 to February 15–20). In certain years, its duration changed: it decreased in 2012–2013 and 2015–2016 and lasted 35 days; in 2002–2003, it increased and lasted 120 days. The annual average air temperature increased by 0.95 °C from 1991 to 2014. If intra-annual temperature changes are under consideration, the warming is observed in the cold period of the year. The average winter temperatures increased by almost 1 °C compared to the average values in the period from 1964 to 1990 [19].

Winter wheat takes the first place in the whole crops amount (60.1%) in Stavropol territory. The seeding time is of high importance for winter crops normal development and successful overwintering. The appropriate period is when the plants grow bushy (with 2–4 stems) by the end of autumn. Such plants overwinter better. When winter wheat outgrows or does not grow bushy well enough in early or late seeding periods, its winter hardiness decreases and the percentage of death under unfavorable conditions increase.

The optimal seeding time for winter wheat is from September 10 to 25 for most of Stavropol territory and from September 5 to September 20 on high ground and in the foothills [17]. The dates coincide approximately with the indicators of air temperature transition in every 15 °C. These seeding dates are typical for the beginning of the XX century. The meteorological factors are of great significance at the first stage of plant growth and development. They comprise not only air and soil temperature, but soil humidification as well. However, the fact that September and October have significantly warmed over the past 30 years is to consider.

Sometimes the seeding dates are shifted to the first decade of October due to insufficient soil humidification. But seeding should be implemented no later than October 10–25, ensuring the mass phase of the 3rd leaf or the beginning of bushing out. It is necessary to provide productive humidification of 25–35 mm in the arable soil layer for the appearance of friendly shoots, which will not be able to appear if soil humidification is less than 5 mm. The humidification reserves provide good shoots for an unpaired antecedent each 3–4 years out of 10 and for a paired one each 5–6 years. Overwintering is a crucial period in winter wheat plants development. The main reason for winter crops death is freezing.

The current trend of winter duration decrease is to be noted. It was 90–100 days in Stavropol territory in the first half of the twentieth century and 70–85 days in two decades of the 21st century [19]. If the shortening of winter duration by 10–20 days occurred throughout 40 years in the second half of the twentieth century, then in the XXI century – during 16 years. The average winter temperature is currently 1 °C higher than in the second half of the twentieth century and 2 °C higher than in the first half of the 21st century. The average maximum and minimum air temperatures have changed in a similar way. It is the evidence of winter period warming trend and this process speed increase. The number of days with the minimum temperature below −5 °C decreased from 42 to 33. The number of days with the temperatures below −10 °C decreased insignificantly (from 17 to 14). The number of days with frosts below −20 °C remained at the same level (2–3 days).

The winters are not stable in most of the territory. The thaw periods in winter weaken the plants because the winter crops vegetation resumes and their damage with subsequent sharp drops in temperature is possible. The average number of days with thaw periods is 50–60. Due to the first frosts late appearance, the number of days with frost-free period has increased. The frost-free period average duration was 180 days from 1956 to 1985, 192 days from 1986 to 2000 and 198 days from 2001 to 2017 [18]. The average air temperature in winter is −1.3 °C. It varies from 4.4 °C to 0 °C. There are over 70 days with the maximum plus temperature in winter. There are 20 days with the minimum plus temperature in December, January and February.

Since the 2000s, the average monthly temperature in December has been positive with the highest values of +5.5 °C. The average duration of the period with stable snow cover is 64 days in the second half of the 20th century and 50 days in the 2000s. The average height of snow cover has increased in a large part of the region. The winter duration has been reduced by two weeks [20]. The spring beginning actually shifted to February 23 in 1991–2000 and to February 20 in 2001–2021. The growing season beginning has also shifted to an earlier time, but its end to a later time.

The earlier dates of spring beginning take place. The winter crops vegetation resumption is in March. There is an increase in spring duration. April and May became significantly colder. The stem elongation is observed at the end of April. The ear formation phase takes place at the end of May. The stem elongation and ear formation phases are 30–35 days. The average reserves of productive humidification in 1 m-deep soil layer are 135–170 mm in the western part of the region and 95–135 mm in the eastern part. The beginning of stem elongation until ear formation phase is provided with humidification, but the end of this period is characterized by insufficient humidification. May and June are still the rainiest months. Then, July, August, April, September and October come in descending order.

The summer is hot, but June has turned cold. The period from ear formation to anthesis of winter wheat is 7–8 days. The milk ripeness phase of winter crops begins in June [16]. In summer, there are more than 50 days with temperatures above 30 °C in the northern and eastern regions and about 20 days on the Stavropol uplands. The absolute maximum of daily temperatures often exceeds 40 °C in July and August. The plumpness period lasts 12–15 days. The humidification reserves are 30–50 mm in most of the territory, which is not enough for good grain plumpness. Waxy ripeness takes place in 10–12 days after milk ripeness. Cereal crops harvesting is implemented in the second decade of July in case of favorable conditions.

Thus, 60 to 80% of the absolute maximum daily temperatures in the region have been updated over the past 30 years [17]. And if 30–50% were updated in the context of general warming in the cold period, these values are much higher in warm period. This fact demonstrates the general increase in the temperature level and the frequency of intense heat in the region. The absolute majority of these maxima took place in the 2000s.

Precipitation in the region is an extremely variable value, both in time and in territory. The annual, monthly, decadal and daily precipitation amounts vary within wide limits. However, in general, the annual precipitation amounts throughout the region have increased, and this increase has amounted in absolute terms from 16 to 73 mm. The average annual precipitation in the region was 556 mm (with a norm of 501 mm) over the period from 2000 to 2016. There was a widespread decrease in precipitation in July, and a widespread increase in October.

In April, precipitation has increased throughout the whole territory (except for the northwest), and in September – except for the central part of the region. The intraseasonal precipitation distribution has changed within the warm period.

In general, the changes in temperature and hydrological modes for Stavropol territory with its highly developed agricultural sector have a beneficial impact on winter crops productivity increased from 25.3 c/ha to 34.1 c/ha from 1991 to 2022.

4 Discussion

The result of combined changes in the temperature mode and precipitation has become the transformation of Stavropol territory humidification system. The hydrothermal coefficient calculations demonstrate that a slight deterioration in humidification conditions has been noticed since the 2000s, as the temperature increase is more significant than the increase in precipitation (Fig. 2). The HTC trend tends to decrease over the period from 1991 to 2022. At the same time, the winter wheat productivity trend shows a positive development dynamics. The year 2006 is characterized by the intersections of trend lines mentioned above, as evidence of new conditions emergence contributing to the cereal crops productivity improvement.

The HTC dynamics over the periods from 1991 to 1998 and from 1999 to 2022 possesses a low value of determination coefficient – $R^2 = 0.1045$ and $R^2 = 0.2085$ respectively. The HTC minimum value was 0.59, the maximum value – 1.42, the average value – 1.01 and deviation from the average value – 0.21 over the period from 1991 to 1998. The HTC minimum value was 0.59, the maximum value – 1.30, the average value – 0.92 and deviation from the average value – 0.149471 over the period from 1999 to 2022.

The wheat productivity dynamics over the periods from 1991 to 1998 and from 1999 to 2022 possesses a high value of determination coefficient $R^2 = 0.7589$ and low – $R^2 = 0.1756$ respectively.

The correlation analysis of agricultural territory management (cultivated area), as an element of arable farming in the 90s of the XX century and the first half of the XXI century with the HTC, gross output and crop productivity over the period from 1991 to 1999 has a moderate relation only with gross output (0.499133), the relation with the other indicators is weak.

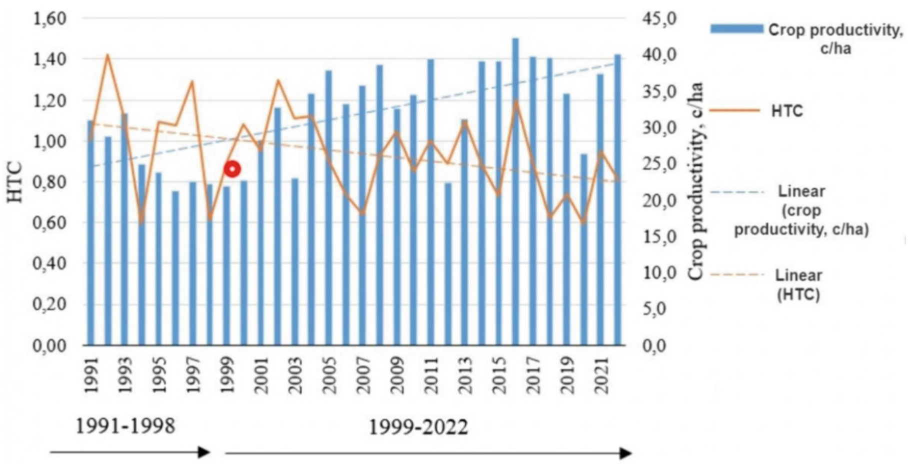

Fig. 2. HTC dynamics and winter wheat productivity in a period from 1991 to 2022. Source: authors' development.

The HTC correlation with all indicators is positive, but insignificant. The HTC correlation with all indicators is weak and moderate over the period from 1999 to 2022, the correlation of the SCC with all indicators is weak, moderate and negative (Table 2). However, the HTC relation with crop productivity, cultivated area and gross output is noticeable and strong (0.678416 and 0.947019, respectively).

The further growth of the linear crop productivity trend is expected at the beginning of the XXI century and up to the 30s of the XXI century, with a specific instability (unpredictability) both in Stavropol territory in general, and in the soil and climatic zones in particular, (Fig. 2, Table 3).

The value of determination coefficient is 0.3570 in the first extremely dry zone (HTC is 0.63–0.72) over the period from 1991 to 1998; it becomes lower (0.1085) from 1999 to 2022. Both stages have a weak connection with winter wheat productivity and temporal factor. $R^2 = 0.1823$ and $R^2 = 0.0403$ respectively in the second dry zone (HTC is 0.64–0.81) over the same periods. The indicators connection is weak. $R^2 = 0.8904$ and $R^2 =$ 0.4794B in the third zone of unsteady humidification (HTC is 0.98–1.09); the indicators connection has been shifted from high to moderate. $R^2 = 0.0819$ and $R^2 = 0.3942$ in the fourth zone of sufficient humidification (HTC is 1.79); the indicators connection has been shifted from weak to moderate.

In general, the indicators connection is weak (0.2842 and 0.1663 respectively) in the first and second soil and climatic zones from 1991 to 2022, it is noticeable in the third and fourth soil and climatic zones over the same period (0.6537 and 0.5105 respectively).

Forecasting of winter crops productivity has shown that the indicator increase is only possible in the first (from 33.06 to 35.81 c/ha), third (from 48.74 to 53.18 c/ha) and fourth (from 39.67 to 42.65 c/ha) soil and climatic zones with probability of various degrees (Table 4).

A decline in the crop productivity is expected only in the second soil and climatic zone from 35.12 to 30.91 c/ha. Therefore, along with further changes in the dynamics of

Table 2. Correlation analysis of HTC, cultivated area, gross output and crop productivity in Stavropol territory, by stages

Markers	Cultivated area, thsd. ha	Gross output, thsd. t	Crop productivity, c/ha	HTC
1991–1998				
Cultivated area, thsd. ha	1			
Gross output, thsd. t	0.499133	1		
Crop productivity, c/ha	0.255557	0.964092	1	
HTC	0.205084	0.337662	0.282513	1
1999–2022				
Cultivated area, thsd. ha	1			
Gross output, thsd. t	0.853349	1		
Crop productivity, c/ha	0.678416	0.947019	1	
HTC	-0.40593	-0.23295	-0.14218	1

Source: authors' development

Table 3. Models of winter wheat productivity in the context of soil and climatic zones of Stavropol territory, c/ha

Soil and climatic zone	Period	Regression equation	R^2	Regression equation in 1991–2022 гг.	R^2
I – extremely dry	1991–1998	У = -0.69x + 19.95	0.3570	У = 0.6898x + 19.07	0.2842
	1999–2022	У = 0.4946x + 24.323	0.1085		
II - dry	1991–1998	У = -0.34x + 23.4	0.1823	У = 0.3024x + 23.385	0.1663
	1999–2022	У = 0.1796x + 26.156	0.0403		
III - unstable humidification	1991–1998	У = 0.64x + 23.7	0.8904	У = 1.1081x + 23.646	0.6537
	1999–2022	У = 1.0221x + 29.174	0.4794		
IV - sufficient humidification	1991–1998	У = -1.17x + 27.2	0.0819	У = 0.7559x + 23.016	0.5105
	1999–2022	У = 0.7219x + 26.512	0.3942		

Note: У – crop productivity, c/ha; x – year
Source: authors' development

Table 4. Winter wheat productivity estimates in the context of soil and climatic zones of Stavropol territory, c/ha

Marker	Soil and climatic zone	Year					
		2024	2025	2026	2027	2028	2029
Estimates	I - extremely dry	33.06	33.61	34.16	34.71	35.26	35.81
Low probability		17.77	18.32	18.87	19,42	19.97	20.52
High probability		48.36	48.91	49.46	50,01	50.56	51.11
Estimates	II - dry	35.12	33.33	30.62	29.86	27.35	30.91
Low probability		27.47	25.63	22.86	22.03	19.46	22.96
High probability		42.77	41.05	38.40	37.70	35.25	38.87
Estimates	III - unsteady humidification	48.74	49.63	50.52	51.41	52.30	53.18
Low probability		38.33	39.22	40.11	40.99	41.88	42.77
High probability		59.16	60.05	60.94	61.83	62.72	63.61
Estimates	IV - sufficient humidification	39.67	40.27	40.86	41.46	42.05	42.65
Low probability		29.28	29.57	29.87	30.17	30.48	30.79
High probability		50.07	50.97	51.87	52.76	53.64	54.52

Source: authors' development

climatic indicators (temperature and precipitation), there will be an escalation between the crop cultivation adaptability and agricultural sector management (cereal production will take place only in the second soil and climatic zone) and the disbalance of agricultural system individual elements will increase.

5 Conclusion

To sum it up, the modern processes of agricultural management will be able to adapt to the current humidification and heat supply in Stavropol territory in the nearest future. A decrease in winter duration and an increase in air temperature and frost-free period length are expected. The spring period will be outlined by its early beginning, an increase in duration and a slight decrease in heat supply. The average annual precipitation will increase in amount and be shifted by seasons.

The effect of territory management (cultivated areas), production activities (gross output and crop productivity) will not be stable only in the second soil-climatic zone. The winter crops cultivation will have to be adjusted (cultivation technologies, new cultivars introduction, the use of new fertilizer and soil treatment systems, plant protection from harmful organisms, and others) because of the influence of climatic factors. The most favorable conditions for the winter crops cultivation will be expected in the first, third and fourth soil and climatic zones. It is where the further growth of winter wheat productivity is forecasted.

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Influence of Accidentally Introduced Fish Species on the Biodiversity of Ichthyofauna of Reservoirs in the Upper Reaches of the Syrdarya River Basin

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Abstract. During the latter part of the previous century, efforts were made to introduce and cultivate several economically valuable fish species in fish ponds, with the aim of enhancing the diversity of valuable fish in the reservoirs of Uzbekistan. In addition to the intentional introduction of fish species, some non-commercial and commercial fish species were inadvertently introduced. As a result, some of these species adapted to the new environment, integrated into the local fish population, and displayed invasive behavior, leading to competition with native species. Upon entering new habitats, numerous invasive fish species were able to reproduce naturally, giving rise to fertile offspring. These processes negatively affected the local ichthyofauna. In some extreme cases, the adverse effects of invasive fish species are evident through their competition with native species for essential resources for life. The article analyzes the consequences of the introduction and naturalization of invasive fish species and their impact on the biodiversity of the ichthyofauna of reservoirs in the upper reaches of the Syrdarya river basin, which were accidentally introduced into the reservoirs of Uzbekistan. The morphometric indicators, the linear logarithmic indicator between body weight and length, the reproductive ability of females, as well as the linear growth over the years of life of invasive fish species from the basin of the upper reaches of the Syrdarya river were determined.

Keywords: Introduction · invasive · ichthyofaunal · commercial · phytoplankton · native species · ecosystem · biodiversity · aquaculture · fecundity

1 Introduction

The modern ichthyofauna of the Syrdarya river basin was formed due to local river inhabitants, planned-acclimatized and accidentally introduced fish. After the degradation of the Aral Sea, many local fish species disappeared, including valuable commercial

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ones. To compensate for these commercial losses and to increase the fish productivity of the republic's pond farms, as well as to effectively use the natural food supply of natural reservoirs, the acclimatization of some commercial fish species into the reservoirs of Uzbekistan began. Thus, since 1961, work has been widely carried out on the acclimatization of such commercial fish species as silver carp, *Hypophthalmichthys molitrix* and grass carp, *Ctenopharyngodon idella* for cultivation in pond fish farming in Uzbekistan from the rivers of the Far East of Asia belonging to the Chinese lowland zoogeographical complex. Subsequently, these fish species penetrated into the natural reservoirs of the region and became part of the ichthyofauna of the Aral Sea basin, occupying practically free ecological niches such as phytoplankton (*Hypophthalmichthys molitrix*) and macrophytes (*Ctenopharyngodon idella*) and became important fishery objects. The introduction was carried out from the floods of the Yangtze River (Central China) and after the planned introduction of *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*, a number of non- commercial and commercial fish species were accidentally introduced. Some of the accidentally introduced species successfully naturalized in new conditions, became part of the local ichthyofauna, and exhibited invasiveness and competition with native species.

In the last century, 47 species of fish were introduced into the water bodies of Uzbekistan, of which 23 species were targeted and 24 were accidentally introduced or invasive. Among invasive species, the bulk are non-commercial. Of all the listed fish, 22 species could not be included in the list of ichthyofauna and did not take root in the water bodies of Uzbekistan. Of the remaining 25 species, 7 occur in small quantities, and 18 species occur in fairly large quantities [17]. In many cases, invasive species, once in new habitats, multiply very quickly and produce fertile offspring. This negatively affects the local ichthyofauna and can even lead to the extermination of the latter [5]. For example, the invasion of predatory fish in new environments leads to an increase in antagonistic relationships between species. If there are few native species in rivers, this can lead to an imbalance in the ecosystem [11, 20]. Therefore, in local water bodies where the number of species is small, to preserve biodiversity it is necessary to prevent the widespread spread of invasive fish species [8]. According to numerous studies, it has become known that invasive species in new environmental conditions show higher viability and multiply quickly [12]. It is precisely these biological adaptations that are observed with many invasive fish in the Aral basin.

2 Material and Methods

The material was collected 2020–2023 from the Naryn river, the Shakhrihansay river, the Central Fergana reservoir, and the ponds of the Namangan fish farm belonging to the basin of the upper reaches of the Syrdarya river. The Naryn river is located 41°01′05.4" north and 71°56′52.8" east, the Shakhrihansai river 40°38′04.4" north and 72°22′24.8" east; Central Fergana reservoir 40°39′21.3" north and 71°31′27.9" east; ponds of the Namangan fish farm 40°39′52.4" northern and 71°15′33.9" eastern longitude. Fish were caught from rivers and reservoirs using fixed nets, fishing nets, and hook gear. The catches of fishermen were also studied. From the ponds of fish farms, material was taken from the hands of fish farmers during the transfer of fingerlings of farmed fish as uncultivated fish species. Uncultivated fish species (*Hemiculter leucisculus, Rhodeus ocellatus, Pseudorasbora parva, Opsariichthys bidens* and *Abbotina rivularis*) make up the species composition of the wild fauna, i.e. non-cultivated fish in fish farm ponds.

To identify fish species, guides from different authors were used [3, 15, 16]. After anesthesia, samples were fixed in 10% formalin. The standard length (SL) without caudal fin (to the end of scale coverlet) in the nearest 1 mm and body weight (W) in the nearest 1 g were recorded for each fish. Morphometric measurements were made according to the method of Kottelat and Freyhof [9]. When measuring the morphometric parameters of fish, the following notations were used: TL-Total length, SL-Standard length, HL-Head length, BDM-Body depth maximum, BWM-Body width maximum, PRD-Predorsal length, PSD- Postdorsal length, PRP-Prepelvic length, PRA-Preanal length, DFL-Dorsal-fin length, DFBL-Dorsal fin base length, AFBL-Anal fin base length, PFL-Pectoral-fin length, VFL-Ventral fin length, CFL-Caudal-fin length, PPD-distances between pectoral and ventral fins, PPA-Distance between pectoral and anal fins, HDN-Head depth at nape, HDE-Head depth at eye, HW-Head width, SNL-nout length, ED-Eye diameter, IOW-Interorbital length, POL-Postorbital length.

Gonad weight (q) was determined for females at stage IV in the nearest 0.1 g. Individual absolute fecundity (AF) was recorded for fish as the number of eggs which were soon to be spawned. Scales (3–4 samples) were taken from 1st row above lateral line under 1st ray of dorsal fin. Scales were cleaned in water and examined under binocular microscope for the age determination. To determine the annual growth of fish, we used the method of inverse calculation of fish growth developed by Einar Lea [13]. Calculations were carried out according to the formula:

$$\frac{L}{C} = \frac{l_x}{c_x}; \, l_x = \frac{L}{C} c_x,$$

where L is the length of the fish;

C is the length of the scales (from the center to the edge in the part where the annual rings are determined);

C_x is the length of the scales for the first year (from the center of the scales and including the first annual ring); the same expression denotes the size of the scales for two, three, etc. years;

l_x is the length of the fish for the first, second, third, etc. years.

The relationship between the mass and length of fish is calculated using the following formula $W = aL^b$ [4]: here W is the total mass (g), L is the total body length (cm), a is the intersection coefficient; b-regression coefficient. Coefficients a and b are calculated by the following linear regression logarithm: $\log(W) = \log(a) + b^* \log(L)$. Statistical data of coefficients of variation and correlation were analyzed using the method of G.F. Lakin [10, 21]. All statistical calculations were performed using MS Excel 2019.

3 Results

Among the accidentally introduced ones *Hemiculter leucisculus, Rhodeus ocellatus, Pseudorasbora parva, Opsariichthys bidens* and *Abbotina rivularis* belong to the Cyprinidae family; *Micropercops cinctus* belongs to the Odontobutidae family; *Channa* *argus* belongs to the snakehead family Channidae and *Rhinogobius bruneus* belongs to the Gobiidae family. These fish species were accidentally introduced from the rivers of the Far East of Asia. *Triplophysa strauchi* and *Barbatula labiata* belong to the family Nemacheilidae and their natural habitat is Lake Balkhash, Zaisan, Alakul, the Tarim and Ili Rivers (Kazakhstan). They were also accidentally introduced with carp larvae in 1961 from the Almaty fish farm to the ponds of the Damachi fish farm (Tashkent region).

Hemiculter leucisculus is widespread in the Russian Far East, northern China, Japan, North and South Korea and Mongolia [1]. *Hemiculter leucisculus* was first discovered in Central Asia in 1958 in the AmuDarya basin, and in 1961 in the Syrdarya basin. Now this species is found in all water bodies of the lowland zone of Central Asia [2, 6, 7].

When comparing the morphometric indicators of different populations of *Hemiculter leucisculus*, some varieties were identified in these indicators (Table 1). For example, in populations of *Hemiculter leucisculus* from Iranian rivers they had the following indicators: TL (mm) 111–140 (125.39 ± 10.04); SL 95–121(106.89 ± 8.18). And as a percentage of the ratio, the standard body length was: TL 112.61–123.01 (117.30 ± 2.75); PRD 50.50–56.64 (52.82 ± 1.67); PRP 46.88–54.87(49.23 ± 2.00); PRA 69.57–76.99 (71.91 ± 1.76); DFL 11.57–17.65(14.84 ± 1.57); DFBL 9.92–12.62(11.09 ± 0.79); AFL 8.26–13.21(10.24 ± 1.32); AFBL 10.62–14.58(12.43 ± 1.08); HW 15.52–19.47(17.31 ± 0.98); HL 16.83–26.55(19.99 ± 2.48), as a percentage of the ratio, the length of the head was: SNL 10.53–26.67(19.73 ± 3.75); POL 47.83–60.00 (53.36 ± 3.72); ED 17.65–29.41(23.52 ± 3.04) [14]. The *Hemiculter leucisculus* population from the upper Syrdarya River basin (Table 1) had TL 137.6–216.9 (172.9 ± 18.4); SL 111.0–173.4 (142.3 ± 15.0). As a percentage of the ratio, the standard body length was: PRD 51.7–62.8 (54.7 ± 8.8); PRP 47.7–57.4 (49.7 ± 6.9); PRA 70.2–85.7 (73.5 ± 11.4); DFL 14.3–22.4 (17.7 ± 1.6); DFBL 8.1–10.1 (8.7 ± 1.1); AFBL 10.9–13.7 (11.8 ± 1.8); HL 22.6–27.5 (24.1 ± 2.5) as a percentage of the ratio, the length of the head was: SNL 29.7–32.8 (31.1 ± 0.6); POL 47.1–49.5 (48.1 ± 1.3); ED 22.1–23.3 (22.6 ± 0.5).

Linear growth of *Hemiculter leucisculus* and *Rhodeus ocellatus* by years of life is shown in Table 2.

Growth rate in female *Hemiculter leucisculus* was rapid growth in the first and second years, and a sharp slowdown in growth in the third year. Females of *Rhodeus ocellatus* have rapid growth only in the first year of life and a sharp slowdown in the second year of life (Table 2). The sharp slowdown in the third year of life in *Hemiculter leucisculus* and in the second year of life in *Rhodeus ocellatus* is explained by the sexual maturation of these individuals, i.e. the main part of the energy is spent on the maturation of the gonads. Some biological parameters of *Hemiculter leucisculus* and *Rhodeus ocellatus* are given in Table 3. Fecundity data show that in both species there is a high positive relationship between fish size and fecundity (Fig. 2).

Table 1. Morphometric parameters of *Rhodeus ocellatus* and *Hemiculter leucisculus.*

Rhodeus ocellatus (n = 15)				*Hemiculter leucisculus* (n = 25)			
	min	max	M ± SD		min	max	M ± SD
TL (mm)	55.3	76.0	68.4 ± 4.6	TL	137.6	216.9	172.9 ± 18.4
SL (mm)	44.1	62.4	55.0 ± 4.3	SL	111.0	173.4	142.3 ± 15.1
% of SL							
HL	19.4	22.8	21.3 ± 0.6	HL	22.6	27.5	24.1 ± 2.5
BDM	42.7	53.7	48.2 ± 0.9	BDM	20.4	25.1	21.6 ± 3.0
BWM	12.5	15.7	13.9 ± 0.2	BWD	11.6	13.9	12.1 ± 1.7
PRD	47.7	55.9	51.1 ± 1.9	PRD	51.7	62.8	54.7 ± 8.8
PSD	41.5	51.3	45.7 ± 0.8	PSD	47.6	59.2	51.8 ± 10.8
PRP	41.7	53.4	46.6 ± 0.6	PRP	47.7	57.4	49.7 ± 6.9
PRA	53.2	68.4	59.4 ± 0.7	PRA	70.2	85.7	73.5 ± 11.4
DFL	16.8	20.8	18.4 ± 07	DFL	14.3	22.4	17.6 ± 1.6
DFBL	29.0	35.8	31.9 ± 0.7	DFBL	8.1	10.1	8.7 ± 1.1
AFBL	25.8	32.3	28.4 ± 0.5	AFBL	10.9	13.7	11.7 ± 1.8
PFL	16.4	22.3	18.4 ± 0.2	PFL	19.5	24.0	20.7 ± 2.4
VFL	14.8	20.4	16.5 ± 0.2	VFL	13.4	17.2	14.6 ± 1.4
CFL	21.6	28.3	24.3 ± 0.4	CFL	20.7	25.4	22.0 ± 3.8
PPD	17.4	21.5	19.1 ± 0.4	PPD	21.4	26.2	22.9 ± 4.6
PPA	16.8	18.8	18.1 ± 0.5	PPA	45.9	55.4	47.8 ± 7.3
% of HL							
HDN	86.3	99.0	92.4 ± 0.3	HDN	60.2	64.3	61.9 ± 1.8
HDE	61.4	72.0	66.8 ± 0.3	HDE	43.5	47.0	45.3 ± 1.2
HW	54.6	58.5	56.7 ± 0.3	HW	43.7	50.6	46.2 ± 1.8
SNL	31.9	38.0	35.1 ± 0.1	SNL	29.7	32.9	31.1 ± 0.6
ED	30.1	33.2	31.6 ± 0.3	ED	22.1	23.3	22.6 ± 0.5
IOW	45.7	51.8	48.5 ± 0.2	IOW	25.7	33.1	30.7 ± 0.6
POL	44.6	50.0	46.9 ± 0.2	POL	47.1	49.5	48.1 ± 1.3

Table 2. Linear growth of *Hemiculter leucisculus* and *Rhodeus ocellatus* by years of life (according to reverse calculations).

Age, year	Body length by year of life (1_1 1_2 1_3 1_4), mm				Number of fish
Hemiculter leucisculus	11	12	13	14	
1 +	65.7	141.7	-	-	4
2 +	74.3	118.7	142.4	-	11
3 +	61.0	94.2	126.5	145.9	1
Average	67	118.2	134.4	145.9	
Growth rate	67	51.2	16.2	11.5	
Rhodeus ocellatus					
1	52.5	-	-	-	5
2	39.6	56.3	-	-	10
Average	46.0	56.3			
Growth rate	46.0	10.3			

Table 3. Biological parameters of *Hemiculter leucisculus* and *Rhodeus ocellatus* females (Individual absolute fecundity - AF).

Age, year	Body length (l), cm (min-max/average)	Body weight (Q), g (min-max/average)	Gonad weight (q), g (min-max/average)	AF (min-max/average)	Number of fish
Hemiculter leucisculus					
2	7–11.8 10.2	6–27.4 18.8	0.4–2.5 1.4	1165–6800 4578	17
Rhodeus ocellatus					
2	5.5–7,6 6.84	2.5–7.1 5.44	0.2–1.4 0.8	115–720 417	14

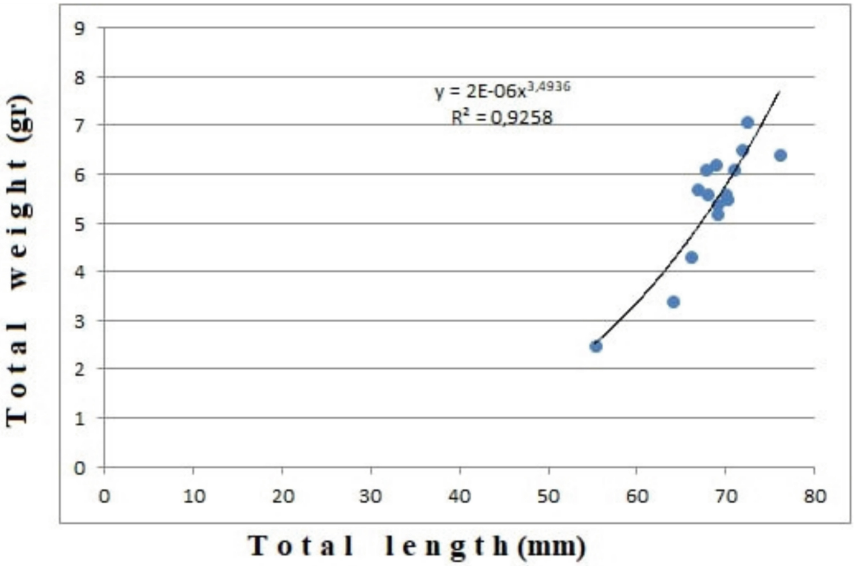

Fig. 1. Linear logarithmic exponent between mass and body length of *Rhodeus ocellatus*

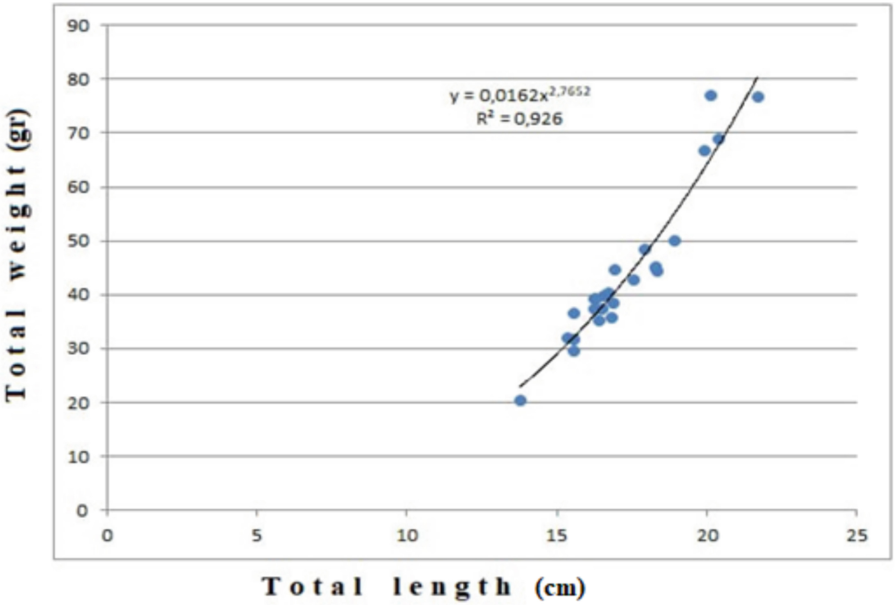

Fig. 2. Linear logarithmic exponent between weight and body length of *Hemiculter leucisculus.*

4 Conclusions

Accidentally introduced fish species first ended up in fish farm ponds in Uzbekistan, where they found suitable habitat conditions and began to produce offspring. Later they penetrated into the natural reservoirs of the region. This is how they gradually settled in all the reservoirs of the republic. The majority of accidentally introduced fish species are small in size and therefore have no economic significance, i.e. refers to non-commercial fish species. In aquaculture, they compete for vital resources with farmed fish. Therefore, fish farmers suppress them with all measures. Despite these efforts, these invasive fish are present in all ponds of fish farms throughout the growing season and to some extent reduce the fish productivity of the ponds. These fish reproduce naturally and are found in almost all natural and artificial reservoirs of the republic. We conducted a comparative analysis of our data on the morphometry of *Hemiculter leucisculus* with those from the rivers of Iran [14, 19]. At the same time, the differences in some plastic characteristics were clarified. For example, many morphometric characters of *Hemiculter leucisculus* in relation to body length are generally high in our samples. But the indicators in relation to head length are generally high in *Hemiculter leucisculus* from the rivers of Iran.

The relationship between body length and weight in *Rhodeus ocellatus* and *Hemiculter leucisculus* in the reservoirs of the upper Syrdarya River basin has been studied for the first time (Fig. 1; 2). The *b* index was equal to 3.49 for *Rhodeus ocellatus* and 2.76 for *Hemiculter leucisculus*. Such a high indicator indicates that the water bodies of the Syrdarya River basin are favorable for habitat for these species, and this may also be due to the low degree of competition for food [4, 18].

At least 50–60 years have passed since accidentally introduced fish species entered the water bodies of our republic. During this time, these invasive species experienced natural reproduction, occupied many ecological niches and were highly competitive with native species. This can be seen in many of their biological indicators. Invasive fish species, having firmly entered the ichthyofauna of local water bodies, have also changed the biological resources of the region. As a result, all this seriously affected the biodiversity of the modern composition of the ichthyofauna both in all reservoirs of Uzbekistan and in the reservoirs of the upper reaches of the Syrdarya River.

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Vectors of Development of National Agricultural Production in Conditions of Transformation

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Abstract. The study was conducted to identify development vectors at the stages of transformation of investments in agriculture established earlier by the authors (stage 1 - 1995–2005 and stage 3 – 2014–2021). Using statistical methods, the chain growth rates of time series of economic indicators of agricultural production in the Russian Federation for 1995–2021, the average geometric growth rates by stages of transformation were studied. The vectors of agricultural production development at both stages of transformation are the growth rates of acreage and gross harvest of sugar beet, production of livestock and poultry for slaughter (in slaughter weight), wool production, cattle and milk production. At the 1st stage of transformation, the vectors of agricultural production development are the growth rate of sunflower acreage, the gross harvest of sunflower seeds, the number of sheep and goats, and wool production. At the 3rd stage, the vectors of development are the growth rates of the acreage of flax, the gross harvest of flax fiber, the acreage of grain and leguminous crops, and the gross harvest of grain. The novelty of the study lies in a new methodical approach based on a quantitative assessment of the periods of transformation in national agriculture.

Keywords: agricultural production · development · growth rate · transformation · vector

1 Introduction

The priority of modern agrarian policy is to ensure import substitution and increase exports of agricultural products and food, which requires an annual 2% increase in production according to the Strategy of the agro-industrial and fisheries complex of Russia for the period up to 2030 [1]. However, the export of food and agricultural raw materials should be carried out only after meeting the domestic needs of the country. Partial equilibrium models are used to estimate the possible volumes of food exports [2].

An important factor in the development of agricultural production is the moral and physical obsolescence of the material and technical base of the domestic agro-industrial complex [3]. Resource availability is also recognized as the main factor of development [4]. However, a quantitative assessment of factors at the regional level creates a prerequisite for characterizing their multidirectional nature.

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The development of agricultural production is associated by A.I. Altukhov with the need for spatial organization of the industry and its sub-sectors [5]. S.O. Siptitz proposed a solution to the problem of optimal allocation of resources under the control of the strategic level and external disturbances to assess measures for low-carbon transformation of agro-food systems [6]. In the work of I.V. Sharfa and Mikhalchuk A.A., it is shown that reproduction processes in subsurface use are reduced in the investment cycle [7]. V. G. Zakshevsky et al. used sustainable development coefficients based on integral indicators to assess sustainable development (territories) [8]. In the work of S.V. Smirnov, E.B. Oleinik and S.S. Kovalenko, the cyclic dynamics of time series was studied and a consolidated leading aggregate index based on peaks and troughs was formed [9].

Modern conditions of agricultural production in Russia are characterized by the predominance of organizations' own funds in the structure of capital investments by sources of financing from 2014 to the present due to economic sanctions and the new reality. It should be noted that the predominance of own funds in investments in fixed assets of the country's agriculture has already taken place in the period from the 1990s to 2005.

Therefore, it is relevant to study the features of the modern period of agricultural production during the second implementation of the cyclical process of transformation of capital investments [10]. At the same time, the impact of changes in the structure of investments in agriculture is used to periodize the transformation process, which represents a novelty in assessing production indicators at its various stages. The purpose of the study is to identify similarities and differences in the vectors of agricultural production development at the 1st and 3rd stages of transformation of the financial structure of investments in agriculture.

2 Materials and Methods

The empirical basis of the study was the open statistical data of Rosstat "Agriculture in Russia" for 1995–2021 [11]. Statistical, monographic, analysis, and synthesis methods were used in the research. Chain growth rates are calculated for time series of economic indicators of agriculture. As part of each stage of the transformation, a paired correlation analysis was performed using the analysis package in MS Excel 2016. The obtained correlation coefficients were estimated by the Student's coefficient at a significance level of 0.95. The average geometric growth rates are calculated for each indicator at the appropriate stage of transformation.

3 Results

The result of calculations shows that the average growth rate of investments during periods of predominance of own funds at both stages of transformation (113.12% in 1995–2005 and 111.73% in 2014–2021) is decreasing (Fig. 1).

The average growth rate for the total volume of capital investments (112, 44% and 107.02%, respectively) and attracted funds (111. 51% and 101.42%, respectively) is also decreasing.

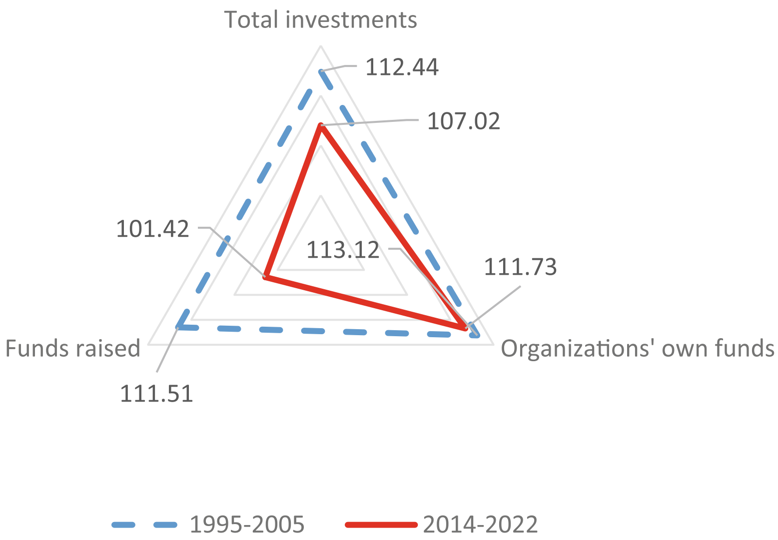

Fig. 1. The average geometric growth rates of investments in fixed assets of agriculture in the 1st and the 3rd stages of transformation

The correlation analysis of the chain growth rates of resource and performance indicators made it possible to differentiate them into two groups (Table 1). The first group of indicators is characterized by a direct and significant correlation at both similar stages of transformation.

Table 1. Significant (significance level – 0.95) coefficients of paired correlation of chain growth rates for indicators at the 1st and 3rd stages (predominance of own funds) of transformation

Indicators	1995–2005	2014–2021
Acreage of sugar beetv & Gross harvest of sugar beet	0.820	0.808
Sunflower acreage & Gross harvest of sunflower seeds	0.797	-
The number of sheep and goats & Wool	0.954	-
Livestock and poultry for slaughter (in slaughter weight) & Wool	0.870	0.830
The number of cattle & Milk	0.800	0.830
Acreage of cereals and legumes & Gross grain harvest	-	0.863
Cultivated areas of flax & Gross flax fiber harvest	-	0.865

Thus, significant coefficients of paired correlation (significance level – 0.95) at both similar stages of transformation (the predominance of organizations' own funds) show that there is a direct and strong correlation between acreage and gross sugar beet harvest (r = 0.82 and r = 0.81, respectively), livestock and poultry production for slaughter (in slaughter weight) and wool production (r = 0.87 and r = 0.73, respectively), as well as cattle and milk production (r = 0.80 and r = 0.83, respectively).

The second group is represented by indicators characteristic of only one stage of transformation. Thus, within the framework of the 1st stage of transformation, a significant direct and strong correlation was established between the number of sheep and goats with wool production (r = 0.95), as well as sunflower acreage and gross seed harvest of this crop (r = 0.79).

At the 3rd stage of transformation, there is a direct strong linear relationship for the rate of the growth of the acreage of flax and the gross harvest of flax fiber (r = 0.86), the acreage of cereals and legumes and the gross harvest of grain (r = 0.86).

An analysis of the average yield growth rate of the above crops shows that the efficiency of crop production is different at the 1st and 3rd stages of transformation (Fig. 2).

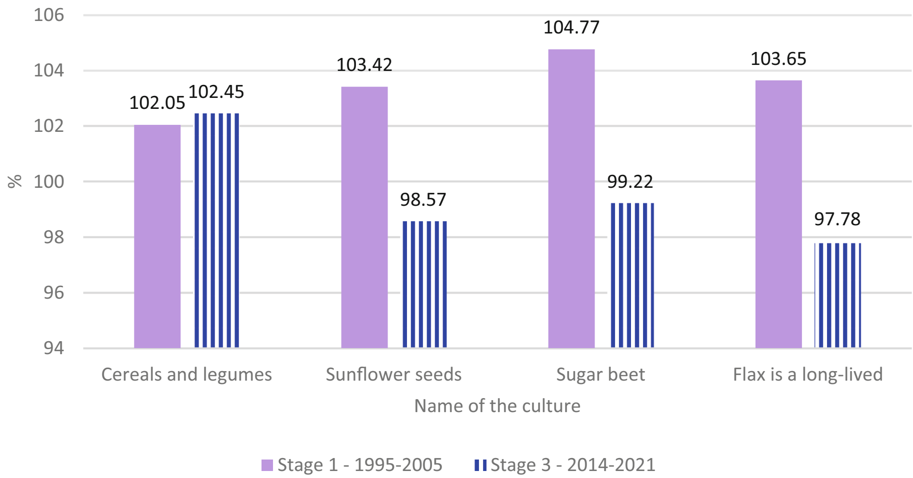

Fig. 2. The average geometric growth rates of crop yields at the 1st and 3rd stages (predominance of own funds) of transformation

At the 1st stage of transformation, conditions were created for the growth of the average yield rate of all crops under consideration. The average yield growth rate was of the greatest importance for sugar beet (104.77%) and the lowest for cereals and legumes (102.05%), the average for flax (103.65%) and sunflower seeds (103.42%).

In the conditions of the 3rd stage, the average yield growth rate decreased for sugar beet (99.22%), flax (97.78%), sunflower seeds (98.57%). However, the average growth rate of grain and leguminous yields increased and amounted to 102.45%.

A comparative analysis of the average growth rates of livestock indicators also shows the difference between similar stages of transformation (Fig. 3).

At the 1st stage of transformation, the average growth rate of animal numbers and their products was most important for the production of livestock and poultry for slaughter (in slaughter weight) (98.51%) and milk production (97.71%), the lowest for wool production (93.75%), the average for sheep and goats (95.97%) and cattle (94.11%).

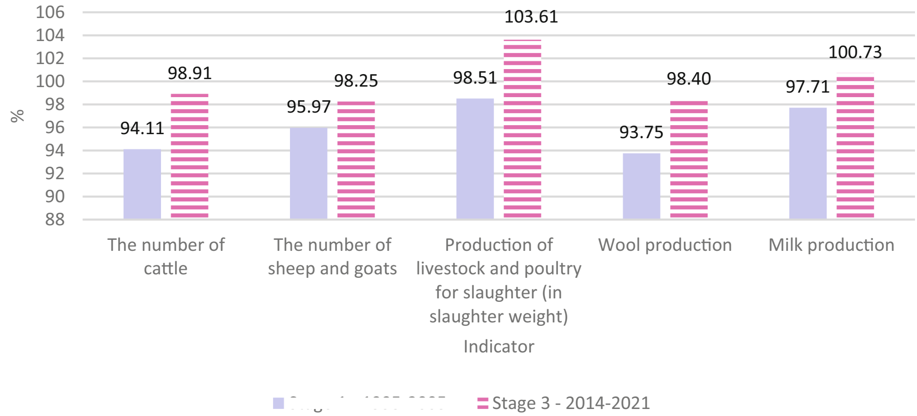

Fig. 3. The average geometric growth rates of livestock indicators at the 1st and 3rd stages (predominance of own funds) of transformation

At the 3rd stage of transformation, the maximum average growth rate is typical for the production of livestock and poultry for slaughter (in slaughter weight) (103.61%) and milk production (100.73%). At the same time, the average rates increased in comparison with the 1st stage for cattle (98.91%), sheep and goats (98.25%), wool production (98.4%).

4 Discussion

In the reaction of agricultural production to the conditions of the predominance of own funds in the structure of investments in the industry, there is a dualism in which the relationship of some indicators manifests itself in the conditions of the 1st and 3rd stages, and others - manifests itself only within one of the listed stages. Consequently, the authors define a significant relationship of indicators within both stages as a vector of development of agricultural production in conditions of predominance of organizations' own funds. Therefore, a stable relationship between the growth rates of acreage and the gross harvest of sugar beet, the production of livestock and poultry for slaughter (in slaughter weight) and wool production, the number of cattle and milk production at both stages of transformation can be considered a vector for the development of agricultural production in conditions of predominance of own funds.

The authors define the relationship of indicators characteristic of only one stage of transformation as a vector of agricultural production development at this stage. Consequently, the vector of agricultural development at the 1st stage of transformation is the number of sheep and goats, wool production, and sunflower seed production. Whereas the vector of agricultural development at the 3rd stage of transformation is the growth rate of the acreage of flax and the gross harvest of flax fiber, the acreage of cereals and legumes, the gross harvest of grain.

For the livestock industry, the vector of development can be considered the production of livestock and poultry for slaughter (in slaughter weight), since the average growth rate of this indicator takes on the maximum value at both stages of transformation, which is confirmed, in turn, by the established links of this indicator.Thus, the production of livestock and poultry for slaughter (in slaughter weight) is a vector for the development of agricultural production at the stages of the predominance of organizations' own funds in the financial structure of capital investments.

The 1st and 3rd stages of transformation are also characterized by the lowest average growth rate for wool production (93.75% and 98.40%, respectively), which is explained by the low average growth rates of cattle (94.11% and 98.91%, respectively), as well as sheep and goats (95.97% and 98.25%, respectively).

5 Conclusion

The established direct and strong correlation of indicators at the 1st stage of transformation, which does not manifest itself at the 3rd stage, and vice versa, may indicate significant differences in the socio-economic conditions of the compared periods. At both stages of transformation, with the predominance of own funds in the financial structure of capital investments, there are common and specific vectors for the development of agricultural production. In general, at the present stage of development of national agriculture, it is necessary to strengthen state support for the production of flax and wool. Thus, the differentiation of the 1st and 3rd stages of transformation in agriculture has been established, which indicates the achievement of the research goal. A subsequent study of this issue will reveal the impact of new external conditions on the vectors of development of the country's agriculture.

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Support for Small-Scale Farming: Impact on the Institutional Subsystem of Rural Areas

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Abstract. The activities of small-scale farming in rural areas are closely interlinked with the life of local communities. The institutional subsystem of rural areas, due to its characteristics, may show less responsiveness to state stimulus policies. This research aims to devise strategies for enhancing the effectiveness of governmental support policies for small-scale farming as constituents of the institutional subsystem of rural areas. Findings indicate that the effectiveness of state support tools is limited by several factors: the subordinate role of municipal development programs to regional initiatives, overlooking the specific characteristics of territories when selecting forms and tools of support, information asymmetry, a fragmented functional support system, and a lack of motivation among the populace. It was determined that the use of social capital of farmers' associations and network trust of the rural population would prevent the rejection of support policy incentives. Recommendations for improving the information interaction between local administrations, farmers' associations, and the population are proposed. The scientific novelty of the research consists in supplementing and refining theoretical-methodological approaches to implementing effective management mechanisms of the institutional subsystem of rural territories, including the implementation of state support programs for small businesses.

Keywords: rural territories · business support · institutional subsystem · adaptive efficiency · network trust · farmers' associations

1 Introduction

The content of regional support programs for farming and entrepreneurial initiatives in the Krasnodar Territory aligns with the Development Strategy of the Russian Federation up to 2030 and correlates with relevant national projects. The effectiveness of these programs at the local level, particularly in rural areas, is crucial for achieving the stated objectives. A notable issue is that local self-government bodies' interpretation of strategic programs and projects focused on sustainable development's is based on partial analysis of the economic efficiency of resource utilization for the state policy implementation. An adaptive aspect, measuring the degree of impact of the used tools of structural, investment, innovation, and social policy on the development trend of the territory's institutional subsystem should complement the aspect of economic efficiency evaluation.

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The concept of adaptive efficiency was developed and introduced by O.S. Sukharev, the creator of the theory of economic dysfunction, in the 2000s. He defined it as the economic system's ability to withstand changes, absorb innovations and knowledge, and mitigaterisks [1; 438]. Stimulating economic policy's programs and tools disrupt the existing equilibrium, with new administrative mechanisms and legal standards introduced or integrated to modify economic agents' behavior and shift informal interaction practices toward desired outcomes.

The effectiveness of small-scale farming support tools is also influenced by social capital and its special form – network trust. According to existing concepts in economic theory, scientists consider it as a set of institutions, social structures, reputation mechanisms organizing and reproducing collective interactions and norms of trust in society [2; 50]. Network trust is formed by group members with closed social ties and governed by their behavior (J. Coleman) [3]. Rural areas possess significant potential for developing both network trust and social capital. The impact of social capital on the behavior of economic entities in rural settings, encompassing both positive and negative aspects, has been extensively documented by researchers globally.

H. Xu, C. Zhang, and Y. Huang, studying the trends in forming network trust and social capital in several provinces of China, India, and Bangladesh, revealed a preference among rural inhabitants for interpersonal relationships to secure transactions or cooperation and potential use of social ties as collateral in the absence of access to traditional credit markets. Positive social capital effects were notably significant among individuals over 30 years of age. [4].

R. Lang and M. Fink, researching depressive agricultural regions of central Greece and western Ireland, highlighted the positive role of network trust in fostering the development of social entrepreneurship in rural communities and facilitating cooperation in implementing municipalities' special development measures for rural communities. Meanwhile, the quality of social capital determines the level of innovation stimulation potential [8; 155].

D.A. Sitkevich's examination of state social programs in rural regions of Morocco, Nepal, and Colombia identified measures for primary financial stimulation of collective actions by local authorities. He concluded that it was possible to achieve positive synergistic effects in the form of subsequent inertial development of cooperations and associations, and growth in public welfare [11; 234–236].

Small businesses and farming in rural areas are interconnected with the life of the local community through family ties, personal contacts, and reputation mechanisms [7]. Informal connections can also be supported by shadow employment [10; 8–10]. Such informal connections are set over a long time. They are stable and can influence the readiness to respond to the perception of state-stimulating mechanisms through the emergence of conflicts of interest. A.T. Pierre, conducting research in rural municipalities in Sweden, notes that in the absence of social capital, interactions, and trust among members of the rural community (individuals, farmers, and entrepreneurs), as well as between residents and municipal authorities, the development of this territory is at risk of a negative scenario. Meanwhile, strong community ties ensure the possibility of sustainable development even in the absence of trust in regulatory bodies [12; 145–147].

These studies validate social capital and network trust level impacts on regional sustainable development policy tools' effectiveness for rural territories. There is a need for analytical tool refinement to assess state stimulation policies' influence on rural territories' institutional subsystems.

The research aims to identify opportunities to enhance the adaptive efficiency of policies stimulating the development of farming and entrepreneurial initiatives in rural areas of the Krasnodar Territory. To achieve this goal, the following tasks were set and solved:

1. Modeling the Krasnodar Territory rural territory's institutional subsystem, where small-scale farming development support policy regulatory impact occurs.
2. Analyzing interactions among state regulation subjects and objects of small-scale farming within this subsystem.
3. Evaluation of the implementation of regional and municipal support programs for small-scale farming in terms of adaptive efficiency.
4. Identifying factors reducing and reserves for increasing the influence of the tools of municipal support for entrepreneurship and farming on the institutional subsystem of rural territory.
5. Developing proposals for improving the implementation of municipalities' tools of policy stimulating the development of small businesses, considering its adaptive efficiency.

2 Materials and Methods

The study employs the methodological framework of neo-institutional economic theory, focusing on the following areas:

1. A descriptive analysis of the institutional subsystem structure of rural areas in the Krasnodar Territory was conducted. The subsystem is the subject of the regulatory policies supporting farming and entrepreneurial initiatives. In this context, the subsystem is understood as the result of the interaction between subjects and both formal and informal institutions and organizations of individual and collective action;
2. The study presents a graphical model of the relationship between the institutional subsystem of a rural territory and the institutional environment of the Krasnodar Territory. The institutional environment is conceptualized as encompassing formal institutions external to the subsystem;
3. A parametric analysis of the policies supporting farming and entrepreneurial initiatives conducted in the territory was carried out to identify reserves for increasing the adaptive impact of the economic tools used. [1; 436–438].

Empirical data for the research were obtained from a variety of public sources. These include official publications from the Administration of the Krasnodar Territory, the Department of Investments and Development of Small and Medium-sized Enterprises of the Krasnodar Territory, the Association of Peasant Enterprises, Cooperatives, and other Small Agricultural Producers of the Krasnodar Territory, the Association of Agricultural Producers "People's Farmer," the "My Business" portal, and social networks used by residents of rural areas in the Krasnodar Territory (VKontakte, Odnoklassniki, and Telegram). The methodology for data collection, analysis, and interpretation incorporates statistical techniques alongside general logical methods, including comparison, deduction, and induction.

3 Results

The elements of the institutional subsystem of rural areas in the Krasnodar Territory and the interaction between them in the context of the functioning of the state support institution for farming and entrepreneurial initiatives are presented in Fig. 1.

The foundational regulatory frameworks are derived from regional subprograms "Creation of a Support System for Farmers and Development of Rural Cooperation (Krasnodar Territory)" and "State Support for Small and Medium-sized Entrepreneurship and Stimulation of Innovative Activity in the Krasnodar Territory." The policy stimulation mechanisms and tools delineated within these subprograms—including conditions and procedures for providing subsidies and grants, consultancy services on selecting business activities, registration processes, market expansion strategies for products and services, report maintenance, and interactions with regulatory and supervisory bodies—are designed to fulfill two primary functions. Firstly, they serve a coordinating role, aiming to unify economic actors involved in this policy—specifically peasant (farm) enterprises, individual entrepreneurs, and the self-employed—and guide their efforts towards accomplishing the strategic objectives established. Secondly, they perform a distributive role, channeling government funds and indirectly steering the private sector's resource allocations into designated activities as specified by the strategic plan.

At the municipal district level, subprograms are subordinate to the regional ones. Therefore, local administrations have limited ability to choose the form and tools of support for small-scale farming considering the specifics and effectiveness criteria of support for a particular rural territory.

Local administrations must primarily implement informational support and the targeting of established support measures. For this purpose, they organize an information field, disseminating key information about available support through official websites and in social networks popular with the local population.

To ensure robust connections with economic entities targeted by regulation and to fulfill the institutional functions of information transfer and motivation Local administrations interact with specially established local branches of business support information and consulting centers and with social organizations. These include district farmer associations part of the Association of Peasant (Farm) Enterprises, Cooperatives, and other Small Agricultural Producers of the Krasnodar Territory (Kuban ACCOR), the Association of Agricultural Producers "People's Farmer of Kuban", the Union of Producers of Kuban, and other. The interaction involves holding joint meetings and events (open days, round tables, exhibitions, etc.), cross-posting information on official websites and official accounts in social networks.

Analysis based on the official websites of municipal administrations, municipal investment portals, official websites of local branches of the "My Business" business support information and consulting centers, and websites of farmer and entrepreneur associations and unions revealed:

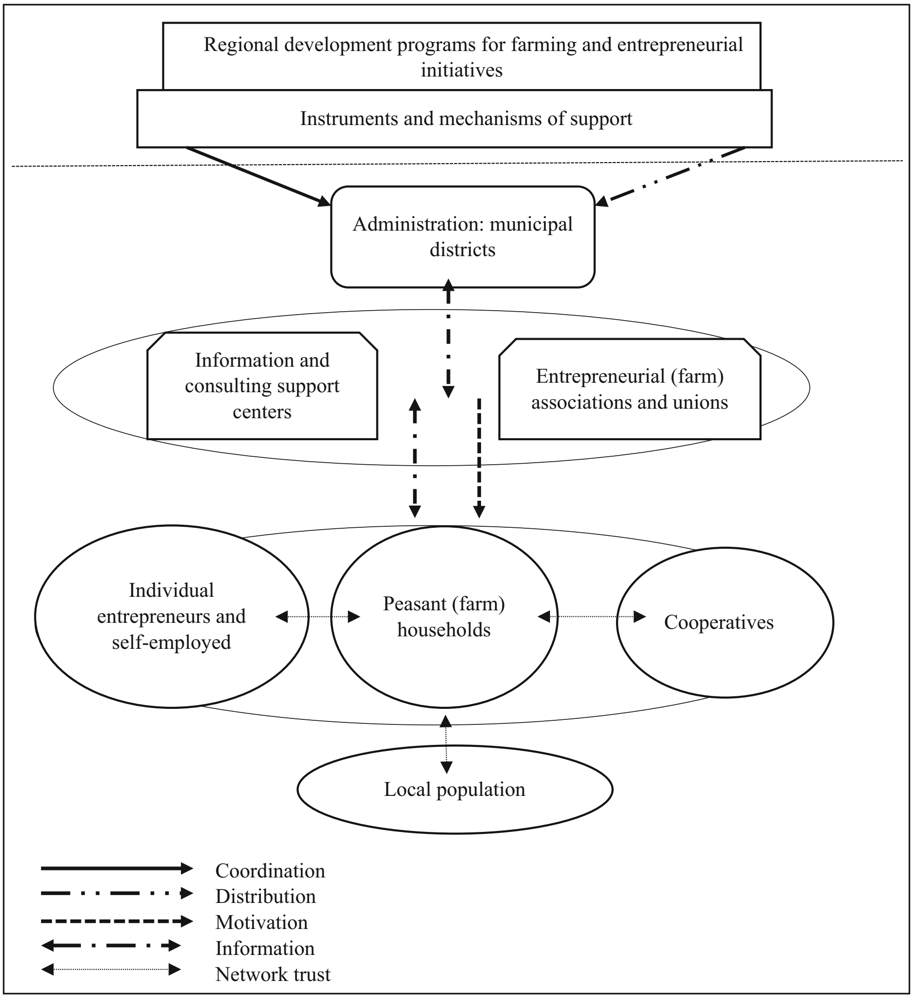

Fig. 1. Institutional subsystem of rural territory

1) The majority of ACCOR district associations do not manage their own social networks nor post information on the official ACCOR of Kuban website, despite the average lifespan of ACCOR district associations in the Krasnodar Territory exceeding 10 years;
2) The number of followers on the official social media pages of municipal administrations and districts does not exceed 2000 people;
3) The new farmer association "People's Farmer of Kuban" is actively engaged in social networking. However, specific information about the association's activities in the Krasnodar Territory is absent from the official website;
4) Information about joint events conducted by administrations and other entrepreneurship support institutions is mainly published in local media.

5) Some administration's official websites and investment portals lack up-to-date information on state support measures or present it in a manner that incurs transactional costs for information searching.

The highest engagement in joint informational and motivational events among the population for the period 2022–2023 was observed in the Gulkievichsky, Caucasian, Labinsky, Vyselkovsky, Dinsky, Bryukhovetsky, Otradnensky, and Uspensky districts. Also, in these districts, the greatest variety of state support tools for small farming forms was presented, such as the grant "Agrostartup", "Beginning Farmer", "Small Garden", participation of local producers in exhibitions and fairs, dissemination of information about state support measures in local internet media and social networks, and organization of features on successful recipients of state support, alongside subsidies and microloans.

District administrations with lower interaction activity with other institutions, as identified through media monitoring, official websites, and social networks, predominantly modernized official local self-government websites and prepared informational brochures as their main tools for information dissemination and motivation. These districts primarily employed subsidies as the financial support tool for small businesses. Additionally, district branches of farmer unions and cooperatives assisted in preparing grant applications for "Agrostartup".

A high level of network trust and social responsibility was noted among peasant-farmer enterprises and cooperatives, particularly in Pavlovsky and Vyselkovsky districts. These entities actively contributed to the welfare of rural settlements, assisting in development-oriented events (such as repairing roads and power lines, maintaining cultural houses, constructing playgrounds, and organizing charity events), showcasing the potential for social capital within the institutional subsystem of rural territories in the Krasnodar Territory.

4 Discussion

In the context of limited options for state support tools and the disunity among program implementation coordinators at the regional level, local administrations must adapt available instruments to their territorial specifics. The perception of the proposed support tools by the local population can be monitored and shaped within the local information sphere. The effectiveness of local policy support tools for farming and entrepreneurial initiatives will be diminished by the population's rejection of proposed measures.

Providing outdated information in official sources leads to information asymmetry and diminishes the local community's trust in the administration and the implemented state business support programs.

The absence of interaction between local administrations and information and consulting centers and producer and farmer associations further exacerbates information asymmetry and transaction costs for the local population seeking support services. This negatively impacts the local population's motivation to participate in business development programs, with informal institutions of interaction becoming crucial in the absence of formal strategic programs.

The willingness of economic entities operating in rural territories to utilize state support tools is likely to increase with successful examples set by reputable heads of farmer enterprises. Local administrations' utilization of network trust mechanisms towards district farmer associations, producers, and cooperatives not only positively influences the local population's perception of business support tools but also has the potential to enhance the economic efficiency of these tools. The high social responsibility observed among local heads of peasant-farmer enterprises, associated with associations, facilitates additional public oversight of projects submitted by beginning farmers and producers for state support competition.

Recommendations for enhancing inter-subject informational interaction include:

1. Development of "Success Diaries" video content by local administrations in collaboration with existing farmer and entrepreneur associations, featuring personal stories and project implementation details of grant support, subsidy, or microloan recipients for business development, and dissemination of this content across popular social networks;
2. Formulation of guidelines for public oversight of the dissemination and perception of information about proposed state support mechanisms for small farming forms, such as monitoring public council feedback on state support measures at local administrations.

5 Conclusion

Within the scope of this study, the following results were obtained:

1. This study presents significant findings on the institutional subsystem of rural territories, focusing on the structure comprising entities such as local administrations, information and consulting centers, and farmer and entrepreneur associations, alongside objects like individual entrepreneurs, self-employed individuals, and cooperatives.
2. It uncovers the relationships between these agents and various mechanisms—coordination, distribution, informational, motivational, and network trust—highlighting the complex interplay within rural development.
3. The study proved dependency of municipal support policies for small-scale farming on broader regional strategic development programs. This linkage reveals the adaptation costs of aligning local practices with overarching strategic goals, shedding light on the challenges faced in harmonizing policies at different governance levels.
4. The research identifies information asymmetry due to the lack of coordination among entities involved in municipal development programs for small-scale farming. This issue contributes to the demotivation of the rural population and the rejection of support policies, underscoring the importance of network trust and social capital of farmer and entrepreneur associations in mitigating these negative impacts.
5. The study offers practical recommendations for local administration and rural populations to develop joint informational, motivational, and controlling tools based on network trust and social capital. These recommendations aim to enhance the effectiveness of support mechanisms for small-scale farming by leveraging community-based resources.

The practical significance of the research lies in enabling rural settlement administrations to develop criteria for assessing the impact of support tools on their activities, considering the adaptive aspect of policy effectiveness.

The proposal for future research to develop a perception index of stimulating state policy tools based on data from information and consulting centers, farmer and entrepreneur associations, and popular social networks is a promising direction for evaluating the impact and effectiveness of policies from the rural population's perspective.

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Analysis of the Topography and Slopes of the Earth Characterizing the Viticultural Territories of the Stavropol Region

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Abstract. This article is devoted to the study of the main directions of ensuring sustainable innovative development of agricultural systems in the Stavropol Region, Russia. The tasks of sustainable development of agricultural systems are currently based on the introduction of innovative highly efficient technologies, the transition of the agro-industrial sector to new electronic and digital technologies and the formation of a unified electronic and communication space. The article describes the analysis of the topography and slope angle in the studied municipal districts of the Stavropol Region in order to determine viticultural areas for cultivating grapes and obtaining high-quality wine products with a protected geographical indication and protected denomination of origin. The study presents digital elevation models and slope diagrams for the studied municipal districts of the Stavropol Region. When creating slope maps, we used methods of working with coordinate systems, processing and using local data, creating and analyzing digital elevation models (DEMs) using the SRTM image interpolation method, spatial research, based on the construction of vector data to calculate the area of slopes, and map design using software methods of information processing [5]. The comprehensive analysis of the soil and climatic conditions of the zones for growing grapes in the Stavropol Region was the basis for the identification of 3 zones with varying degrees of favorableness for the industrial cultivation of grapes.

Keywords: grapes · agroclimatic conditions · microzone · protected geographical indication · protected designation of origin · winemaking · terroir

1 Introduction

The allocation of zones and terroirs for the industrial cultivation of grapes is based on the requirements of the industrial grape assortment and the natural resources of the Stavropol Region located in Russia. Scientists in the field of viticulture and winemaking from different countries are conducting research on the influence of agroclimatic conditions on the development of grapes. Scientists from All-Russian Research Institute of Viticulture and Winemaking named after Y.I. Potapenko conducted research in the conditions of the Rostov region on the influence of the temperature of the interphase

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periods of grapes [6]. US scientists studied the temporal and spatial variability of the Winkler and Huglin climate indices affecting grapes [7, 8]. Dr. A.J. Winkler and M.E. Amerin at the University of California developed a system for classifying climatic zones of viticulture based on the summation of daily temperatures and expressing them in degree days on an accrual basis [1]. Researchers from All-Russian Research Institute of Viticulture and Winemaking "Magarach" RAS analyzed the territorial distribution of climatic factors characterizing the formation of industrial viticulture on the territory of the Crimean Peninsula [9].

Scientific research in the field of viticulture and winemaking showed that an increase in the Huglin index by 100–600 units by 2050 in Europe leads to a latitudinal shift in industrial viticultural areas [10]. Having analyzed the material on the topic under study available in literary resources, we can conclude that insufficient attention is paid to the study of this topic in the Stavropol Region. Currently, studies on zoning the Stavropol Region for the placement of industrial vineyards using information systems have not been carried out. Therefore, the solution to this problem is urgent. According to the classification of M.N. Fisun (1982), slope lands allocated for grape cultivation, depending on the steepness and morphology of the surface, are divided into groups:

– steepness up to 6–8 degrees, slightly dissected, with "soft" changes in exposure
– gently sloping, with steepness ranging from 8 to 12 degrees, slightly dissected
– sloping, with steepness ranging between 12–18 degrees, slightly dissected
– steep, between 18 and 25 degrees, slightly dissected
– very steep, exceeding 25 degrees [2]

Thus, the goal of the article was to determine suitable areas for industrial cultivation of grapes, taking into account the topography and steepness of the slopes in the studied municipal districts of the Stavropol Region: Zunkarnoye LLC agricultural enterprise "Opytny", Zunkar village, Neftekumsky municipal district; CJSC Agricultural Enterprise "Vinogradnoe", Vinogradny village, Budennovsky Municipal District; "Golubovsky V.M." farm, Stavropol Region, Levokumsky Municipal District, Levokumskoe village.

2 Materials and Methods

Research on the creation and analysis of digital models of the topography and structure of areas suitable for growing grapes in the studied municipal districts was first carried out in the educational and scientific laboratory of winemaking technology and food products from plant raw materials of the Stavropol State Agrarian University. To substantiate the theoretical positions, topography analysis was used. The relief analysis was based on the SRTM-3 digital topography model (NASA Shuttle Radar Topography Mission) with a spatial resolution of 3 arcseconds [2]. The data files were a matrix of 1201 × 1201 values, in Geotiff format, for easy use in most GIS and remote sensing software applications. Based on the SRTM data, a perspective image of a 3D surface was created, colored by elevation values. This is a raster image whose pixels contain an absolute height value (elevation matrix). This raster is called a digital elevation model. Using DEM, various morphometric parameters of the topography are calculated, such as surface slope, aspect and slope curvature [4].

To visualize the spatial distribution of agroecological resources and to analyze the influence of morphometric features of the area on agroclimatic conditions, as well as the purposes of agroecological modeling, the geographic information system QGIS Desktop was used [3]. When creating slope maps, the following methods were used:

1. Working with coordinate systems, processing and using local data
2. Creating and analyzing digital elevation models (DEMs) using the interpolation method with an SRTM image [3]
3. Conducting spatial research – taking into account the construction of vector data to calculate the area by slope
4. Designing maps using software methods of information processing

3 Analysis of the Topography and Slopes of Viticultural Territories

3.1 Zunkarnoye LLC Agricultural Enterprise "Opytny", Zunkar Village, Neftekumsky Municipal District

Terroir Zunkarnoe LLC agricultural enterprise "Opytny", Zunkar village is located in the south-eastern part of the Stavropol Region on the territory of the Neftekumsky Municipal District in the Terek-Kuma Lowland. When considering the topography, the territory of the terroir can be divided into two parts: western and eastern, which occupy the upper parts of the slopes of the plateau with absolute elevations above sea level of 150–170 m. It is characterized by the presence of wide ridge plains (Fig. 1).

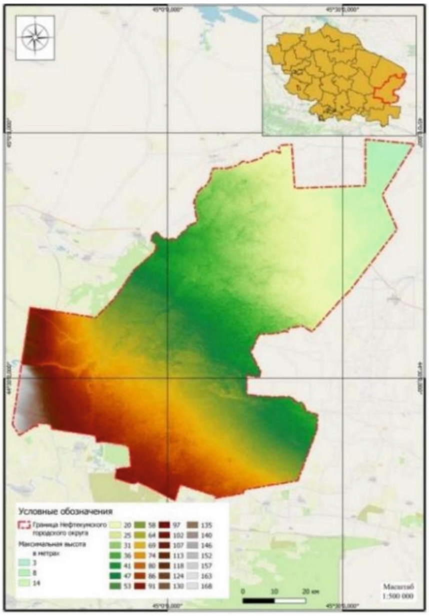

Fig. 1. Digital elevation model of the Neftekumsky Municipal District

According to the nature of the topography, the territory as a whole is a flat area, intersected by a canal with low elevations and a general gradual slope of the territory to the north-east. The topography of agricultural lands under arable land and perennial plantings is flat. The topography on the pastures in the eastern part of the land is represented by a dune plain. Here, the dunes alternate with basin-like depressions formed as a result of the blowing out of sandy soils.

Based on the criteria for assessing the site of the Neftekumsky Municipal District, 8.8 hectares of land with a steepness of 8–9 degrees were allocated. These territories are weakly dissected, gentle slopes suitable for growing grapes (Fig. 2).

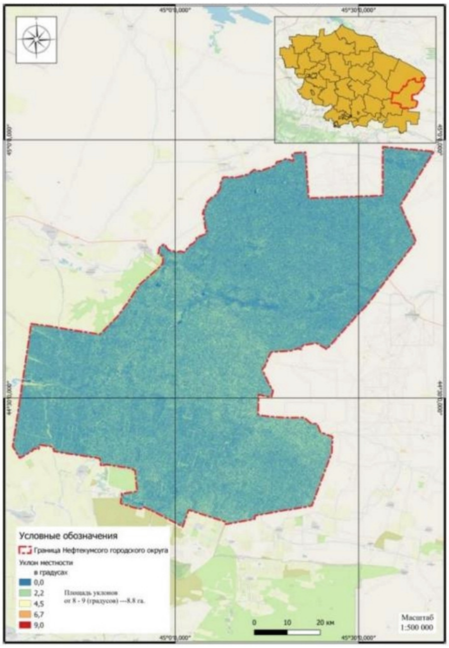

Fig. 2. Slope steepness diagram of the Neftekumsky Municipal District

3.2 CJSC Agricultural Enterprise "Vinogradnoe", Vinogradny Village, Budennovsky Municipal District

The land used by CJSC Agricultural Enterprise "Vinogradnoye", Vinogradny village, Budyonnovsky Municipal District is geomorphologically located on the north-eastern slope of the Stavropol upland, transitioning to the Primanychesky depression. The action of flowing waters formed erosion-accumulation landforms here. This form of topography can be represented as a plain with a valley-beam dissection. The agricultural territory is located 100–200 m above sea level (Fig. 3). From the south to the north, it is divided by the Tomuzlovsky Canal. To the right, along the stream, a terrace above the floodplain has formed, which has a beam dissection. Furthermore, the mezorelief of the land is represented by ravines, hills, and hollows. The highest point of the land is a hill on the outskirts of the village with a height of 202 m. The microrelief is represented by small depressions, gullies, and hills with a diameter of up to 50 m and a height of up to 1 m. The southern part is a broadly ridged plain, crossed by gullies and stretches. The farther away from the canals, the calmer the relief, the longer the slopes, and the smoother the cross-section of the gullies.

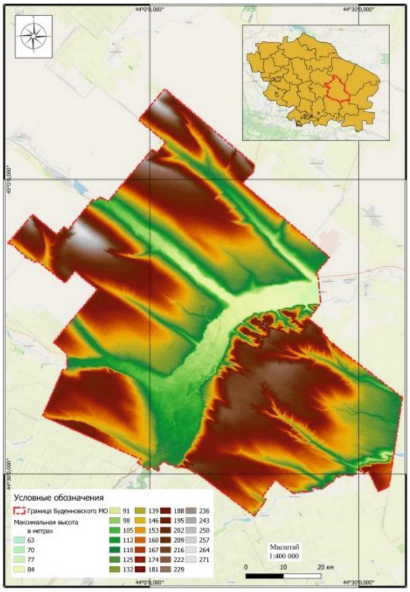

Fig. 3. Digital elevation model of the Budyonnovsky Municipal District

The slopes of the northern exposures are much longer than the southern ones. The beams have a rational direction and are oriented towards the latitudinal direction. The tops of the watersheds are mostly wide with a developed system of steppe saucers. In the southwestern part of the land there is a long, weakly expressed hollow at the tops of the watersheds. Watersheds tend to be long, often with elements of corrugation, which, when plowed, creates the prerequisites for the formation of water flows, which causes the phenomena of primarily linear water erosion. The closer to the bed of the gullies, the higher the steepness of the slopes with northern exposures. The beds of the beams are poorly reclaimed.

The decrease in heights occurs in the northern and eastern directions. At altitudes from 170–180 m above sea level, dark chestnut soils are identified up to the level of 180 m. At the tops of watersheds, depressions (as a result of subsidence processes) developed greatly, in which meadow-chestnut soils were formed. On slopes with intensive plowing, linear erosion is often developed, which in some places is aggravated by the presence of corrugated slopes. But the channels of the gullies often have temporary watercourses and their mouths are often swampy areas with meadow-swamp saline soils. Extensive flat watersheds, smoothly transitioning into wide hollows, have relative heights of no more than 20 m. The slope angles do not exceed 1–1.5 degrees. In this depression, the microrelief is well developed, causing the formation of soil complexes (Fig. 4, Table 1).

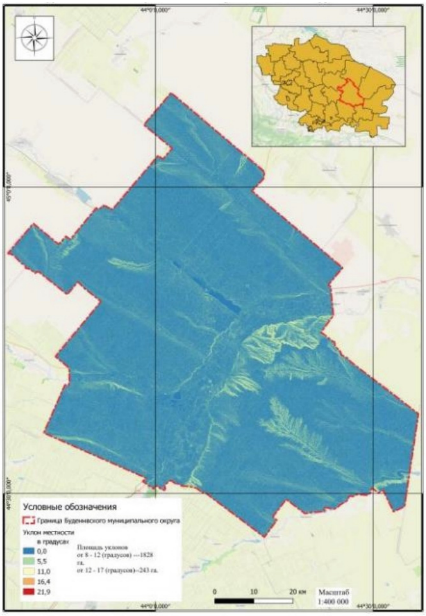

Fig. 4. Slope steepness of the Budyonnovsky Municipal District

Groundwater lies deeper than 6 m and does not affect the soil-forming process. In terms of occurrence conditions, suitability and degree of groundwater supply, the Budennovsky Municipal District occupies the leading position among the eastern areas of the region. There are several aquifers located at a depth of 140–300 m from the surface.

Table 1. Site assessment structure of the Budyonnovsky Municipal District

Number	Slope angle	Area	
		Hectares	%
1	8–12 degrees	1828	88.26
2	12–17 degrees	243	11.73
3	More than 25 degrees	0	0
4	Other	0.20	0.01
Total favorable		2071	99.99
Not favorable		0.20	0.01
Total		2071.2	

Thus, 88.26% of the Budennovsky Municipal District favorable for arable grape terraces are gentle slopes with a steepness angle of 80–120 degrees, which is equivalent to 1828 hectares of land. Slopes with a steepness angle of 120–170 degrees occupy an area of 243 hectares of land (11.73%).

3.3 "Golubovsky V.M." Farm, Stavropol Region, Levokumsky Municipal District, Levokumskoe Village

The territory of the terroir of the "Golubovsky V.M." farm, Levokumsky Municipal District, Levokumskoye village, is geomorphologically located in the northwestern part of the Terek-Kuma Lowland, on alluvial-accumulative quaternary plains covered with loess. The mezorelief is represented by a slightly undulating plain, crossed by gullies and valleys, the Kuma-Manych Canal, the floodplain of the Kuma River, ridge-like hills, and slopes of varying steepness (Fig. 5).

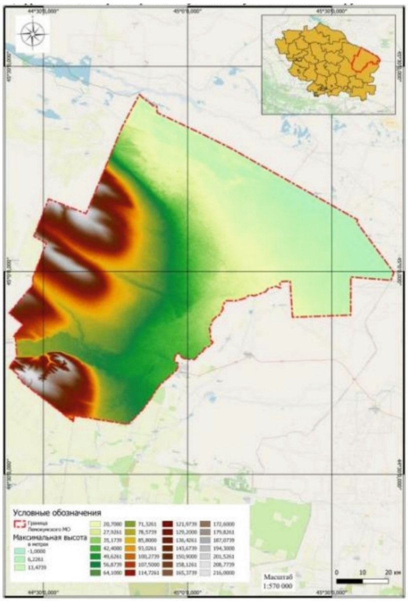

Fig. 5. Digital elevation model of the Levokumsky Municipal District

Based on the surface structure, the terroir can be divided into three parts: northern, central and southern. The natural hydrographic network of the territory is represented by the Kuma-Manych Canal, the Kuma River and temporary watercourses flowing along the bottoms of the gullies during spring snowmelt and precipitation. The artificial hydrography consists of an irrigation and drainage-collector network. Groundwater lies at a depth of 1.8–2.5 m. It is mineralized (salts content – 2.7–6.0 g/L). To prevent secondary salinization and for the creation of a favorable reclamation environment, the groundwater level should be below 2.5–3.0 m, and its mineralization should not exceed 2.0–3.0 g/L.

Otherwise, when irrigating vineyards, progressive secondary salinization of the soil in the rows (under the bushes) may occur, which negatively affects the growth and development of plants of this crop. In other words, plants begin to wither and die. Therefore, the main part of the terroir is located in the northern and central parts, where the depth of groundwater is below 10–20 m.

Based on the criteria for assessing the territory of the Levokumsky Municipal District, slope lands favorable and unfavorable for grape cultivation were identified, depending on the steepness and morphology of the surface (Fig. 6, Table 2).

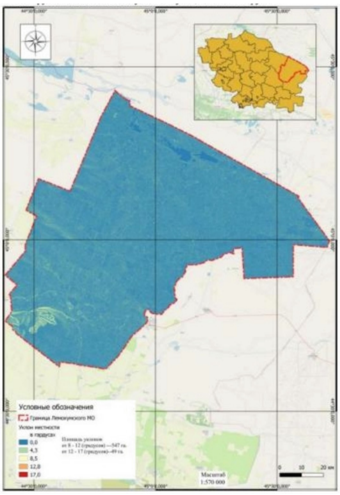

Fig. 6. Slope steepness of the Levokumsky Municipal District

Table 2. Site assessment structure of the Levokumsky Municipal District

Number	Slope angle	Area	
		Hectares	%
1	8–12 degrees	547	91.77
2	12–25 degrees	49	8.22
3	More than 25 degrees	0	0
4	Other	0.0596	0.01
Total favorable		596	99.99
Not favorable		0.0596	0.01
Total		596.0596	

The predominant part of the district is favorable for growing grapes and covers an area of 596 hectares (99.99%). There are no slopes over 25 degrees in this district. The majority of favorable areas for vineyards are located in the southern part of the district.

Thus, the predominant part of the Neftekumsky, Budennovsky and Levokumsky Municipal Districts has weakly dissected, gentle slopes of 8–12 degrees, which is equivalent to 2391 hectares of land, and steeper slopes with a steepness angle of 12–17 degrees, namely an area of 292 hectares (with the exception of the Neftekumsky municipal district), which are favorable for growing grapes. There are no slopes with a steepness angle of more than 25 degrees in the studied municipal districts.

4 Conclusion

Based on the criteria for assessing topography and slopes, the predominant part of the Neftekumsky, Budennovsky and Levokumsky Municipal Districts has favorable areas for industrial allocation and cultivation of grapes.

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The Study of the Influence of the Uterine Microbiome in Metritis on Milk Quality

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Abstract. The relevance of sustainable development concept of dairy farming is of great importance for improving the system of food security and food quality. Microbial contamination of cow's milk can occur at the very first stage of its production, when it is still in the cow's udder. The aim of the study was to investigate the influence of the uterine microbiome in metritis on the quality of milk produced. Studies were conducted on 128 milk samples from 8 Holstein-Friesian cows with metritis and clinical mastitis immediately after delivery, one, two and three weeks after delivery and 16 samples of uterine contents from the same cows. Columbia agar with 5% sheep blood and McConkey agar medium were used to culture the samples. Based on the results of samples isolated from the diseased uterus and from milk samples (colostrum), representatives of selected genera of pathogens *Coliform*, *Enterococcus*, *Staphylococcus* and *Streptococcus* were isolated. A statistically significant decrease in both the total number of isolated microorganisms and the number of representatives of individual genera of *Coliform, Enterococcus*, *Staphylococcus* and *Streptococcus* was observed. These results are statistically significant at $P \leq 0.5$. We found a tendency of multidirectional changes in the indicators of total microbial contamination of uterine contents samples and microbial contamination of milk samples (colostrum).

Keywords: uterine microbiome · culture · metritis · dairy cow · milk quality

1 Introduction

The relevance of the concept of sustainable development of dairy farming is of great importance for improving the level of the system for ensuring food security and food quality. Numerous empirical studies conducted in recent years in many countries [1–10] have shown that both agricultural development and overall economic growth are necessary to improve food security and food quality. The animal microbiome is in a relationship characterized by the ability to interchange microorganisms. It follows that microorganisms can possibly pass from reproductive organs to the mammary gland and initiate nonspecific udder infections. A number of works in Russia [1, 2] and in different countries of the world [3–10] have been devoted to these problems of milk and dairy products quality reduction in case of metritis in cows. Thus, Filatova, A. V. et al. (2021)

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[1] investigated the contamination of the reproductive tract with microorganisms and its influence on the contamination of milk from sick cows in farms in the Volgograd region. Ryhlov, A. S. et al. (2021) [2] found a relationship between microbial contamination of the uterus of cows with metritis and a decrease in the activity of enzymes of lactic acid products in the Volgograd, Saratov and Tambov regions of Russia. Ghavi Hossein-Zadeh, N., Ardalan, M. (2011) [3] found a relationship between metrites and milk yield in their research in the USA. Comparable results were also obtained by Dubuc, J., et al. (2011) [4]. The relationship between metritis and milk yield was also followed in the studies of Mahnani, A. et al. (2015, 2018) [5, 6] in Iran. Pérez-Báez, J. et al. (2020) [7] also observed the effect of metritis in cows on milk production in the state of Florida. Kaniyamattam, K et al. (2020) [8] noted the effect of metritis on economic performance in milk production in the United States. Paiano, Renan Braga et al. (2012) [9] noted the significance of metritis cow disease on milk production in Brazil. Studies on the relationship between metritis disease in dairy cows and clinical mastitis were recently conducted by Rial, C. et al. (2023) [10] and focused on the study of clinical signs using sensors on the body of the animals and microbiological studies of milk samples.

The aim of our research was to investigate the effect of uterine microbiome in metritis on the quality of milk produced.

2 Materials and Methods

2.1 Objects of Research

The study was conducted in LLC SP "Donskoe" of Kalachevsky district, Volgograd region, Russian Federation on diagnostic material collected from high-yielding cows of Holstein-Friesian breed of 3–5 years of age with average annual milk yield of 8560–8942 kg. A total of 32 uterine swab samples from 8 cows and 128 milk samples from these cows from different quarters of the udder were collected for the study. Samples were taken immediately after delivery, one, two and three weeks after delivery. All 8 animals showed clinical signs of metritis and clinical mastitis simultaneously.

2.2 Methods of Research

Samples were taken immediately after calving (day 1), one, two and three weeks after calving. All 8 animals showed clinical signs of metritis and clinical mastitis simultaneously. The cytobrush method described by Kasimanickam R. et al. (2005) [11] was used to sample uterine contents. The sampling device consisted of a cytobrush attached to a stainless metal rod inserted into a thin-walled stainless steel metal tube and closed with a disposable plastic catheter and placed the construct in a disposable plastic protective sleeve. The vulva of each cow was cleaned with paper disposable wipes before sampling. The vulvar skin surface was disinfected by wiping with 70% ethanol solution. During the sampling process, the plastic protective sleeve was removed, then the cytobrush was pulled out and rolling motions were made on the surface of the uterine wall 3–5 times. Before removing the device from the genital tract, the cytobrush was retracted inside the tube to protect against contamination. The cytobrush head together with the selected diagnostic samples was cut off with sterile scissors and immediately placed in a plastic disposable 1.5 ml Eppendorf tube containing transport medium. Manipulation of the tube was performed in a room that is isolated from contact with animals and bystanders. The sample material was transferred into Petri dishes filled with Colombian agar with 5% sheep blood and McConkey's agar medium (BioMedia, St. Petersburg). The dishes were incubated at 37 °C for 48 h. Using a metal Drigalsky spatula, the material was spread on the agar surface. The isolates were identified according to the laboratory protocol.

Sampling of milk from udder was carried out in disposable elastomer medical gloves (Benovy, SPb.) The skin surface of the udder teat tip was disinfected by wiping with 70% ethanol solution. The first trickles of milk (6–10 ml) were siphoned off to avoid contamination of samples into separate dishes and then disposed of. Samples for subsequent bacteriological examination were collected by direct siphoning into a sterile plastic sample container of 25 ml. (Vitlab, GmbH). Samples were transported as quickly as possible to the laboratory for testing.

2.3 Statistical Methods

Statistical processing of the obtained results was performed using Microsoft Excel (Microsoft, USA) and IBM SPSS Statistics 27.0 software (IBM, USA).

3 Results

During microbiological examination of 32 samples of uterine contents and 128 samples of milk from these animals, the following number of isolates of microbial cultures identical in microbiological properties was determined, which is graphically shown for easy perception in the form of box plot in Fig. 1.

Thus, the indicators of microbial contamination of uterine content samples (M ± m) on the first day (Day 1) of the study amounted to 665 ± 21.64 microbial colonies, and the indicators of total microbial contamination of milk (colostrum) samples on the first day of the study amounted to 218 ± 10.22 microbial colonies. The values of microbial contamination of uterine contents samples after one week (Day 7) of the study were 896 ± 24.88 microbial colonies, and the values of total microbial contamination of milk (colostrum) samples, after one week of the study were 274 ± 16.64 microbial colonies. We observed an increase in the total microbial contamination of uterine contents and milk samples. Then we observed a tendency to decrease the indices. It was observed that the microbial contamination of uterine contents samples (after two weeks (Day 14) of the study was 434 ± 12.82 microbial colonies, and the total microbial contamination of milk samples (colostrum), after one week of the study was 253 ± 18.44 microbial colonies. Further, there was a tendency to multidirectional change of indicators. Thus, the indicators of microbial contamination of uterine content samples (after three weeks (Day 21) of the study were reduced to 266 ± 10.82 microbial colonies, and the indicators of total microbial contamination of milk (colostrum) samples, after three weeks of the study, on the contrary, increased and amounted to 290 ± 24.64 microbial colonies.

Key indicators not shown on the box plot are summarized in the figures in Table 1.

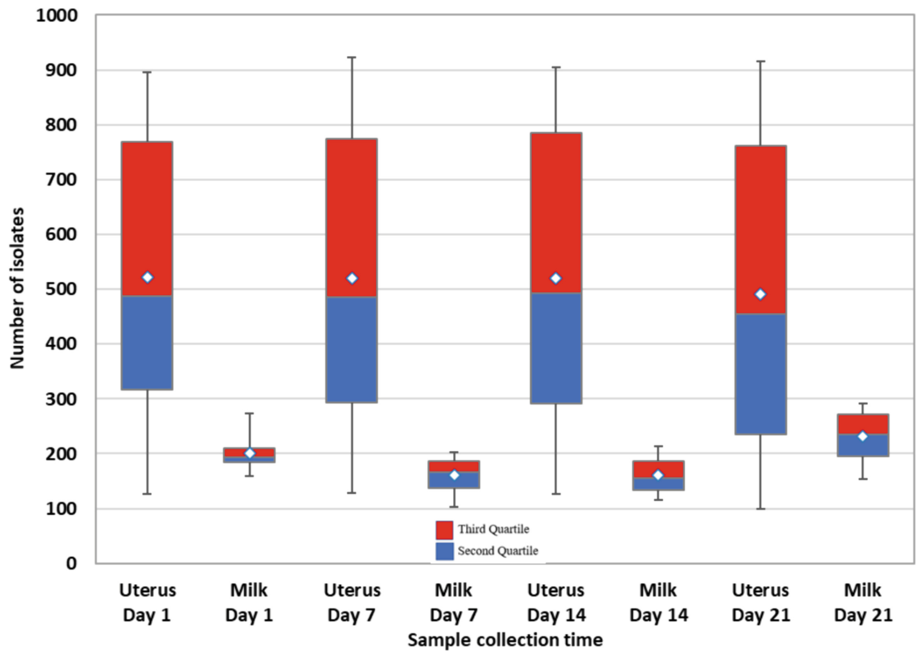

Fig. 1. Diagram box plot of key indicators by days of the experiment

Table 1. Statistical indicators by days of the experiment

Indicators	Sample collection time							
	Uterus Day 1	Milk Day 1	Uterus Day 7	Milk Day 7	Uterus Day 14	Milk Day 14	Uterus Day 21	Milk Day 21
Min	126	160	128	103	126	115	100	153
Second Q	317	184	294	137.50	292	134	236	195
Mediane	488	194.50	485	166	492	156	455	236
Third Q	768.5	210	774	186.5	784	186.5	762	271.50
Max	896	274	922	202	904	214	916	291

In order to clarify the possible common origin and the possible hematogenous route of infectious agent penetration from the diseased uterus into the udder tissue of some dairy cows, we determined the main genera of microorganisms common to the identified microflora isolated from uterine contents and milk (colostrum) samples. These genera of microorganisms were: coliform bacteria, enterococci, staphylococci and streptococci. Their prevalence by days of the experiment is shown in the diagram of Fig. 2.

Thus, coliforms were ($M \pm m$) 26.5 ± 9.5 microbial colonies, enterococci 27.5 ± 9.5 microbial colonies, staphylococci 28 ± 10 microbial colonies and streptococci 28 ± 9.5 microbial colonies. These results are statistically significant at $P \leq 0.5$.

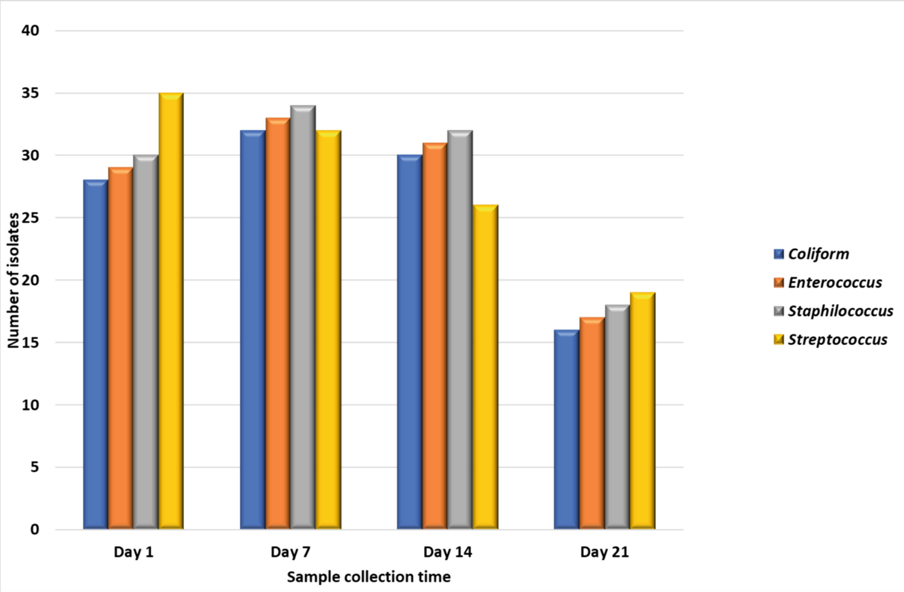

Fig. 2. Indicators of samples of detected microorganism groups

The results of statistical processing of data on isolates common to samples isolated from a diseased uterus and from milk (colostrum) samples are summarized in Table 2.

Table 2. Statistical parameters of the samples of the identified groups

Indicators	Sample collection time			
	Day 1	Day 7	Day 14	Day 21
Average	30.50	32.75	29.75	17.50
Median	29.50	32.50	30.50	17.50
Standard deviation	3.11	0.96	2.63	1.29
Range	7	2	6	3
Min	28	32	26	16
Max	35	34	32	19

We observed a statistically significant decrease both in the total number of isolated microorganisms and in the number of representatives of individual genera of *Coliform*, *Enterococcus*, *Staphylococcus* and *Streptococcus*. These results are statistically significant at $P \leq 0.5$.

4 Discussion

Indicators of microbial contamination of samples of uterine contents and milk (colostrum) samples when examined one week after the beginning of the experiment showed an increase in values. These results may be explained by the increased intensive growth and multiplication of microflora after its adaptation to new habitat conditions.

As a result of the study of samples isolated from the sick uterus and from milk (colostrum) immediately after calving (day 1), one, two and three weeks after calving, we identified representatives of some genera of pathogens *Coliform*, *Enterococcus*, *Staphylococcus* and *Streptococcus*. So, in our earlier work Ryhlov, A. S. et al. (2021) [2], conducted in the Saratov, Volgograd and Tambov regions, it was noted that from 1450 cows with metritis was studied laboratory 149 samples of udder secretion of cows. According to the results of these studies, coliforms (*E. coli*), staphylococci and streptococci were isolated. This confirms the newly obtained data of our study. We obtained comparable results from samples isolated from the diseased uterus and from milk (colostrum) samples and isolated representatives of separate genera of pathogens *Coliform*, *Enterococcus*, *Staphylococcus* and *Streptococcus*.

We observed a tendency of multidirectional change in the indicators of total microbial contamination of uterine content samples and microbial contamination of milk (colostrum) samples during the research process, while the indicators of microbial contamination of uterine content samples decreased quite intensively, and vice versa the indicators of total microbial contamination of milk (colostrum) samples increased after three weeks of research. This can be explained by different intensity of nonspecific immunity of uterus and udder tissues of cows. Similar is noted by other researchers [4–10].

5 Conclusion

It should be noted that from the milk of cows with metritis, we isolated microorganisms similar to isolates isolated from the uterine contents of the respective cows in this study. In conclusion, it should be noted that microorganisms similar to isolates isolated from the uterine contents of the corresponding cows were isolated from milk from cows with metritis. This is possible in the presence of a hematogenous route of transmission from the uterus of cows to the mammary gland tissue.

For further development of these researches, increasing their perspective and practical significance it is necessary to conduct scientific researches on disclosure of possible hematogenous way of transmission of infectious beginning from uterus of cows to udder of cows. It is necessary to introduce modern more sensitive and selective methods (e.g., genomic studies).

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Analysis of the Impact of Agricultural Application of Fertilizers on the Balance of Basic Nutrients and Sustainability of Agriculture in Spain

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Abstract. This work is devoted to the analysis of the impact of agricultural fertilizers on the balance of macronutrients and the sustainability of agriculture in Spain. It has been established that the balance of the main elements of nutrition is deficient in nature, which is associated with the systematic use of mineral and organic fertilizers. Nevertheless, the intensive use of fertilizers entails a number of negative consequences, among which are problems associated with greenhouse gas emissions. For this reason, it is necessary to introduce methods to optimize the norms of fertilizers used to balance the need to increase yields and protect the environment in Spain taking into account the complex impact of fertilizers on the sustainability of agriculture, greenhouse gas emissions and global warming. In order to achieve this goal, scientific research in the field of sustainable agriculture should be continued and innovative methods of using fertilizers should be developed, as well as information work among agricultural producers on methods that help reduce the negative effects of fertilizer use.

Keywords: sustainable agriculture · fertilizers · balance of plant nutrition elements

1 Introduction

In modern world, the problem of sustainable development and ensuring food security is becoming more and more urgent. The growing global population, climate change, unstable markets and problems of access to food make ensuring the food needs of the whole world one of the main global tasks [1–4]. Fertilizers play a critical role in this process. Fertilizers are a key tool for increasing crop yields and increasing the nutritional value of the products produced. They provide plants with essential nutrients, improve soil fertility and promote more efficient use of resources. Fertilizers help to increase

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farmers' incomes and ensure stable and adequate nutrition for the population [5–9]. On the other hand, intensification of production, excessive fertilization in some countries had led to pollution of soil, air and water, and serious violations of the diversity of biocenoses [10].

2 Materials and Methods

General scientific methodological approaches and methods of economic statistics were used in this work. The information base of the study is: the FAOSTAT database of the Food and Agriculture Organization of the United Nations, data from the International Association of Fertilizer Producers (IFA), data from the Organization for Economic Cooperation and Development (OECD).

3 Results

The use of fertilizers in agriculture in Spain is regulated by a number of laws and regulations that establish restrictions, rules and requirements for agricultural enterprises. These measures are aimed at a more sustainable and environmentally friendly use of fertilizers, minimizing their negative impact on the environment.

Spain, as a member of the European Union, must comply with the EU Directive on the protection of waters from nitrate pollution from agricultural sources (91/676/EEC) directed towards protecting water resources from nitrate pollution. In accordance with the directive, measures to control the use of fertilizers have been established, including restrictions on the time of application, volume and frequency of application of nitrogen fertilizers.

One of the most important legislative act of Spain in the field of fertilizer application is the Law on Agriculture and Agricultural Development (Ley de Agricultura y Desarrollo Rural), which establishes requirements for the application of fertilizers. According to this law, agricultural enterprises are required to comply with certain rules and regulations regarding the use of fertilizers (total norms, single doses, depth of embedding, etc.).

Another important act is the Action Plan for the elimination of water pollution by nitrogen compounds, as well as animal husbandry waste (Plan de Accion para la Reduccion de la Contaminacion de las Aguas por Nitratos procedentes de Fuentes Agrarias y Ganaderas).

The plan provides for:

- Development and implementation of a national strategy for the management of water pollution by nitrogen compounds and livestock waste. This includes setting up a coordinating body, defining goals and activities, as well as setting deadlines and responsibilities.
- Development and strengthening of legal acts and regulations governing the placement, storage, disposal and treatment of livestock waste, including
- Establishment of standards for maximum permissible emissions of nitrogen compounds, requirements for the location of farms and waste management requirements.

- Developing measures to support and assist farmers in applying sustainable agricultural practices and compliance with regulations. This may include training farmers, providing financial incentives, access to new technologies, and consulting support.
- Introduction of new technologies and innovations to reduce water pollution by nitrogen compounds and livestock waste.
- Development of a monitoring and evaluation system to determine the effectiveness of measures taken and adjust the strategy based on regular audits, monitoring of water and waste quality, analysis of data and reports on compliance with regulations.

The Phosphorus Fertilizer Management Plan (Plan de gestion de fertilizantes fosforicos) regulates and restricts the use of phosphorus fertilizers in order to minimize the negative impact on the environment and the quality of water resources. The plan determines the optimal doses of application, recommended methods and timing of fertilization, as well as requirements for storage and processing of phosphorus fertilizer residues.

The National Act on Agricultural Systems (Ley de Sistemas Agrarius) defines rules and requirements for various aspects of agricultural activities, including the use of fertilizers. The Act establishes the need for special training programs for agricultural workers that cover the issues of effective and environmentally sustainable use of fertilizers.

In addition, the Law on Water Resources Management (Ley de Gestion de Recursos Hidraulicos) also regulates the use of fertilizers, taking into account their impact on water regime and water quality. In accordance with this law, agricultural enterprises must comply with certain requirements to reduce pollution of water resources when using fertilizers.

There are regional regulations and programs that also regulate the use of nitrogen fertilizers in Spain. These rules may vary depending on the specific autonomous region or province. For example, some regions may impose additional requirements and restrictions on the use of nitrogen fertilizers in certain ecological zones, such as nature reserves or water protection zones.

The overall objectives of these laws and regulations are to promote sustainability and protect the environment. They are designed to ensure a balanced use of fertilizers in agriculture and minimize their negative impact on soil, water resources and biological diversity.

However, in practice, the technologies and techniques used in Spain, irrational and prolonged use of fertilizers are the cause of erosion processes in soils, environmental pollution. For example, in 2021, in the southeastern province of Murcia, about five tons of dead fish washed up on the beaches along the Mar Menor lagoon. According to Spanish ecologists, the cause of fish death is water runoff saturated with nitrates that entered the lagoon from the vast surrounding area (60 thousand hectares), where fruits and vegetables are produced using intensive technologies. To solve this problem, a ban on the use of mineral nitrogen fertilizers within 1.5 km of the lagoon was introduced [11].

According to FAOSTAT data, a positive nitrogen balance in soil was observed annually in the country's agriculture in the period 2011–2021. However, according to Jose Albiac et al. [12], the current level of nitrogen application is excessive and exceeds the needs of crops by 33%. If we consider the data on the nitrogen balance in the soil per unit area (Fig. 1), then it can be seen that, on average, in the period 2001–2007, the positive balance was 26.3 kg/ha. In 2008, with the onset of the global economic crisis, this indicator decreased to 12.1 kg/ha, due to decrease in nitrogen application in mineral fertilizers from 58.4 kg/ha in the period 2001–2007 to 42.8 kg/ha in 2008 (Fig. 2).

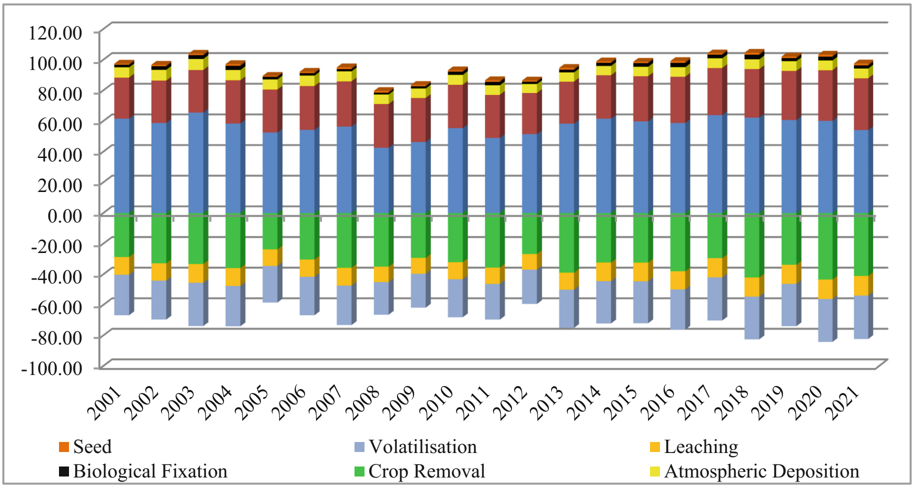

Fig. 1. Nitrogen balance in the soil per unit area, kg/ha

In the period from 2009 to 2017, the volume of application of nitrogen fertilizers demonstrated steady growth with a cumulative average annual growth rate (CAGR) of 4.13%. In 2017, the volume of nitrogen fertilizers applied to the area of arable land amounted to 63.5 kg/ha. In subsequent years, fluctuations in nitrogen application volumes were insignificant, ranging from 60.7–62.2 kg/ha.

The use of organic fertilizers (manure) also increased during the study period (CAGR in 2011–2021 – 1.11%). Spain has a fairly developed pig farming industry. Pig farms are concentrated mainly in Catalonia and Aragon.

According to Eurostat data, the number of pigs in the country reached its historical maximum in 2021 of 34.5 million, while in other countries of the European Union (Germany, Poland, Romania, the Netherlands, France, Serbia, etc.) it is decreasing annually. However, starting in 2022, there is a tendency to reduce the number of sows and piglets in Spain due to decrease in pork exports to China and other non-EU countries. According to the data of the Ministry of Agriculture, Fisheries and Food of Spain, consumption of fresh pork has decreased in Spanish households by almost 11% due to rising pork prices.

In addition, the Animal Welfare Law Spain 2023 came into force in the country, which established stricter requirements for keeping pigs in Spain than in the EU. Pig farms have been given two years to adapt to new standards and requirements.

However, in 2023, pork exports from Spain to the European Union increased by 13.5% in value terms due to an increase in the cost of products, which offset a decrease in volumes by 9%.The reduction in the number of pigs in the country in 2023 is partially

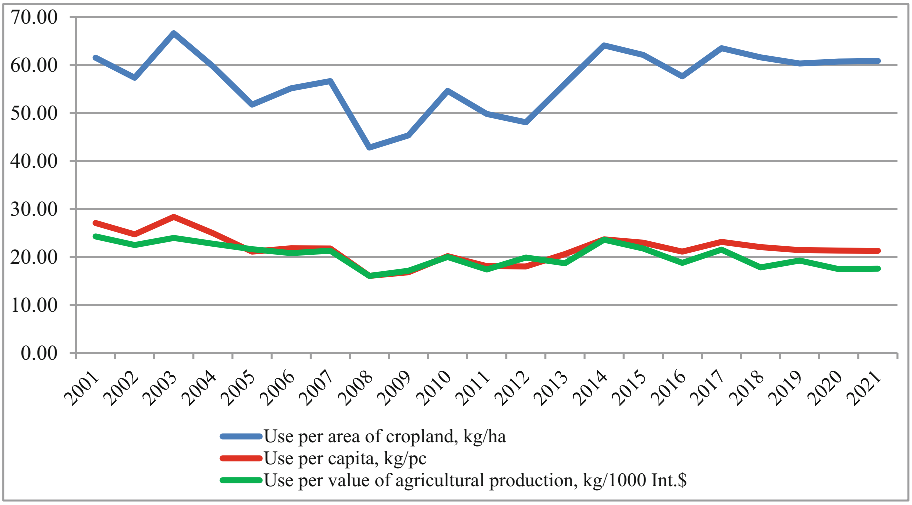

Fig. 2. Application of nitrogen fertilizers in Spain

offset by an increase in imports of piglets from the EU, mainly from the Netherlands and Portugal.

Cattle production in Spain has grown by an average of 1.3% since 1966. According to forecasts presented on the Reportlinker portal [13], the number of cattle in the country will increase from 6.0 million heads (2022) to 6.2 million heads in 2026 (+3.33%). Cattle farms and complexes are located mainly in the regions of Castile and Leon, Galicia.

For many centuries, sheep farming has been one of the tools of human existence in areas unfavorable for agriculture in Spain – natural and semi-natural open areas such as steppes, uplands and moorlands, primarily in the regions of Extremadura, Castile and Leon.

However, the traditional, extensive sheep farming technologies have low economic efficiency, and therefore, this industry in Spain as in most EU countries directly depends on government subsidies and agricultural policy measures taken. According to study by J. Traba and C. Perrez-Granados published in the journal PeerJ [14], the number of sheep in Spain decreased by 37.3% between 1992 and 2020. According to EUROSTAT data, the number of sheep continued to decline in subsequent years, reaching a minimum in December 2022 – 14.5 million heads [15].

Thus, it can be concluded that Spain is transitioning to intensive animal husbandry, one of the key aspects of which is the use of large production complexes with a high density of animals. This causes a high concentration of animal husbandry waste, primarily manure, per unit of occupied area, which in turn leads to a number of problems associated with its disposal, processing and introduction into the soil.

The phosphorus balance in the country's agriculture in the period 2011–2021 was deficit-free. In the period 2001–2007, the phosphorus balance in the soil per unit area averaged +13.3 kg/ha (Fig. 3).

In 2008, with the onset of global economic crisis, the country saw a 50% reduction in the use of phosphorus mineral fertilizers compared to 2007 (Fig. 4), in connection

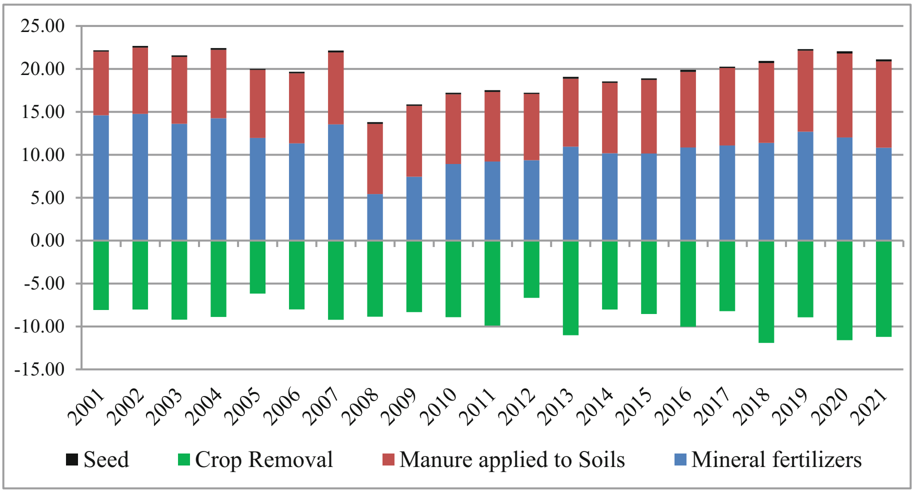

Fig. 3. Phosphorus balance in the soil per unit area, kg/ha

with which, the phosphorus balance decreased to 4.94 kg/ha. In the period 2009–2021, the volume of application of these fertilizers increased and reached a maximum of 28.89 kg/ha in 2021, the CAGR in the period 2009–2021 was 4.98%. The phosphorus balance was in the range of 7.53–13.37 kg/ha.

The application of phosphorus fertilizers to the area of arable land in the period 2001–2021 decreased by 4.57 kg/ha (13.7%), per capita – by 4.64 kg/person (31.5%), the cost of agricultural products – 4.87 kg /1000 Int.$ (36.8%).

The application of phosphorus in organic fertilizers has the upward trend, CAGR in the period 2001–2021 is 1.45%.

The potassium balance in agriculture in Spain in the period 2011–2021 was also positive. Organic fertilizers accounted for an average of 60.7% of the potassium entering the soil during this period. In the period 2001–2006, the potassium balance in the soil per unit area averaged +29.7 kg/ha (Fig. 5). With the onset of the global economic crisis, the potassium balance per unit area began to decrease, reaching a minimum in 2009 of 19.4 kg/ha, which was due to a decrease in the application of potassium fertilizers by 62.5% – from 25.6 to 9.6 kg/ha (Fig. 6). In 2010, there was a rapid increase in the use of potash fertilizers to 20.9 kg/ha (+117.7 by 2009), and therefore, the potassium balance reached 24.8 kg/ha. This fact is due to reinvestment in potash fertilizers in view of the stabilization of prices for agricultural products, an increase in grain prices relative to the pre-crisis period.

In the period 2011–2012, the application of potash fertilizers decreased, and since 2013 there has been an upward trend with a peak in 2018 of 24.7 kg/ha, the CAGR in the period 2012–2018 is 5.16%. In the period 2019–2021, the indicator stabilized at the level of 21.1 active substance kg/ha due to a decrease in fertilizer production within Europe because of rising energy prices, primarily for natural gas, as well as droughts.

In order to reduce dependence on fertilizer imports, the largest fertilizer producer in Spain, Grupo Fertiberia, together with PepsiCo, with the assistance of the National

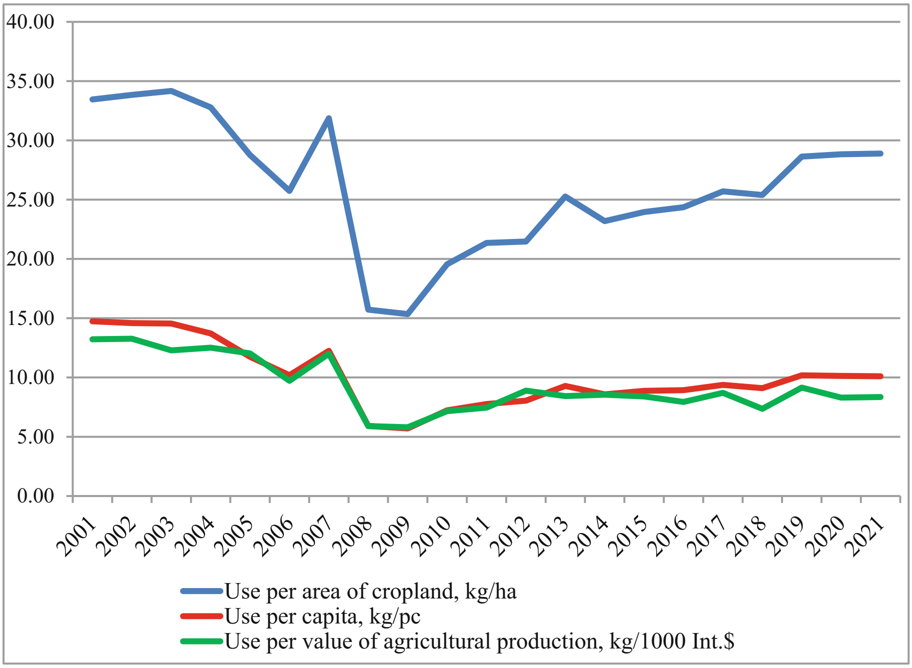

Fig. 4. Application of phosphorus fertilizers in Spain

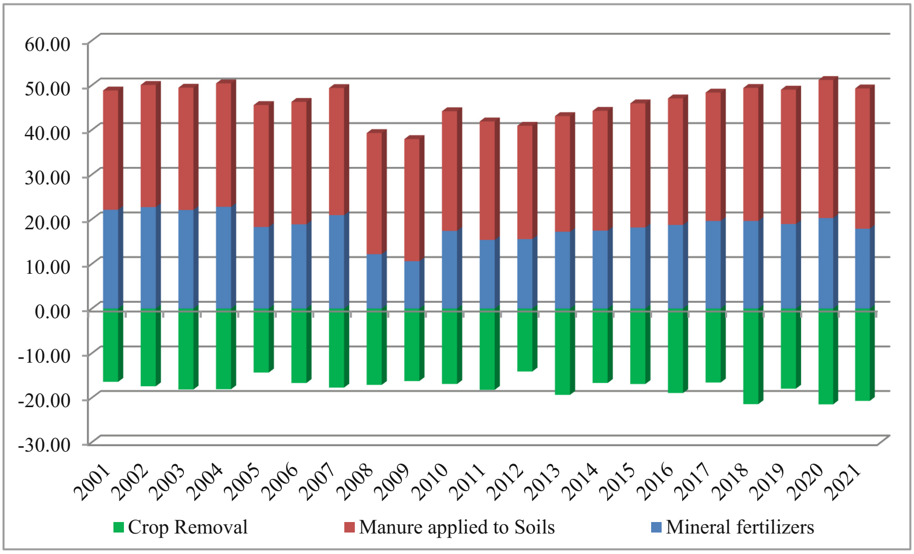

Fig. 5. Potassium balance in the soil per unit area, kg/ha

Association of Fertilizer Manufacturers of Spain (National Association of Fertilizer Manufacturers, ANFFE), are engaged in research and development in the field of producing "green hydrogen" replacing natural gas, "green ammonia", as well as extracting nutrients from alternative sources, in particular organic waste.

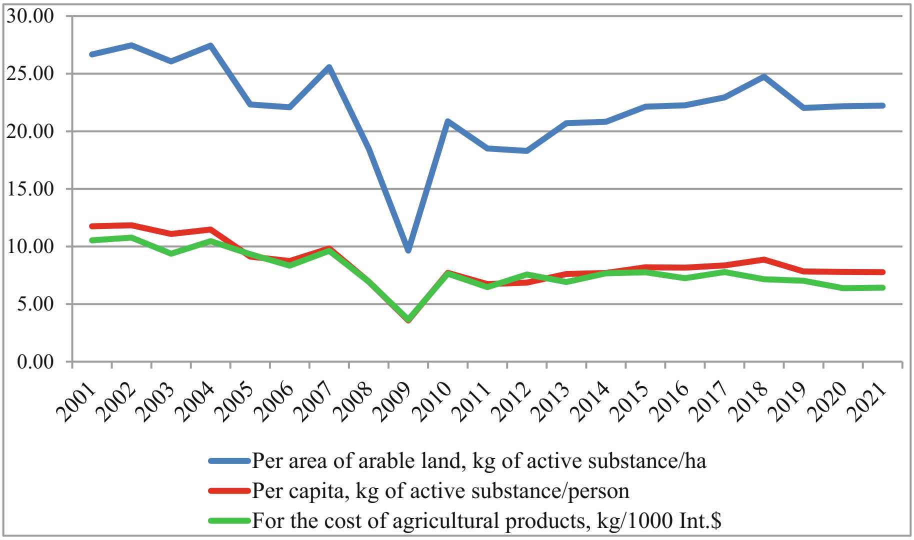

Fig. 6. Application of potash fertilizers in Spain

Spain's policy on reducing greenhouse gas emissions in agriculture is regulated by a number of laws, agreements and strategies.

1. The National Program for Combating and Adapting to Climate Change (Plan Nacional de Lucha contra el Cambio Climatico y de Adaptacion al Cambio Climatico), which was in effect from 2014–2020. The purpose of the program was to promote sustainable development, environmental protection and social and economic equity, taking into account climate change. Key aspects of this program included: (1) Reduction of greenhouse gas emissions by 10% by 2020 compared to 2005 levels by implementing measures to improve energy efficiency, reduce emissions from transport and industry; (2) Achieving a 20% share of renewable energy sources in the total amount of energy consumed; (3) implementation of measures and actions for adaptation to climate change, such as coastal protection, water management, sustainable technologies in agriculture and urban planning; (4) Increased investment in climate change research and innovation.
2. The Law on Climate Change and Energy Transformation (Ley de Cambio Climatico y Tacisio Energetica) was adopted by the Spanish Parliament in May 2021. This law is aimed at implementing Spain's policy of reducing greenhouse gas emissions and transitioning to a sustainable, low-carbon economy. Within the framework of this law, the following main measures are established: (1) reduction of greenhouse gas emissions by 23% by 2030 compared to 1990 levels, as well as by 90% by 2050; (2)

development of action plans to reduce greenhouse gas emissions in various sectors of the economy, including agriculture; (3) establishment of a state register of greenhouse gas emissions, which obliges companies and organizations, including agricultural enterprises, to provide information on their emissions; (4) support and stimulation of the introduction of innovative technologies into the country's agriculture through financial support, provision of tax benefits; (5) Identification of tools and measures to improve the resilience of regions and sectors to climate change; (6) Introduction of professional training programs in the field of innovative low-carbon technologies.

The total contribution of the Spanish agricultural sector to greenhouse gas emissions was estimated at 10% of the total emissions in the country [16].

The volume of nitrogen oxide emissions in Spain in the period 2001–2007 was in the range of 58.1–65.3 kt/g (Fig. 7). During the global economic crisis of 2008–2013, emissions decreased to an average of 54.8 kt, which was due to a decrease in the use of mineral and organic fertilizers. In subsequent years, one can see a tendency to increase nitrogen oxide emissions (CAGR in the period 2013–2021 is 0.94%), which is associated with an increase in NO_2 emissions from: storage, processing and application of manure (19.0%), use of mineral fertilizers (5.2%), application of manure to the soil (19.7%), on-farm energy use (36.8%).

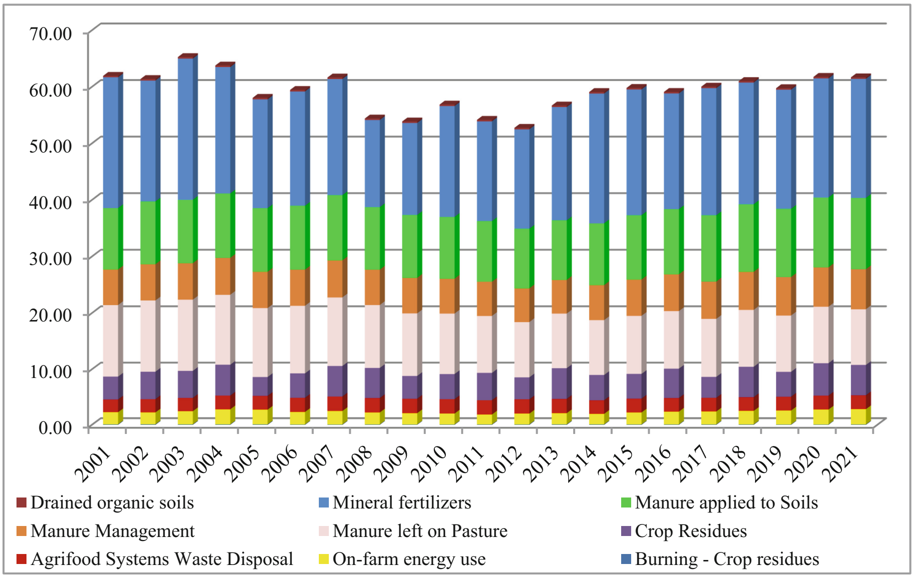

Fig. 7. The structure of nitrogen oxide emissions during agricultural activities in Spain, kt

The volume of methane emissions from agricultural production in the period 2001–2004 averaged 1,759 kt (Fig. 8). Starting in 2005, this indicator began to decrease and reached a minimum in 2013 – 1,323.0 ct, which is 24.8% less than in 2004.

This fact can be explained by a number of reasons, the most significant of which is the decrease in methane emissions from waste disposal of agri-food systems from 740.5

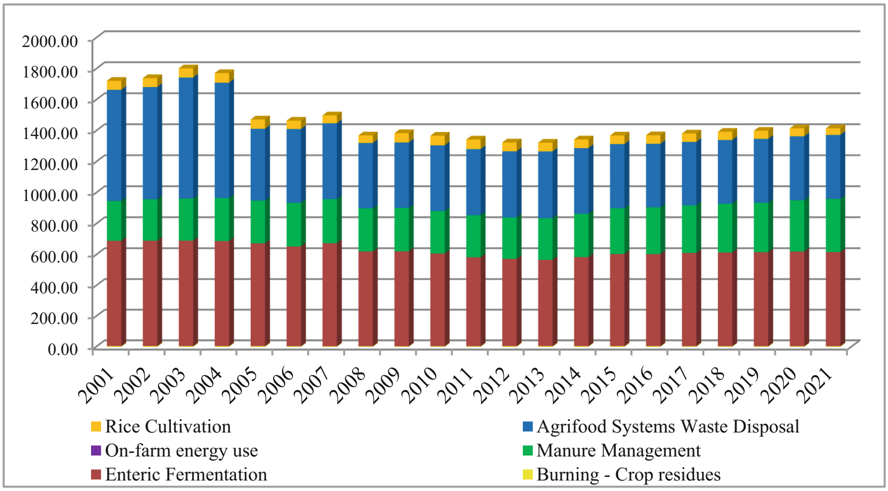

Fig. 8. Methane emissions from agricultural activities in Spain, kt

kt in the period 2001–2004 to 475.2 kt in 2005–2007 and subsequent stabilization at the level of 408.6–429.7 kt, the CAGR in the period 2004–2021 is (−3.22%). There is also a tendency to reduce emissions from the livestock industry in the context of the global economic crisis – from 956.4 kt in 2007 to 832.6 kt in 2013 (−12.9%).

In subsequent years, the volume of CH_4 emissions increased annually and reached a maximum in 2021 – 1,415.8 kt (+7.0% by 2013), which is associated with an increase in the number of farm animals in the country.

The main source of carbon dioxide emissions in Spanish agriculture is the use of energy (Fig. 9). As can be seen from the presented data, in the period 2004–2010 CO_2 emissions in the country decreased from 10930.7 kt to 6764.2 kt, the CAGR in the period 2004–2010 is (−6.63%). This fact is related to the policy pursued in the country to promote the production and use of electricity from renewable energy sources [17].

In particular, A Royal Decree (Real Decreto) 661/2007 establishing rules and conditions for the support and development of electricity production based on renewable sources as well as setting tariffs and conditions for the sale of electricity from renewable sources in Spain was issued in 2007. This decree has been a key tool to promote the use of renewable energy sources in the country. This legislative act has contributed to the fact that Spain has become a world leader in the field of photoelectricity. As a result of the Spanish government's active promotion of renewable energy sources, the share of electricity produced using fossil fuels decreased from 74% in 2000 to 52% in 2012. Also, as of 2021, there were 1,265 wind farms operating in Spain.

However, due to the economic problems that arose during the Global Economic Crisis of 2008–2013, the Spanish government was forced to revise budget items, including reducing spending on the development of green energy. a new law on the electric power industry (24/2013) was adopted in 2013, aimed at improving the economic and financial stability of the industry. In this regard, Spain's share in global solar energy decreased from 80% in 2012 to 40% in 2020 [18]. Therefore, it is possible to observe an upward

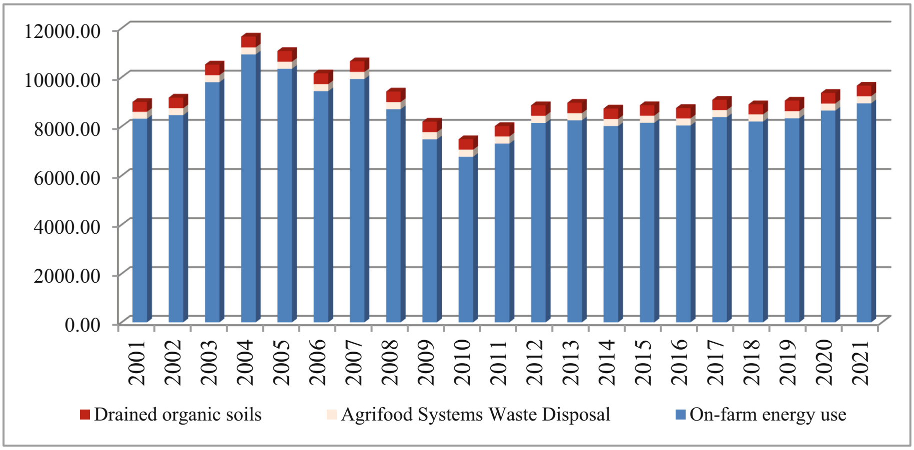

Fig. 9. Carbon dioxide emissions from agricultural activities in Spain, kt

trend in carbon dioxide emissions from energy use in agriculture. During the period of 2010–2021 CO_2 emissions increased by 2,177.2 kt, with a CAGR of 2.35%.

The volume of CO_2 emissions from the disposal of waste from agri-food systems and the use of drained peat soils are stable and average 289.2 and 425.1 kt in the period of 2001–2021 respectively.

Per capita carbon dioxide emissions in Spain peaked at 8.47 tons in 2005 and decreased to 4.92 tons in 2021 [18].

About 20% of continental Spain is already subject to desertification, which is the result of climate change and human activities, including overuse of water resources and, in particular, the exploitation of groundwater. More than 74% of the country's territory is under threat of desertification.

According to FAOSTAT (Fig. 10) there is a trend of increasing deviations from the average long-term annual air temperature in Spain. According to William Chislett (The Elcano Royal Institute) [18], Spain is one of the countries most affected by global warming in the European Union. About 20% of continental Spain is already subject to desertification, which is the result of climate change and human activities, including overuse of water resources and, in particular, the exploitation of groundwater. More than 74% of the country's territory is under threat of desertification.

4 Discussion

According to the results of the study, it can be stated that Spain, which is one of the largest producers of agricultural products in Europe, faced the challenge of balancing the need to increase agricultural productivity and minimize the negative impact on the environment. The use of fertilizers in Spanish agriculture has both positive and negative aspects in the context of sustainable agriculture and climate change. On the one hand, the use of fertilizers helps to increase yields and ensure the country's food security. Without the use of fertilizers, many types of crops could not provide high yields in

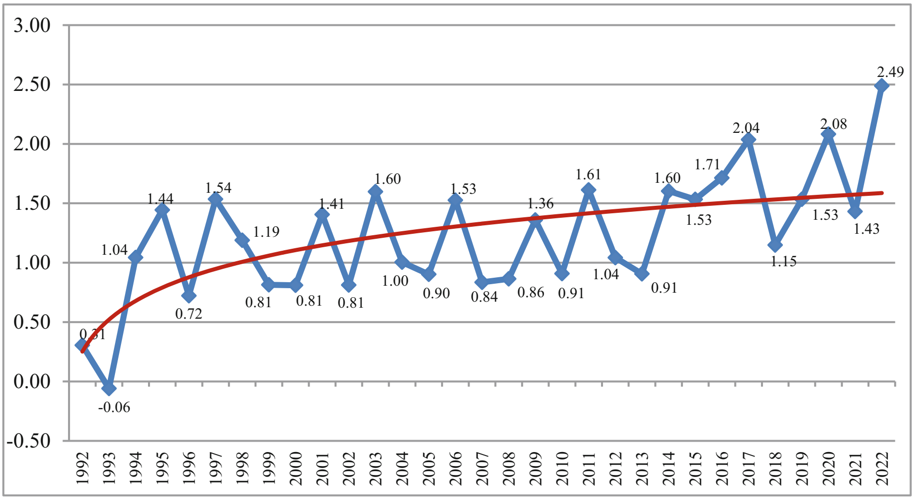

Fig. 10. Deviations from the average long-term annual air temperature in Spain, °C

Spain, which would further lead to the need to expand the area under crops by reducing forest lands and natural ecosystems. Thus, fertilizers make a significant contribution to ensuring food security and sustainability of agriculture. On the other hand, intensive use of fertilizers leads to a number of undesirable consequences, among which the problems associated with greenhouse gas emissions are particularly highlighted. Thus, the intensive use of nitrogen and organic fertilizers stimulates soil leaching, which leads to an increase in emissions of hydrogen sulfide, ammonia and other harmful substances into the atmosphere. These emissions contribute to the formation of the greenhouse effect and increase global warming. In addition, intensive use of fertilizers can lead to pollution of water resources and loss of biodiversity.

In order to increase the sustainability of agriculture and reduce the negative impact of agricultural activities on the environment, various initiatives are being carried out in Spain to promote more sustainable soil management methods and introduction of more efficient fertilizer use systems. Such methods include precision farming technologies, methods of biologization of agriculture.

5 Conclusion

Thus, taking into account the complex impact of fertilizers on agricultural sustainability, greenhouse gas emissions and global warming, it is necessary to introduce methods for optimizing the rates of applied fertilizers in order to balance the need to increase yields and environmental protection in Spain. To achieve this goal we need to continue scientific research in the field of sustainable agriculture and the development of innovative methods of applying fertilizers, as well as to carry out information work among agricultural producers on practices that help reduce the negative effects of fertilizers' use.

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Application of Various Methods for Assessing the Quality of Meat Products Using the Example of Semi-smoked Sausages

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Abstract. Assessing the quality of food makes a major contribution to human health and is of great importance within the framework of sustainable development. The purpose of the research was to assess the qualitative composition of meat product on the example of semi-smoked sausages. 8 samples of sausages were examined. An organoleptic assessment, histological studies (hematoxy-eosin staining) and PCR analysis with species-specific DNA primers for bos, sus, ovis, soybean and GM soybean were carried out. In general, the quality of the studied samples was shown to be quite high. Histological analysis revealed the structure of raw meat and different degrees of processing. The histological method revealed spices (black pepper, allspice) in varying degrees of grinding in 7 samples. No spices were found in one of the samples, although garlic was declared. Also, the histological method revealed in two samples an undeclared vegetable protein supplement, morphologically similar to soy protein isolate, but PCR analysis did not confirm the presence of soy. PCR analysis identified undeclared chicken DNA in one sample. Using methods separately does not create a holistic picture of the quality and composition of products, while their combined use creates a more complete picture. It was not possible to establish the nature of the vegetable protein supplement by any of the methods, which indicates the need to study the microstructural properties of the ingredients used in the meat industry.

Keywords: Meatproducts · Authentication · Morphology · Processed meat · Falsification · PCR analysis

1 Introduction

One of the most important goals in the concept of sustainable development is to ensure a healthy lifestyle for people, an important component of which is nutrition. To provide the population with nutritious and safe food products, it is necessary to improve quality assessment methods in the food industry in general, and in the meat industry in particular. Violations of the microbiological safety indicators of sausage products can occur when low-quality raw materials are used or technological processes are violated;

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also, during the production of sausage products, their contamination with microorganisms from production premises is possible. In this regard, at present, when conducting the examination of sausage products, much attention is paid to safety indicators, while the issues of assessing the quality of sausage products are less covered in the literature. Important qualitative characteristics are the content of nutrients (proteins and fats); these indicators are standardized by GOST and TU. However, achieving the required levels of protein can be achieved by adding vegetable proteins to the recipe while reducing the number of animal squirrels, or by replacing raw meat with offal. One of the types of falsification of the composition of sausages is the replacement of expensive beef meat with cheap raw materials. Determining the true composition of sausages is a pressing issue in most countries [1–5]. To do this, you can use various techniques, the most common are microstructural (histological method) and PCR analysis.

PCR analysis is based on the isolation of DNA molecules from samples with further determination of species, and is considered highly accurate and reliable [3, 6, 7]. It is widespread in the world; the need for its use is due to the possibility of replacing one type of meat with another. In this case, expensive cattle meat is replaced with meat from chickens, pigs or other animals (buffalo, horses, sheep). Cases of such information falsification have been identified in different countries and on different continents, which indicates the high relevance of conducting research to identify the species composition of products [3, 6, 8, 9]. The advantage of the method is its ability to detect DNA after heat treatment, including high temperature exposure [6, 7]. According to the literature, raw meat, as well as meat products - minced meat, sausages, canned meat, cutlets, can be falsified [1, 3, 4, 8, 10, 11]. In the case of meat products, the PCR method makes it possible to identify undeclared components when added in an amount of 1; 0.5 and 0.01% depending on the nucleotide sequence of the target and sample preparation [3, 6, 7].

In addition to replacing expensive meat raw materials with cheaper ones, there is another type of falsification when additives based on plant proteins are introduced into the recipe without indicating them on the label [12]. The most accessible soy supplement is soy protein isolate. The addition of soy proteins to the recipe of meat products not only allows one to maintain the protein content in the finished product required by law, but also improves the organoleptic properties. Thus, replacing 1–2% of meat with soy proteins has a positive effect on consistency, elasticity, uniformity, and water-holding capacity [13–16]. To determine the presence of soy in meat products, commercial kits have been developed to detect soy DNA, however, according to some authors, due to the inability to extract a sufficient amount of amplifiable DNA, they may be ineffective [12]. Also, the results of DNA analysis can be influenced by the sampling method [17].

The PCR analysis method allows us to identify the species composition of the product, but it does not allow us to determine which animal tissues were used in its manufacture. Currently, there are cases of replacement of expensive meat raw materials with low-value fabrics. For example, in the production of sausages, internal organs, skin, cartilage and bones are used for such substitution [18–20]. The presence of smooth muscle tissue in sausage samples has also been described [21]. To determine this kind of falsification, a histological method is used, which allows one to obtain information about the tissue composition of meat products. This method is quite simple, does not require expensive equipment and reagents, and is performed relatively quickly [22]. It can be used to identify the quality of raw meat used, including determining mechanically separated meat [23–25] and the presence of plant components [25–27]. Methods have been developed for determining the ratio of ingredients in meat products [27, 28].

The purpose of our work was to assess the quality of semi-smoked sausages using PCR analysis and histological method.

2 Materials and Methods

Semi-smoked sausages "Krakovskaya" (samples 1–4) and "Hunter's sausages" (samples 5–8) of leading Russian brands were taken as objects of research. Semi-smoked products were purchased in the form of loaves and were subjected to research during the current expiration dates.

Organoleptic studies were carried out in the laboratory of veterinary and sanitary examination of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy in accordance with GOST 31785–2012 "Semi-smoked sausages".

Histological analysis was performed at the Educational and Scientific Laboratory of Histology and Histochemistry of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy. Samples 1 cm3 in size, taken from the middle part of the loaves, were fixed in 10% neutral formalin, successively passed through 12.5% and 25% gelatin, and filled with 25% gelatin. Sausage sections were prepared using a freezing microtome. Staining of sections was carried out using standard methods of hematoxylin-eosin and hematoxylin-eosin-Sudan III according to GOST 19496–2013 "Meat and meat products. Stained sections were embedded in glycerol-gelatin and examined under a microscope at different magnifications.

Identification of the species composition of raw materials using the polymerase chain reaction method was carried out in the laboratory of DNA plant markers of the All-Russian Research Institute of Agricultural Biotechnology. To identify beef, pork and chicken in the raw materials, we used a test system we had previously developed [29]. The presence of soybeans and GM soybeans (genetically modified soybeans) was determined by amplification of total DNA of samples with primers for the soybean lectin gene and the 35S promoter of the transgenic construct.

Using a set of reagents from the SINTOL company, total DNA was isolated, 70 ng of which was used to carry out the polymerase chain reaction with a mixture volume of 25 μl.

Amplification was carried out in a GeneAmp PCR System 2700 device (Applied Biosystems, Inc., USA) under the following conditions:

- for raw meat 94 °C, 3 min; 35 cycles (94 °C, 30 s; 64 °C, 30 s; 72 °C, 1 min), final synthesis 72 °C, 5 min;
- for soybeans and TG-soybeans 94 °C, 3 min; 35 cycles (94 °C, 30 s; 70 °C, 30 s; 72 °C, 30 s), final synthesis 72 °C, 5 min.

Identification of the resulting amplification products was carried out by electrophoretic separation in a 1% agarose gel in 0.5X TBE buffer.

3 Results

3.1 Organoleptic Studies

The results of organoleptic studies show that samples 2 and 3 met the requirements of GOST, but experts noted that in sample 2 the taste of spices was weakly expressed. Sample 1 did not meet the requirements of regulatory documentation; a loose consistency and greasy taste of the bacon were noted. Sample 4 was also not highly rated. An unpleasant foreign taste was detected in the sample, which is not typical for this type of sausage product.

As a result of the organoleptic assessment of the "Hunting Sausages" sausage products, it was revealed that samples 6, 7 and 8 fully complied with the requirements of GOST, however, sample 8 was more preferable due to its pleasant aftertaste. Also, the tasting commission noted the pronounced taste of spices and the color of sample 6. Sample 5 had an unusual taste of bacon, and the experts also noted the inelastic consistency of this sample.

3.2 Histological Studies

Microstructural analysis shows that the main form-building component in the samples is minced meat, represented by striated muscle tissue (Fig. 1). Connective tissue is present in the form of small fragments. In all semi-smoked "Krakowska" sausages, striation is best expressed in sample 1, worse in sample 4. In the group of samples of sausage products "Hunter's sausages", significant heterogeneity in this characteristic is observed. In sample 6, the striation is not expressed; it is best represented in sample 4. In samples 1 and 6, large fragments of connective tissue are found. In sample 8, fragments of connective tissue are few in number, but are large in size, which may indicate the level of grinding of raw materials during the production process. In the remaining samples, connective tissue occurs in fragments, and muscle tissue predominates.

In all samples, except for sample 8, the manufacturers declared spices in the composition. In samples 2 and 4, their composition was not specified; in other cases it was garlic, black pepper, allspice. Sample 6 also contains cumin and coriander. Histological examination (Fig. 2) showed that in most cases, spices are represented by small, few fragments - samples 1, 4 and 5. Medium-sized fragments were found in samples 3 and 6. In samples 2 and 7, numerous large fragments of natural spices were found, such as like black pepper and allspice. No spice fragments were found in sample 8.

Of all the samples presented, only the manufacturer of sample 6 declared the use of non-meat protein additives in the formulation; however, components not declared by the manufacturer were found in some samples. In sample 2, there were single particles of plant protein isolate. Sample 7 contained a moderate amount of plant protein isolate, in addition, a slight accumulation of starch grains was detected in this sample (Fig. 2).

3.3 Results of PCR Analysis

The results of the PCR analysis are presented in Table 1 and in Figs. 3 and 4. In the "Krakowskaya" and "Hunter's sausages" sausages, according to GOST 31785-2012, in

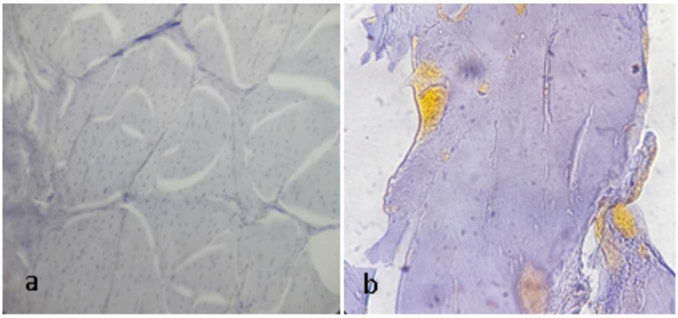

Fig. 1. Histological picture of the studied samples: a – connective tissue; b – muscle fibers

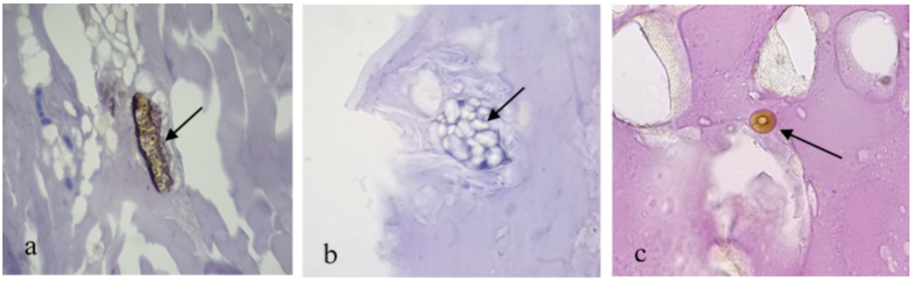

Fig. 2. Fragments of spices and additives in the product: a – black pepper; b – starch grains; c – vegetable protein isolate

accordance with the recipe, beef and pork DNA must be present. All declared samples, with the exception of sample 8, corresponded to the declared recipe. All samples did not contain soy and genetically modified soy (Fig. 3/Table 1).

Based on the results of PCR analysis, falsification of the composition of the raw materials of the "Hunting Sausages" sausage product sample 8 was revealed; chicken was found in it, which should not be present according to GOST, and the composition of the sausage did not indicate "the product may contain traces of eggs, chicken" (Fig. 4/Table 1).

4 Discussion

Meat products are subject to high demands; they must be safe for consumers and meet quality standards [30]. The first method for studying product quality is organoleptic, since it is used not only in scientific laboratories, but also by every consumer when using the product. The consumer chooses a meat product based on organoleptic characteristics. But research shows that a high organoleptic rating does not always correspond to a high quality product [31]. For example, in our case, sample 8 received the highest rating for organoleptic indicators, which was not confirmed in further studies.

Table 1. Results of PCR analysis of sausages and sausage products

sample/DNA	Bos	Sus	Ovis	Soy	GM Soy
Sausage "Krakovskaya"					
1	+	+	–	–	–
2	+	+	–	–	–
3	+	+	–	–	–
4	+	+	–	–	–
Sausage "Hunter's sausages"					
5	+	+	–	–	–
6	+	+	–	–	–
7	+	+	–	–	–
8	+	+	+	–	–

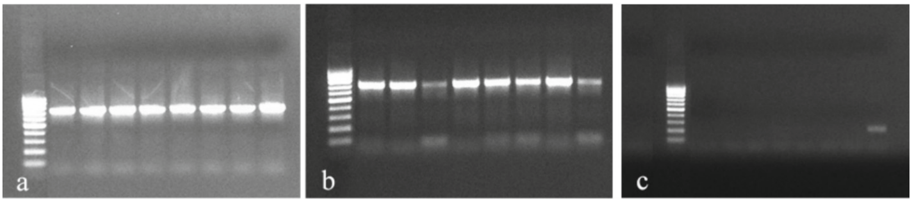

Fig. 3. Results of PCR amplification of DNA isolated from the analyzed samples with species-specific primers: a – for a Sus; b – Bos; c – Ovis

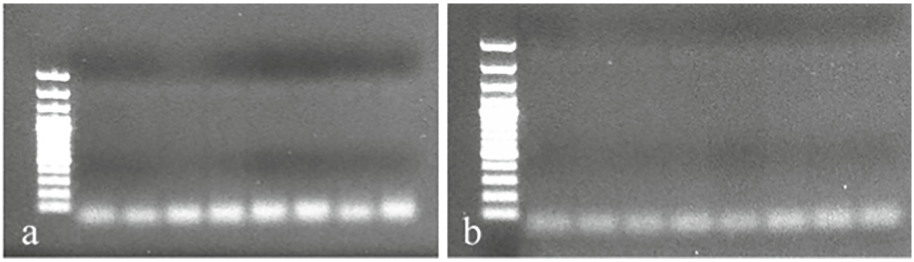

Fig. 4. Results of PCR amplification of DNA isolated from the analyzed samples with primers specific for soybean DNA: a – soy; b – GM soy

Recently, histological (microstructural) assessment of the quality of meat products has been under development [26]. This method of assessing the quality of meat products is recommended in addition to the standard ones [17, 20]. Currently, this method makes it possible to determine compliance with the declared quality category, which is determined, among other things, by the ratio of muscle and connective tissue and the size of connective tissue fragments [23, 32]. In our case, in sample 8, the presence of large parts of tendons was noted, which is not typical for high-category products. You can also evaluate the structure of muscle fibers. Our studies revealed the heterogeneity of the samples in terms of the state of striation, which is also noted by other researchers; this picture indicates the use of raw materials of different quality [23].

Using the histological method, it is possible to determine the presence of plant components, including spices, the degree of their grinding, and the volume of administration. In our study, we found large fragments of natural spices (black and allspice) in samples 2 and 7, small fragments in all except sample 8. Coriander and cumin, declared in sample 6, were not detected. The discrepancy between the information on the label and the histological picture can be explained either by a small amount of spices added, or by their replacement with spice extracts, which most likely happened with sample 8.

In addition to spices, other plant components can be identified; we only detected starch. In our case, a single inclusion of starch may not be associated with targeted adulteration with starch as a moisture-retaining component, but rather with adulterated spices. Adulteration of spices with starch is a common case [33]. Starch in boiled-smoked sausages retains its structure due to low-temperature exposure [34]. The use of starch as a moisture-retaining additive has been described by other authors [23].

The histological method shows high accuracy in identifying animal tissues [18, 28]. In the case of herbal supplements, it is not always possible to know with certainty the origin of the supplement [17]. Our studies revealed a component morphologically similar to soy isolate, but PCR analysis did not reveal the presence of soy. Thus, we agree with researchers who believe that the histological method needs to be improved [26], including the creation of atlases and databases on the microstructural picture of various food additives.

In our research, PCR analysis showed undeclared chicken DNA. Chicken is the most common adulterating ingredient [1, 2]. Since chicken meat is a strong allergen, products that are not labeled for its presence can be dangerous. At the same time, PCR analysis can give a positive reaction to a chicken egg, as in the case we described earlier [29].

PCR analysis makes it possible to determine the species of raw materials, which may have religious and medical significance [4]. However, it does not allow identifying the tissues used, so it is advisable to supplement it with a histological method [17, 35].

5 Conclusion

The sausage samples we examined mainly consisted of skeletal muscle tissue and were generally of high quality. No significant violations of the recipe were identified; minor violations included the presence of undeclared vegetable protein additives and chicken DNA. Identification of these components was possible thanks to the use of a complex of two methods. For the full implementation of the histological method, it is necessary to continue studying the microstructure of the components used in the production of meat products, including their ability to accept dyes. It is necessary to create a database of microphotographs for the examination of meat products.

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Functional Diagnostics of Pea Varieties on Different Nutritional Systems on Leached Chernozem Using a Non-invasive Method

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Abstract. The article examines the functional diagnostics of pea plants using the example of the varieties Salamanca, Madonna and Rodnik, which are cultivated on three agricultural backgrounds using recommended ($N_{15}P_{30}K_{30}$), calculated ($N_{20}P_{45}K_{30}$) and minimal ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer.

The work was carried out on the territory of the educational and experimental farm of the Stavropol State Agrarian University. The meteorological conditions of the territory are characterized by sufficient moisture, but uneven precipitation throughout the year. The average annual precipitation is 551 mm. The sum of active temperatures is 3000–3200 °C. The farm soil is leached chernozem with an average supply of organic matter.

The purpose of the study was to analyze the influence of mineral fertilizers in various doses and complex microfertilizers on indicators characterizing the state of the pigment complex and nitrogen content in pea leaves. A spectral analysis of plant leaves was carried out under the field conditions using a Polypen RP 410 device, which makes it possible to determine the physiological state of plants using vegetation indices: PSSRa (Pigment Specific Simple Ratio Chlorophyll a), PSSRb (Pigment Specific Simple Ratio Chlorophyll b), CRI550 (Carotenoid Reflectance Indices), SIPI (Structure-Intensive Pigment Index) and N550 (Nitric Index). The obtained data were processed in the Spectrapen program.

To obtain stable yields of the Rodnik and Salamanca varieties, it is advisable to cultivate them on the recommended ($N_{15}P_{30}K_{30}$) and calculated agricultural background ($N_{20}P_{45}K_{30}$) and the Madonna variety only on the recommended ($N_{15}P_{30}K_{30}$).

Keywords: Peas · Vegetation Index · Chlorophyll · Agricultural Background · Functional diagnostics

1 Introduction

Pea plants require a wide range of nutrients for optimal growth. Nitrogen, phosphorus and potassium are the main macronutrients. Chemical elements stimulate the development of the root system, growth, shoots, flowering and fruiting of plants. Macroelements

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influence the formation of morphological characteristics, the course of biochemical reactions and the metabolic process in the body of pea plants - photosynthesis. Thus, nitrogen regulates a wide range of plants enzymatic activity [1, 2]. Phosphorus affects the branching of roots, the formation of flowers, seeds and energy transfer and regulates respiration processes. The energy of phosphate bonds of adenosine triphosphate and adenosine diphosphate affects the plant growth and development [3, 4]. Potassium regulates water balance, the flowering process, the quality of bean formation, the biosynthesis of plant proteins, enzymatic catalysis and photosynthesis kinetics and immunity [5]. The macroelement increases the activity of enzymes involved in carbohydrate and protein metabolism.

Managing nutrient cycling between soil and pea plants is critical to maintaining higher productivity of pea varieties in different agricultural backgrounds and their stress tolerance [2]. Changes in nutrient cycling may indicate ongoing changes in the agrocenosis functions of field pea varieties. In this case it is important to quantify, in terms of phases, the speed as well as the quality of these changes with which nutrients are able to be assimilated. Using microelements and macroelements together allows you to balance plant nutrition and, to some extent, alleviate stress. The use of a chelated form of fertilizer allows plants to better absorb the agrochemical.

The purpose of our study is to analyze the influence of mineral fertilizers various doses and complex microfertilizers on indicators characterizing the state of the pigment complex and nitrogen content in pea leaves. In accordance with the purpose, a spectral analysis of plant leaves was carried out in the field using a Polypen RP 410 device, which makes it possible to determine the physiological state of the organism. The obtained data were processed in the Spectrapen program.

The work was carried out on the territory of the educational and experimental farm of the Stavropol State Agrarian University. The research subject was the nutrition system according to the following options:

1. Recommended ($N_{15}P_{30}K_{30}$) - for pre-sowing cultivation NPKS 10:20:20:6 (NPKS-2) 150 kg/ha;
2. Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer. When sowing NAFC 62.5 kg/ha + fertilizing in the phase of 1–3 pairs of leaves START 15:30:15 + 2MgO + ME, 11:40:11 + 2MgO + ME, 13:40:13 + ME.
3. Calculated for 2.5 t/ha ($N_{20}P_{45}K_{30}$) - for the cultivation of Diammofosk ($N_{11}P_{30}K_{30}$) 110 kg/ha, for sowing Af (N_3P_{15}) 25 kg/ha + fertilizing in the phase of 1–3 pairs of leaves START 15:30:15 + 2MgO + ME, 11:40:11 + 2MgO + ME, 13:40:13 + ME.

2 Materials and Methods

The educational and experimental farm of the Stavropol State Agrarian University is located in an area of sufficient moisture. The meteorological conditions of the territory are characterized by moderate humidity, but uneven precipitation throughout the year. According to long-term data, the average annual precipitation is 551 mm, the sum of active temperatures is 3000–3200 °C.

The soil is leached chernozem with an average supply of organic matter (5.1–5.4%), $N\text{-}NO_3$ (16–30 mg/kg), P_2O_5 and K_2O (20–25 mg/kg and 220–270 mg/kg, respectively), as well as mobile forms of manganese (16.1–17.0 mg/kg); low supply of zinc (0.5–0.6 mg/kg) and copper (0.12–0.18 mg/kg). The reaction of the soil solution is neutral (6.1–6.5 units).

2.1 Object of Study

The soil type of the educational and experimental farm is leached, powerful, low-humus, heavy-loamy chernozem. The area of one plot is 1.2 hectares. Agrochemical characteristics of the experimental plot during the study period (2023): organic matter content - 4.26%, pH - 5.81 units, mobile phosphorus content - 28.3 mg/kg, mobile potassium content - 250 mg/kg, ammonium nitrogen content - 14.2 mg/kg, nitrate nitrogen content - 5.8 mg/kg.

The objects of the study were pea varieties Madonna (originator Norddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany), Rodnik (originator "Federal Research Center for Pulses and Cereals", Russia), Salamanca (originator Orddeutsche Pflanzenzucht Hans-Georg Lembke KG, Germany). All varieties are leafless, mid-season. To determine the pigment complex of plants, spectral analysis was carried out using a Polypen RP 410 device, which made it possible to determine the content of chlorophyll a (PSSR) [6], chlorophyll b (PSSRb) [6], carotenoids (CRI_{550}) [7], nitrogen in leaves (N_{550}) [8], plant health index (SIPI) [9].

3 Results

In phase of 1–3 true leaves, a comparison of deviations of vegetation indices from the average values for the experimental options showed that the lowest values were noted for the option with a yield calculation of 2.5 t/ha, where the PSSRa value was 0.185; PSSRb - 0.154; PSSRa/PSSRb - 0.004; CRI_{550} - 0.121; SIPI - 0.007; N_{550} - 0.003 (Table 1).

An increase in deviations from the average value was noted according to the recommended fertilizer application schedule ($N_{15}P_{30}K_{30}$): PSSRa was 0.156; PSSRb - 0.159; PSSRa/PSSRb - 0.011; CRI_{550} - 0.181; SIPI - 0.008; N_{550} - 0.006. And the largest ones are at economic control: 0.182; 0.086; 0.020; 0.858; 0.552; 0.293 respectively. The value of the SIPI indicator for all experimental variants is 0.961–1.005, which indicates a healthy physiological state of the plants. In the phase under consideration and subsequently, deviations of vegetative indicators from average values are caused not only by the nutrition system, but also by the varietal specificity of peas, and their reaction to external influencing factors.

In the budding phase, the analysis of the smallest deviations of indicators from the average value was noted according to the calculation scheme at 2.5 t/ha ($N_{20}P_{45}K_{30}$). They amounted to PSSRa - 0.041; PSSRb - 0.058; PSSRa/PSSRb - 0.007; CRI_{550} - 0.167; SIPI - 0.001; N_{550} - 0.010 (Table 2).

Further comes an increase in deviations from the average value according to the recommended scheme ($N_{15}P_{30}K_{30}$). The indicators were according to PSSRa - 0.103; PSSRb - 0.079; PSSRa/PSSRb - 0.005; CRI550 - 0.104; SIPI - 0.129; N550 - 0.006. The highest indicators for the economic control scheme are 1.653; 1.330; 0.082; 0.041; 0.431; 0.005 respectively.

Table 1. The value of vegetation indices in the phase of 1–3 true leaves

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.432	3.843	1.153	2.234	0.974	0.298
Rodnik	4.479	3.884	1.153	2.195	1.005	0.293
Salamanka	4.865	4.056	1.199	2.263	0.981	0.336
Average value	4.592	3.928	1.168	1.585	1.407	0.534
Deviation from the average value	0.182	0.086	0.020	0.858	0.552	0.293
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.485	3.826	1.172	2.135	0.973	0.320
Rodnik	4.933	4.262	1.157	2.581	0.983	0.302
Salamanka	4.679	4.104	1.140	2.214	0.961	0.312
Average value	4.699	4.064	1.156	2.310	0.972	0.311
Deviation from the average value	0.156	0.159	0.011	0.181	0.008	0.006
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.440	3.805	1.166	2.086	0.971	0.317
Rodnik	4.802	4.090	1.174	2.407	0.979	0.307
Salamanka	4.330	3.681	1.176	2.184	0.990	0.312
Average value	4.524	3.859	1.172	2.226	0.980	0.312
Deviation from the average value	0.185	0.154	0.004	0.121	0.007	0.003

In the budding phase, N_{550} according to all schemes has a lower value than in the phase of 1–3 true leaves. The SIPI indicator has also been reduced. The SIPI value for the Rodnik and Salamanca varieties in the economic control experiment is 0.015 and 0.010, which indicates plant stress. Perhaps such low values reflect the response of the physiological state of pea varieties to mineral nutrition and water stress.

The quantitative content of carotenoids in pea plants is inherited and passed on to offspring. In the vegetative phases discussed above and further during plant ontogenesis, CRI_{550} value changes, but in our opinion does not have a pronounced identification feature for determining the phase transition.

In the flowering phase, the analysis of the smallest deviations of vegetation indices from the average value is noted according to the calculation scheme ($N_{20}P_{45}K_{30}$). They amounted to PSSRa - 0.052; PSSRb - 0.039; PSSRa/PSSRb - 0.007; CRI_{550} - 0.112; SIPI - 0.005; N_{550} - 0.009 (Table 3).

Table 2. The value of vegetation indices in the budding phase

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.350	3.608	1.206	2.301	0.983	0.029
Rodnik	0.580	0.578	1.003	2.236	0.010	0.037
Salamanka	0.680	0.652	1.042	2.356	0.015	0.043
Average value	1.870	1.613	1.084	2.298	0.336	0.036
Deviation from the average value	1.653	1.330	0.082	0.041	0.431	0.005
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.419	3.844	1.149	2.392	0.976	0.286
Rodnik	4.705	4.051	1.161	2.487	0.980	0.296
Salamanka	4.597	3.991	1.151	2.673	1.268	0.302
Average value	4.574	3.962	1.154	2.517	1.075	0.295
Deviation from the average value	0.103	0.079	0.005	0.104	0.129	0.006
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.377	3.728	1.174	2.290	0.972	0.308
Rodnik	4.399	3.715	1.184	2.188	0.974	0.302
Salamanka	4.480	3.852	1.163	2.614	0.975	0.282
Average value	4.419	3.765	1.174	2.364	0.974	0.297
Deviation from the average value	0.041	0.058	0.007	0.167	0.001	0.010

Further comes an increase in deviations of the indices from the average value according to the recommended scheme ($N_{15}P_{30}K_{30}$): PSSRa - 0.097; PSSRb - 0.095; PSSRa/PSSRb - 0.013; CRI_{550} - 0.193; SIPI - 0.006; N_{550} - 0.004. The largest deviations of indicators according to the economic control scheme are 1.540; 1.321; 0.026; 0.035; 0.229; 0.004 respectively.

In the flowering phase, in all experiments, N_{550} and SIPI indicators increased compared to the budding phase (but not significantly), possibly due to the immune status stabilization of the varieties to the effects of pests against the background of improved weather and climatic conditions [10–12].

During the flowering phase, mineral nutrition plays a special role in the formation of carotenoids. In pea leaves, the value of $CRI_{550}0$ indicator increases towards the flowering period, reaching a maximum and then decreases towards the end of the growing season.

It has been established that the difference in the doses of nitrogen fertilizers is not equally reflected in the content of the indicator in pea plants: in the calculated experiment

Table 3. The value of vegetation indices during the flowering phase

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.491	3.797	1.182	2.319	0.988	0.059
Rodnik	1.072	0.862	1.243	2.221	0.475	0.049
Salamanka	0.979	0.789	1.240	2.260	0.469	0.052
Average value	2.181	1.816	1.222	2.267	0.644	0.053
Deviation from the average value	1.540	1.321	0.026	0.035	0.229	0.004
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.609	4.001	1.151	2.311	0.989	0.303
Rodnik	4.892	4.203	1.163	2.221	0.992	0.299
Salamanka	4.764	4.226	1.127	2.700	0.977	0.309
Average value	4.755	4.143	1.147	2.411	0.986	0.304
Deviation from the average value	0.097	0.095	0.013	0.193	0.006	0.004
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.567	3.930	1.162	2.402	0.974	0.315
Rodnik	4.601	3.891	1.182	2.499	0.983	0.309
Salamanka	4.700	3.999	1.175	2.703	0.988	0.291
Average value	4.623	3.940	1.173	2.535	0.982	0.305
Deviation from the average value	0.052	0.039	0.007	0.112	0.005	0.009

($N_{20}P_{45}K_{30}$) the indicator increases significantly. And a decrease (for example, economic control) in the doses of applied nitrogen inhibits the accumulation of yellow pigments.

In the phase of bean formation, the analysis of the smallest deviations of the indices from the average value was noted according to the calculation scheme ($N_{20}P_{45}K_{30}$). They amounted to PSSRa - 0.052; PSSRb - 0.040; PSSRa/PSSRb - 0.008; CRI_{550} - 0.113; SIPI - 0.005; N_{550} - 0.007 (Table 4).

Then there is an increase in deviations from the average value according to the recommended scheme ($N_{15}P_{30}K_{30}$). The indicators were according to PSSRa - 0.099; PSSRb - 0.094; PSSRa/PSSRb - 0.013; CRI_{550} - 0.195; SIPI - 0.006; N_{550} - 0.004. The highest indicators according to the economic control scheme are, respectively, 1.498; 1.325; 0.031; 0.034; 0.189; 0.010.

In the technical ripeness phase, the analysis of the smallest deviations of the indices from the average value was noted according to the calculation scheme ($N_{20}P_{45}K_{30}$) and

Table 4. The value of vegetation indices during the phase of bean formation

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.382	3.812	1.149	2.321	0.988	0.160
Rodnik	1.068	0.870	1.227	2.227	0.565	0.143
Salamanka	0.957	0.790	1.211	2.264	0.561	0.132
Average value	2.136	1.824	1.196	2.271	0.705	0.145
Deviation from the average value	1.498	1.325	0.031	0.034	0.189	0.010
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.603	4.009	1.148	2.315	0.991	0.310
Rodnik	4.889	4.211	1.161	2.227	0.993	0.319
Salamanka	4.761	4.228	1.126	2.709	0.979	0.318
Average value	4.751	4.149	1.145	2.417	0.988	0.316
Deviation from the average value	0.099	0.094	0.013	0.195	0.006	0.004
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.561	3.935	1.159	2.410	0.980	0.318
Rodnik	4.598	3.888	1.182	2.501	0.989	0.317
Salamanka	4.697	4.001	1.173	2.709	0.992	0.302
Average value	4.619	3.941	1.171	2.540	0.987	0.312
Deviation from the average value	0.052	0.040	0.008	0.113	0.005	0.007

amounted to 0.051 according to PSSRa; PSSRb - 0.042; PSSRa/PSSRb - 0.008; CRI_{550} - 0.111; SIPI - 0.005; N_{550} - 0.003 (Table 5).

Then there is an increase in the deviations of the indices from the average value according to the recommended scheme ($N_{15}P_{30}K_{30}$). The indicators were according to PSSRa - 0.098; PSSRb - 0.094; PSSRa/PSSRb - 0.012; CRI_{550} - 0.195; SIPI - 0.004; N_{550} - 0.002. The highest indicators according to the economic control scheme are, respectively, 1.501; 1.326; 0.021; 0.035; 0.128; 0.013. In all experiments, there was an increase in the CRI_{550} index and a change in the PSSRa/PSSRb ratio towards an increase in the concentration of chlorophyll b. as a result - the formation of peas.

In the biological ripeness phase, the analysis of the smallest deviations from the average index value was noted according to the calculation scheme ($N_{20}P_{45}K_{30}$) and amounted to PSSRa - 0.051; PSSRb - 0.044; PSSRa/PSSRb - 0.008; CRI_{550} - 0.112; SIPI - 0.005; N_{550} - 0.002 (Table 6).

Table 5. The value of vegetation indices in the phase of technical ripeness

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.379	3.824	1.145	2.330	0.988	0.148
Rodnik	1.055	0.881	1.197	2.232	0.701	0.130
Salamanka	0.948	0.799	1.186	2.271	0.699	0.109
Average value	2.127	1.835	1.176	2.278	0.796	0.129
Deviation from the average value	1.501	1.326	0.021	0.035	0.128	0.013
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.598	4.013	1.145	2.319	0.989	0.208
Rodnik	4.880	4.218	1.156	2.232	0.990	0.213
Salamanka	4.757	4.230	1.124	2.714	0.981	0.211
Average value	4.745	4.154	1.142	2.422	0.987	0.211
Deviation from the average value	0.098	0.094	0.012	0.195	0.004	0.002
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.558	3.940	1.156	2.417	0.984	0.221
Rodnik	4.591	3.894	1.178	2.512	0.992	0.224
Salamanka	4.690	4.012	1.168	2.715	0.999	0.215
Average value	4.613	3.949	1.167	2.548	0.992	0.220
Deviation from the average value	0.051	0.042	0.008	0.111	0.005	0.003

Further comes an increase in deviations of indicators from the average value according to the recommended scheme ($N_{15}P_{30}K_{30}$). The indicators were according to PSSRa - 0.100; PSSRb - 0.094; PSSRa/PSSRb - 0.012; CRI_{550} - 0.186; SIPI - 0.005; N_{550} - 0.012. The highest indicators according to the economic control scheme are, respectively, 1,500; 1.327; 0.014; 0.034; 0.099; 0.012.

4 Discussion

Analysis of the chlorophyll ratio (PSSRa/PSSRb) in the economic control scheme showed that the largest standard deviations in all phases of development were shown by the variety Rodnik (0.171), then Salamanca (0.057) (Fig. 1). The smallest is the Madonna variety (0.028). The budding phase for the varieties Rodnik and Salamanca was the most critical. Analysis of the chlorophyll ratio (PSSRa/PSSRb) in the recommended scheme ($N_{15}P_{30}K_{30}$) showed that the Rodnik variety had the largest standard deviations in all

Table 6. The value of vegetation indices in the phase of biological ripeness

Variety	Index value					
	PSSRa	PSSRb	PSSRa/ PSSRb	CRI_{550}	SIPI	N_{550}
Minimum (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer						
Madonna	4.366	3.831	1.139	2.345	0.899	0.128
Rodnik	1.043	0.892	1.169	2.251	0.698	0.116
Salamanka	0.937	0.800	1.171	2.287	0.656	0.095
Average value	2.115	1.140	1.160	2.294	0.751	0.103
Deviation from the average value	1.500	1.327	0.014	0.034	0.099	0.012
Recommended ($N_{15}P_{30}K_{30}$)						
Madonna	4.587	4.020	1.141	2.391	0.967	0.121
Rodnik	4.875	4.224	1.154	2.252	0.978	0.124
Salamanka	4.749	4.239	1.120	2.740	0.967	0.096
Average value	4.737	4.161	1.138	2.461	0.971	0.114
Deviation from the average value	0.100	0.094	0.012	0.186	0.005	0.012
Calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$)						
Madonna	4.550	3.951	1.151	2.442	0.976	0.196
Rodnik	4.582	3.900	1.174	2.539	0.989	0.201
Salamanka	4.680	4.024	1.163	2.743	0.978	0.199
Average value	4.604	3.958	1.163	2.575	0.981	0.199
Deviation from the average value	0.051	0.044	0.008	0.112	0.005	0.002

development phases (0.014) (Fig. 2). The smallest is the Madonna variety (0.008). Analysis of the chlorophyll ratio values (PSSRa/PSSRb) during the period of ontogenesis in the calculation scheme for 2.5 t/ha ($N_{20}P_{45}K_{30}$) showed that the largest standard deviations were observed in the variety Rodnik (0.012), then Madonna (0.010) (Fig. 3). The smallest is in the Salamanca variety (0.008).

Analysis of nitrogen values (N_{550}) during the ontogeny period in the economic control experimental scheme showed that the largest standard deviations were observed in the varieties Rodnik and Salamanca (0.183 and 0.092, respectively) (Fig. 4). The smallest is in the Madonna variety (0.083). The largest range of deviations of the indicator occurs during the budding phase. During the flowering phase, all varieties experienced stress, primarily water stress.

Analysis of nitrogen values (N_{550}) during the period of ontogenesis in the recommended scheme ($N_{15}P_{30}K_{30}$) showed that the largest standard deviations were observed in the Rodnik variety (0.150) (Fig. 5). The smallest are for Salamanca and Madonna

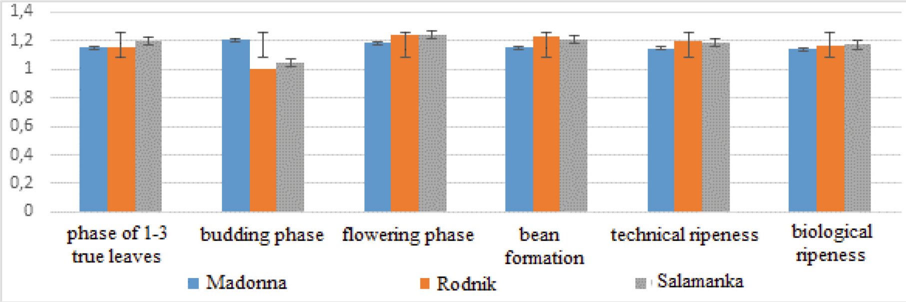

Fig. 1. Dynamics of the PSSRa/PSSRb ratio during the ontogenesis of the varieties Madonna, Rodnik, Salamanca (experiment scheme - minimal (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer)

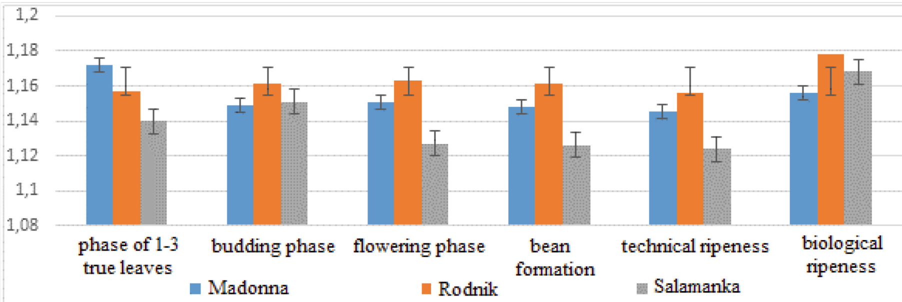

Fig. 2. Dynamics of the PSSRa/PSSRb ratio during the ontogenesis of the varieties Madonna, Rodnik, Salamanca (experimental scheme - $N_{15}P_{30}K_{30}$)

(0.075 and 0.063, respectively). From the phase of bean formation to the phase of biological ripeness, a decrease in the indicator is observed for all varieties of peas, caused by the outflow of plastic substances from the leaves into the seeds.

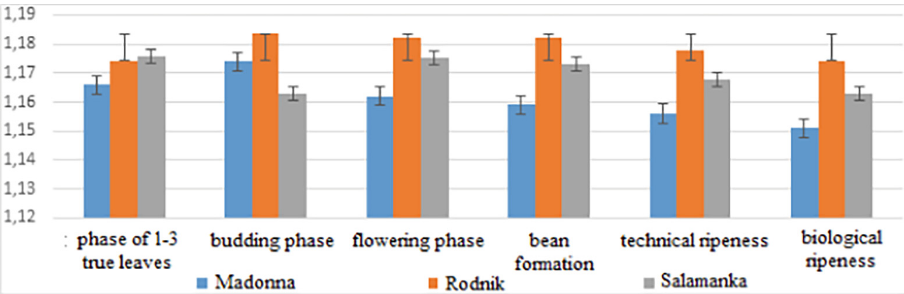

Fig. 3. Dynamics of the PSSRa/PSSRb ratio during the ontogenesis of the varieties Madonna, Rodnik, Salamanca (experimental scheme - $N_{20}P_{45}K_{30}$)

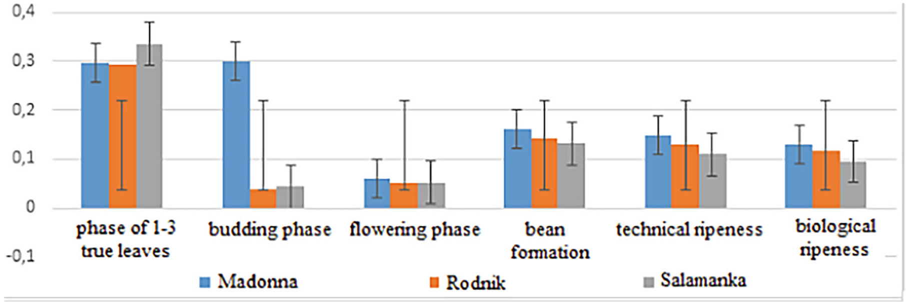

Fig. 4. Dynamics of nitrogen (N_{550}) during the ontogenesis of varieties Madonna, Rodnik, Salamanca (experiment scheme - minimal (economic control) ($N_{10}P_{10}K_{10}$) + water-soluble fertilizer))

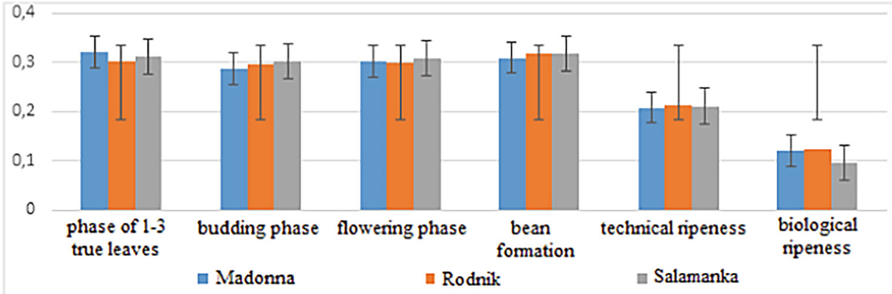

Fig. 5. Dynamics of nitrogen (N_{550}) during the period of ontogenesis of varieties Madonna, Rodnik, Salamanca (experiment scheme - recommended ($N_{15}P_{30}K_{30}$))

Analysis of nitrogen values (N_{550}) during the period of ontogenesis in the experimental scheme calculated at 2.5 t/ha ($N_{20}P_{45}K_{30}$) showed that the largest standard deviations were observed in the Rodnik variety (0.100) (Fig. 6).

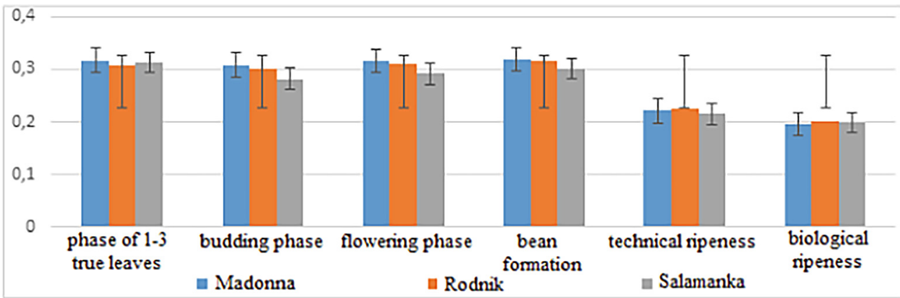

Fig. 6. Dynamics of nitrogen (N_{550}) during the ontogeny of the varieties Madonna, Rodnik, Salamanca (experimental scheme - calculated for 2.5 t/ha ($N_{20}P_{45}K_{30}$))

The smallest are in the Madonna and Salamanca varieties (0.044 and 0.056, respectively).

5 Conclusion

The most susceptible to external influencing factors is the Rodnik variety, which according to the average deviations of indicators, has the maximum values for all experimental variants and the studied varieties. The variety is not recommended for cultivation on a low agricultural background (($N_{10}P_{10}K_{10}$) + water-soluble fertilizer). When cultivating a variety according to the recommended and calculated schemes, environmental conditions will always dominate. The Salamanca variety is not recommended for cultivation on a low agricultural background and recommended, because this will affect the physiological state of plants - an imbalance in the concentration of chlorophyll and nitrogen in the plants leaves and, as a consequence, the manifestation of stress in the budding and flowering phases. The Madonna variety tolerates low agricultural background well and is also recommended. Vegetation indicators are relatively uniform. If unfavorable external conditions occur against the background of nitrogen and phosphorus increasing doses (at $N_{20}P_{45}K_{30}$), the physiological state of plants will become unstable.

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The Effect of Shortened Light/Dark Cycles on Growth, Yield and Nutritional Value of Pea Shoots

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Abstract. Vertical farming shows great potential as a solution to address food security challenges and promote sustainable agriculture. This solution should be considered as part of a broader range of strategies to create a more resilient and sustainable food system. The aim of the work was to study the effects of shortened light/dark cycles (8/4 h, 4/4 h and 4/2 h) on the external appearance and internal quality of pea (*Lathyrus oleraceus* Lam.) shoots used as ready-to-eat baby-leaf vegetable. Conventional photoperiod 12/12 h was used as a control treatment. Shortened light/dark cycles increased robustness index, water use efficiency, flavonoid, proline, protein and soluble sugars content. The effects were most pronounced in plants treated by L/D cycles 8/4 h and 4/4 h. Photosynthetic activity, water and chlorophyll content were unaffected by shortened light/dark cycles. Hydrogen peroxide content was higher in plants grown under shortened light/dark cycles. Obtained results have shown that plant responses to abnormal shortened light/dark cycles do not necessarily depend on daily light integral.

Keywords: *Lathyrus oleraceus* · baby leaf · abnormal light/dark cycles

1 Introduction

Nowadays vertical farming is emerging as a potential solution to address food security challenges and promote sustainable agriculture. With a smaller ecological footprint and higher yield potential, this innovative approach has the potential to revolutionize agriculture systems [1, 2]. Vertical farming maximizes crop output in a limited space and the seasons don't matter.

Pea (*Lathyrus oleraceus* Lam.) is one of the most common legumes that is popular in the world and economically important contributing to over 25% of the total pulse production [3]. It is normally consumed as a seed food, and is a good source of proteins, vitamins and minerals [4]. At the same time the pea plant is a well-established classic model for genetics and agronomic studies [5, 6]. The consumption of leaves of the pea plants, also known as pea shoots, is not as common as eating the peas. Pea shoots are the young edible herbaceous leaves and stems of pea plants. They are harvested in a

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very early maturation stage, when the leaves and tendrils are tender, crispy and have an intense pea flavor [7]. Pea shoots are generally 5–15 cm long and include 2 to 4 pairs of leaves. Traditionally grown in Asia, this baby-leaf green vegetable become increasingly popular worldwide as functional food rich in health-promoting bioactive compounds such as nutrients (vitamins, minerals, protein etc.) and non-nutrients (fibers, phenolic compounds etc.) [8]. This baby-leaf green leafy vegetable can be eaten fresh in salads, or cooked with others ingredients. Pea shoots are a very perishable product with a high market value, when compared to other common leafy vegetables [7].

In Europe most supply of pea shoots comes from open field growers, but when it gets too hot in the summer, the supply gets unstable. On vertical farms growing pea shoots may take place anytime, anywhere. The results of the conducted blind taste test demonstrated that vertically grown pea shoots were well-received by the participants, almost matching the appeal of their organic counterparts.

As the pea plant is one of the most-studied vegetables, the nutritional composition of peas is published in official nutritional tables [8]. On the other hand, specific scientific data regarding the nutritional composition of pea shoots is scarce. Most of the available information is based on the generalization of the green leafy vegetable composition [7]. There is no data available on pea shoot quality related traits as affected by abnormal L/D cycles. In cultivation facilities depending on natural light the light/dark (L/D) cycle period (the length of the cycle) is equal to the diurnal cycle period (24 h). In vertical farms with artificial lighting the L/D cycle may have any length and be shorter or longer than the period of 24 h. Such cycles are called abnormal L/D cycles [9]. So far, few research were focused on the influence of shortened L/D cycles on plant production [10, 11]. Thus, the objective of this investigation was to evaluate the effects of shortened L/D cycles on pea shoots growth, yield and content of phytochemicals.

2 Materials and Methods

Seeds of pea (*Lathyrus oleraceus* Lam.) cultivar Madras variety were sown in 16 × 11 cm trays with rockwool growing mats. The seeds were kept at air temperature of 22 ± 1 °C and relative air humidity of 60 ± 5% in darkness to promote germination. On the fourth day after sowing light germinated seeds were transferred under LED lamps (LED GL V300, China) with a ratio (%) red:green:blue 50.3:21.1:17.6 and lighting treatments were initiated. Photosynthetically active radiation (PAR) was 150 μmol/(m^2 s). Plants were exposed to different shortened L/D light/dark cycles: 8/4 h, 4/4 h, and 4/2 h. Control plants were grown under conventional photoperiod of 12/12 h. Daily light integral (DLI) for control cycle and cycle 4/4 h was 6.48 mol/(m^2 day), and for cycles 8/4 h and 4/2 h - 8.64 mol/(m^2 day). Plants were watered daily with 50% Hoagland nutrient solution (pH 6.2–6.4).

On day 8 after the light treatments were initiated ten shoots were randomly sampled from each treatment to measure the stem length (SL). Fresh mass (FM) of shoots were recorded before being dried in an oven at 105 °C for dry mass (DM) measurements. LMA values (leaf mass per area) were calculated as the ratio of the dry mass of the lamina disks to their area. The robustness index (RI) was defined as the ratio of shoot DM to SL. Absolute water content (WC) was calculated on a dry biomass basis.

The net photosynthesis (A_n) rate, transpiration rate (Tr), stomatal conductance (g_s), and ratio of intercellular to ambient CO_2 concentration (C_i/C_a) were measured using a portable HCM-1000 photosynthetic system (Walz, Germany) at a leaf temperature of 23 °C, air humidity of 65–70%, CO_2 concentration of 400–420 ppm, and PPFD of 1000 μmol/(m^2 s). The parameters were measured on day 8 after the beginning of light treatments, and not earlier than 2 h after the start of a light period. The values of photosynthetic water use efficiency (WUE) were calculated as a ratio of A_n to Tr.

Chl fluorescence parameters of the plants were measured using a Pulse Amplitude Modulation Fluorometer (MINI-PAM, Heinz Walz, Germany). The values of potential quantum yield of photochemical activity of PSII (F_v/F_m) were determined after leaves were dark-adapted for 30 min with leaf clips.

Content of chlorophyll (Chl) *a* and *b* and carotenoids (Car) was measured in 96% ethanol extracts with a SF2000 spectrophotometer (Spectrum, Russia) and calculated according to the known formulas [12].

Anthocyanins were extracted from leaves according to Kang et al. [13]. Fresh leaves tissues (0.1 g) were homogenized in 4 mL of 95% ethanol-1.5 N HCl- (85:15, *v:v*). After overnight extraction at 4 °C in darkness, each sample was centrifuged at 10,000 *g* for 5 min. The absorbance of the supernatant was measured at 530 nm (peak of absorption of anthocyanin) and 657 nm (peak of absorption of Chl degradation products). The results were plotted as a difference in absorption at 530 and 657 nm relative to tissue fresh weight ($\Delta A \bullet g^{-1}$ FW) and the formula $\Delta A = A530 - 1/4A657$ was used to deduct the absorbance contributed by chlorophyll and its degradation products in the extract [14]. The relative amounts of flavonoids were measured spectrophotometrically [15]. The supernatant for anthocyanins was diluted 10 times and the absorbance was measured at 300 nm. Flavonoids content in the sample was expressed as absorbance at 300 nm g^{-1} fresh weight of tissue. The content of free proline in leaf tissues was estimated by the ninhydrin method [16].

The soluble sugar content was determined by anthrone method [17]. Approximately 0.3 g fresh tissue was homogenized with 5 mL deionized H_2O, conducted for 4 h at room temperature with mixing and centrifuged at 14,000 *g* for 15 min. Then the extracts (0.6 mL) were incubated with the anthrone reagent (2.4 mL) in a boiling water bath for 10 min and after cooling to room temperature the absorbance was measured at 620 nm. The content of soluble sugars was calculated by comparison with a standard calibration curve and expressed in mg per g FM.

Hydrogen peroxide content was determined according to Velikova et al. [18]. Leaf tissues (0.1 g) were homogenized in ice bath with 2 mL 0.1% (*w/v*) trichloracetic acid. The homogenate was centrifuged at 12,000 *g* for 15 min at 4 °C and 0.5 mL of supernatant was added to 0.5 mL potassium phosphate buffer (pH 7.0) and 1 mL 1M KI. The absorbance of supernatant was measured at 390 nm. The content of H_2O_2 was calculated by comparison with a standard calibration curve and expressed in μmol per g FM.

To analyze the activity of antioxidant enzymes catalase (CAT, EC 1.11.1.6), superoxide dismutase (SOD, EC 1.15.1.1), ascorbate peroxidase (APO, EC 1.11.1.11), and guaiacol peroxidase (GPO, EC 1.11.1.7), plant leaves were homogenized in 50 mM phosphate buffer (pH 7.8), the homogenate was centrifuged at 15,000 *g* for 10 min at 4 °C, and the activity of enzymes was determined in the supernatant using an SF-2000 spectrophotometer. CAT activity was determined by the enzymatic degradation of H_2O_2 at 240 nm; SOD activity was determined by the ability to inhibit the photochemical reaction of nitro blue tetrazolium; APO activity was determined in the presence of 0.5 mM ascorbic acid and 0.25 mM H_2O_2 by the decrease in optical density at 290 nm; GPO analysis was based on the oxidation of guaiacol in the presence of H_2O_2 with optical density measured at 470 nm [19]. The total protein content was determined by the Bradford method using bovine serum albumin as a standard.

The tables and figures show mean values and standard errors. Significant differences between the means were revealed at $p < 0.05$ using one-way ANOVA analysis.

3 Results

Plants grown under control and L/D cycle 8/4 h had the greatest shoot FM and DM (Table 1). The lowest shoot FM and DM had plants grown under L/D cycle 4/2 h. Plants treated by all shortened L/D cycles were shorter than control plants. LMA values did not differ significantly between the treatments. RI values were the highest in plants grown under L/D cycles 8/4 h and 4/4 h. The WC of shoots was similar in control plants and those treated by L/D cycles 8/4 h and 4/2 h and lower in plants grown under L/D cycle 4/4 h.

There were no any signs of leaf photodamage in plants grown under shortened L/D cycles (Fig. 1).

Table 1. Growth characteristics of pea shoots

Variable	Control	8/4 h	4/4 h	4/2 h
FM, mg	795 ± 35^a	827 ± 25^a	692 ± 25^b	626 ± 30^c
DM, mg	72 ± 4^a	76 ± 2^a	67 ± 2^b	62 ± 3^c
SL, mm	119 ± 2^a	115 ± 2^b	101 ± 2^c	97 ± 2^d
LMA, mg/cm^2	1.8 ± 0.1^a	1.8 ± 0.1^a	1.9 ± 0.1^a	1.8 ± 0.1^a
RI, mg/sm	6.1 ± 0.3^c	6.6 ± 0.2^a	6.7 ± 0.1^a	6.4 ± 0.2^b
WC, g H_2O/g DM	10.04 ± 0.30^a	9.88 ± 0.30^a	9.33 ± 0.28^b	10.08 ± 0.30^a

Here and later different letters for each plant species indicate significant differences between the mean values at $p \leq 0.05$.

Total Chl, Car and anthocyanin contents were unaffected by shortened L/D cycles compared to control (Table 2). However, the ratio of Chl to Car decreased in plants grown under shortened L/D cycle being the lowest in case of the cycle 8/4 h. The content of flavonoids was higher in plants grown under the L/D cycle 8/4 h. All shortened L/D cycles increased proline content (by 8–30%), protein content (by 46–71%) and soluble sugar content (by 6–15%) compared to control. Maximum values were observed in plants grown under the L/D cycle 4/4 h, which provided plants with the same DLI as control treatment.

Fig. 1. Pea shoots grown under (a) control photoperiod and shortened light/dark cycles: (b) 8/4 h, (c) 4/4 h and (d) 4/2 h.

Table 2. Chlorophyll, carotenoids, anthocyanin, flavonoid, protein and soluble sugar content in leaves of pea plants grown under shortened light/dark cycles

Variable	Control	8/4 h	4/4 h	4/2 h
Chl $a + b$, mg/g DM	14.5 ± 1.2^{a}	12.0 ± 1.4^{a}	14.0 ± 0.9^{a}	13.1 ± 1.9^{a}
Car, mg/g DM	1.64 ± 0.45^{a}	1.88 ± 0.27^{a}	2.00 ± 0.12^{a}	1.78 ± 0.22^{a}
Chl/Car	8.8 ± 0.2^{a}	6.4 ± 0.3^{c}	7.0 ± 0.2^{b}	7.4 ± 0.3^{b}
Anthocyanin, (A530-0.25A657)/g FM	0.66 ± 0.07^{a}	0.57 ± 0.01^{a}	0.57 ± 0.03^{a}	0.59 ± 0.01^{a}
Flavonoids, A300/g FM	18.21 ± 0.52^{b}	22.05 ± 0.80^{a}	18.50 ± 0.48^{b}	18.26 ± 0.38^{b}
Proline, µmol/g FM	244.9 ± 7.9^{c}	280.1 ± 14.0^{ab}	320.2 ± 18.7^{a}	266.9 ± 13.4^{ab}
Protein, mg/g FM	17.2 ± 1.7^{b}	24.4 ± 1.0^{a}	28.3 ± 2.7^{a}	26.7 ± 1.1^{a}
Soluble sugars, mg/g FM	14.1 ± 0.4^{d}	15.0 ± 0.1^{c}	16.2 ± 0.1^{a}	15.8 ± 0.3^{b}

No significant differences in A_n were found among the light treatments (Table 3). The shortened L/D cycles did not affect Tr and g_s significantly, but Tr and g_s tended to decrease under unconventional L/D cycles being the lowest under the cycles 4/4 h and 4/2 h. The highest ratio of C_i to C_a was associated with the control treatment, and the lowest was found under 4/4 h cycle. The photosynthetic WUE values tended to increase under shortened L/D cycles and were the highest in plants grown under the cycle 4/4 h. F_v/F_m values were significantly decreased in plants grown under the cycle 4/2 h.

Hydrogen peroxide content tended to be higher in plants grown under shortened L/D cycles being the highest under 4/4 h and 4/2 h cycle (Table 4). The activities of CAT, SOD, APX and GPX were unaffected shortened L/D cycles compared to control except for decreased activity of SOD in plants grown under the cycle 4/2 h, and APX in plants grown under the cycle 8/4 h.

Table 3. Photosynthetic parameters of leaves of pea plants grown under shortened light/dark cycles

Variable	Control	8/4 h	4/4 h	4/2 h
A_n, μmol/(m^2 s)	7.1 ± 0.9^a	7.1 ± 0.1^a	6.5 ± 0.5^a	6.3 ± 0.2^a
Tr, mmol/(m^2 s)	1.3 ± 0.1^a	1.2 ± 0.0^{ab}	1.0 ± 0.1^b	1.0 ± 0.1^b
g_s, mmol/(m^2 s)	83 ± 10^a	68 ± 1^{ab}	52 ± 9^b	60 ± 8^b
C_i/C_a	0.56 ± 0.04^a	0.50 ± 0.03^{ab}	0.37 ± 0.05^b	0.45 ± 0.09^{ab}
WUE, μmol CO_2/mmol H_2O	5.5 ± 0.4^b	6.2 ± 0.2^{ab}	6.9 ± 0.3^a	6.1 ± 0.6^{ab}
F_v/F_m	0.785 ± 0.005^a	0.786 ± 0.003^a	0.784 ± 0.005^a	0.762 ± 0.005^b

Table 4. Hydrogen peroxide content and the activities of catalase (CAT), superoxide dismutase (SOD), ascorbate peroxidase (APX), and guaiacol peroxidase (GPX) in plants grown under shortened light/dark cycles

Variable	Control	8/4 h	4/4 h	4/2 h
H_2O_2, μmol/g FM	0.45 ± 0.02^b	0.50 ± 0.03^{ab}	0.54 ± 0.07^a	0.54 ± 0.05^a
CAT, μmol/(mg FW)	145.7 ± 8.3^a	140.0 ± 18.5^a	135.5 ± 13.8^a	151.3 ± 2.9^a
SOD, U/mg FW	59.9 ± 2.9^a	63.8 ± 17.6^a	58.6 ± 4.3^a	38.5 ± 13.2^b
APX, μmol/(mg FW min)	456.6 ± 19.6^a	286.1 ± 21.5^b	440.8 ± 15.5^a	435.6 ± 9.4^a
GPX, μmol/(mg Fw min)	7299 ± 178^a	7816 ± 155^a	7725 ± 300^a	6852 ± 389^a

4 Discussion

The external appearance and internal quality of baby-leaf green vegetables are very important for marketing [20]. The quality of leafy vegetables is divided into internal and external quality. The internal quality is related to minerals, vitamins, antioxidants, and other functional components, such as pigments, polyphenols etc. The external quality may be defined as visual appearance of leafy vegetables like color and leaf biomass [21].

In the present study, L/D cycles 8/4 h and 4/4 h caused the shoots to achieve greater RI compared to control. RI characterizes external quality of pea shoots serving as an integral morphophysiological indicator that combines the volume of the hypocotyl with the dry biomass of shoots. The smallest values of RI were recorded for pea shoots grown under the cycle 4/2 h, which is rather unexpected taking into consideration that light treatments by L/D cycles 8/4 h and 4/2 h have provided plants with the same DLI (8.64 mol/(m^2 day)). Shortened L/D cycles did not affect such quality characteristics as water content and leaf color determined by Chl content. However, shortened L/D cycles increased WUE in plants compared to the control. Content of carotenoids tended to increase in plants treated by unconventional L/D cycles and it resulted in decreased Chl/Car ratio, which was the most pronounced in plants treated by 8/4 h cycle. Decreased

Chl/Car ratio testifies for the photoprotective plant response induced by abnormal L/D cycles. In regard of internal quality beneficial effect of the L/D cycle 8/4 h included increased content of flavonoids. Flavonoids protect plant tissues against excess radiation by absorbing ultraviolet radiation and a part of visible rays (520–560 nm). Flavonoids have a wide range of health-promoting properties and therefore increase nutritive value of functional food with their elevated content. Pea shoots are known to be a good source of these antioxidant compounds. Moreover, flavonoids show great stability during the storage [22].

All shortened L/D cycles significantly increased protein content in pea shoots. Addition of such food to the diet provides the possibility to get the necessary protein without the fat, cholesterol, and calories that typically come with animal meats. Soluble sugar and proline contents were also increased by shortened L/D cycles, which also improved the nutritional value of pea shoots.

All plants grown under shortened L/D cycles had slightly higher content of H_2O_2 compared to control. The maximum H_2O_2 was recorded in plants treated by L/D cycles 4/4 h and 4/2 h. It is rather unexpected result as these light treatments provided plants with different DLI. Besides, the total amount of radiation obtained by plants was the same in control treatment and under the cycle 4/4 h, but the latter induced accumulation of H_2O_2. Thus, we may suggest that DLI does not play the key role when we compare plant responses to conventional photoperiod and abnormal L/D cycles. It can be suggested that patterns of shortened L/D cycles were such that plants could be illuminated during the nyctophilic phase and vice versa photophilic phase could concur with darkness. In other words, light was provided to the plants during subjective night, which implies a circadian asynchrony, i.e., the mismatch between the internal (circadian) biorhythms and the external L/D cycle.

5 Conclusion

In the present study we compared and characterized responses of pea shoots to shortened L/D cycles 8/4 h, 4/4 h and 4/2 h using conventional photoperiod 12/12 h as a control. Beneficial effects of non-conventional L/D cycles included higher RI, WUE, flavonoid, proline, protein and soluble sugars content, which improved the external appearance and internal quality of pea shoots. The effects were most pronounced in plants treated by L/D cycles 8/4 h and 4/4 h. The results of the study have shown that plant responses to abnormal L/D cycles do not strictly depend on the DLI. The effects of shortened L/D cycles require further studies as some plant responses observed in the study were unexpected, possibly due to induced circadian asynchrony.

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The Acute Toxicity of a New Feed Additive for Poultry Based on the Biometal: Chromium

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Abstract. Poultry farming is a world leading industry in the production and consumption of meat products. The issue of developing effective tools remains relevant according to the intensive technological cycles and inevitable stressful stimuli, and the need to obtain high-quality products that meet safety standards. In this regard our research particular interest is the design and preclinical examination of chemotherapeutic agents that are not aggressive stimulants. Such agents include nutrient-based feed additives that supplement the basic diet of poultry. The research team has developed a feed additive based on chromium biometallic and amino acid complex. This article presents the results of the toxicological examination of the developed drug, namely acute toxicity. The objects of the study were white nonlinear mice, white nonlinear rats, and broiler chickens. During the experiment, it was not possible to establish the average lethal dose of the feed additive. The use of the supplement at doses of 4000, 4500, 5000 and 5500 mg/mg of body weight showed no signs of toxic effects. The data obtained make it possible to classify the developed additive to hazard class 4, that is, low-hazard substances, and also allow us to talk about a significant range of toxicological harmlessness. The information obtained empirically allows us to assert the prospects for further study of the developed chemotherapeutic agent.

Keywords: Feed Additive · Chromium · Amino Acids · Preclinical Evaluation · Acute Toxicity · Rats · Mice · Broilers

1 Introduction

Today, poultry farming continues to be one of the most promising areas of meat production, including export development: the volume of global poultry meat production amounted to more than 102 million tons in 2022. The attractiveness of poultry products is due to a number of advantages: protein quality, dietary characteristics, price attractiveness, high profitability both due to conversion rates, primarily due to the genetic potential of crosses, and due to the absence of the need to use voluminous biotic resources (pastures, watering volumes, and etc.), as well as the absence of confessional restrictions [5].

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At the same time, it is important to take into account that intensive technological cycles are associated with the impact of negative environmental factors (housing conditions, nutritional value, and etc.), a significant stress load on the poultry body (heat stress, vaccine stress, and etc.), which ultimately leads to a decrease in productivity, resistance, and increased susceptibility to infectious diseases agents and requires correction [11, 16, 21]. Thus, in the studies of S. Shini et al. data on the suppression of the immune system against the background of a temperature stimulus and the subsequent involution of immune organs are presented [22]. In addition, it is important to remember that heat stress is also associated with the peculiarities of the metabolism of meat poultry. So, in the article of O.M. Onagbesan et al. information is provided that a characteristic feature of broiler chickens of modern commercial crosses is an intensive metabolism, which in turn leads to the release of a large amount of heat and makes the bird more susceptible to thermal stress [16].

We take into account that it is utopian the use of a single, universal means of controlling metabolic processes, effective at all stages of bird development and adapted to all species diversity. In our opinion, the development of schemes combining best practices is the most promising and effective. At the same time, today it is possible to identify several key approaches to the issue of stress correction, the commonality of which lies not only in goal setting, but also in the management of metabolic processes of the bird's body at different stages of the life cycle. Genetic strategies and technology of embryonic thermal conditioning are quite successful experimental techniques. Genotyping of poultry and selection in the breeding process as a tool for creating heat-resistant breeds is a promising and long-term project. It is based on the study of molecular markers designed to recognize potential candidate genes associated with desirable (productivity, growth, reproduction, etc.) and undesirable (temperature susceptibility, low resistance, etc.) inheritance parameters, while improving correlating traits. The study of gene expression, reflected in the work of A.H. Nawaz et al., revealed pronounced thermal stability in chickens of dwarf breeds [14]. M.M. Fathi et al., studying the genetic diversity of birds of native breeds of Saudi Arabia and the white leghorn line using 25 markers, established different polymorphism potential: the greatest similarity was found between black, brown, and gray populations (the genetic distance between pairs is 0.11), while the black breed had the least attractive productive indicators. It is important to take into account that the inclusion of closely related lines in breeding programs will create a precedent for weak genetic improvement, in this regard, the reflected data are of interest for the direction of creating adaptive highly productive lines [6].

The technology of embryonic thermal conditioning is aimed at developing thermal tolerance in adult birds. In their studies V. De Basilio et al. confirm the hypothesis put forward in earlier studies by other authors about the conditional "training" of poultry and the adaptive potential formed due to controlled moderate preventive thermal effects to which the bird is exposed both during incubation and in the first days of life [2, 15].

At the same time, one of the most widely used tools for correcting the metabolism of animals and poultry is the use of pharmacological agents. The issue of dietary manipulation deserves special attention (including leveling negative stress stimuli). This is not only the usefulness of the main diet, the selection of modes, multiplicity and characteristics of feeding (including temperature and humidity parameters of feed), but also the introduction of feed additives, nutrient agents in addition to the main diet of poultry. Today, the task facing veterinary pharmacology is not only to develop tools capable of unlocking the genetic potential of poultry due to cross-over characteristics, but also to obtain a full-fledged protein that meets the requirements of quality and safety. In this regard, the use of “pure” feed additives that do not contain aggressive stimulants is a promising direction. It is important to remember that nutrients are considered not only as a building and/or energy material for maintaining vital functions of the body, but also as a component, often a catalyst, of complex biochemical processes. Thus, in the studies by K. Seifi et al. it is broadcast that the use of saturated fatty acids in the diets of Ross 308 cross broilers can have a positive effect on the correction of thermal stress by influencing the expression level of mRNA of uncoupling proteins (UCP) found in the inner membranes of mitochondria and adenine nucleotide translocators (ANT), as well as the level of heat shock proteins HSP70, as a result reducing metabolic heat load [21]. Amino acid complexes, both mono- and multicomponent, have also proven to be effective stimulants and adaptogens. Amino acid balance is important not only as a component of supporting energy homeostasis and transamination, but also as a component regulating all types of metabolism, as well as a target of the rapamycin signaling pathway necessary for gaining muscle weight in broilers. Despite compliance by feed producers with NRC standards to ensure minimum needs, including in basic nutrients, it is important to take into account that the actual need of modern poultry, especially meat production, often exceeds recommended thresholds due to changes in the genetic background as a result of effective breeding in poultry farming; it also directly depends on the type of diet, breed and the age of birds [12]. Studies by Castro et al. (2019a) indicate the positive effects observed against the background of the use of arginine in addition to the basic diet: an increase in bone mineralization, an improvement in conversion parameters, and against the background of non-induced stress [1]. The results of the research (presented in the work of Q.Swennen et al.) show that the additional introduction of a source of methionine in the form of DL-2-hydroxy-4-methylthiobutyric acid (DL-HMTBA) into the diet improves the antioxidant status, which was reflected in lower lipid peroxidation and higher concentrations of total glutathione [24]. In turn, the introduction of chromium methioninate into the diet (which is not only a source of amino acids, but also a vital trace element) has a positive effect on productivity indicators (quantitative criteria of body weight and the rate of its gain, feed conversion), as well as on the morphological status of the intestine [13]. In addition, the use of chromium in the form of chelated compounds helps to mitigate the effects of oxidative stress in birds by increasing the activity of glutathione peroxidase in blood plasma and reducing the level of malondialdehyde in blood serum [26]. H.Y. Tang et al. have found that oral administration of chromium methioninate to mice at doses of 500 and 1000 mcg/kg of body weight has a beneficial effect on glucose and lipid metabolism, and has a hepatoprotective effect [25]. The data obtained indicate the prospects of using chromium-based compounds as an effective tool for correcting metabolic processes.

Within the framework of the project “Technology of Controlled Metabolism: Correction of Thermal Stress Through the Development and Application of New Feed Additives Based on Biometals” the research team has developed a feed additive based on chromium methioninate and an amino acid complex (the study was carried out at the expense of a grant from the Russian Science Foundation No. 23–26-10025, https://rscf.ru/project/23-26-10025/, implemented in the priority direction of the research supported by the Region "Development of Scientific and Methodological Foundations for the Production and Processing of Crop and Livestock Products, Improvement of Technologies for Obtaining High-Quality Agricultural Raw Materials in Stavropol Krai") [19]. At the same time, it is important not only to design a new pharmacological agent aimed at optimizing metabolic processes, but also to ensure its compliance with the parameters of toxicological safety. Since an excess, as well as a shortage, of nutrients leads to undesirable consequences and the use of such chemotherapeutic agents can have the opposite, negative effect on both productivity criteria and the quality, safety of the final product. For example, in the article of V. Bampidis information is provided on the effectiveness of using a feed additive based on the chelated form of chromium methioninate for dairy cows. The work reflects information on the absence of undesirable side effects, confirmed by the results of biochemical and hematological analyses, as well as the positive dynamics of body weight gain and the schedule of milk yields. However, the lack of toxicological examination conducted on laboratory models does not allow specialists to be convinced of the safety of the proposed product, on the basis of which the EFSA (European Commission on additives and products or substances used in animal feed) recommended that the author's team supplement the experimental database [4].

In this regard, it is necessary to conduct a comprehensive preclinical toxicological examination of the chromium-based feed additive developed by our research team, first of all, to determine acute toxicity. The aim of the researching was to study the acute toxicity parameter of a new feed additive based on chromium biometall (developed by our team in an experiment using laboratory models), as well as the target species – poultry of the meat production line. These experimental data comply with the requirements of both the Russian standards for the development and implementation of animal feed additives and the European Commission EFSA on the panel on additives and products or substances used in animal feed (FEEDAP).

2 Materials and Methods

The research was carried out at the expense of a grant from the Russian Science Foundation No. 23–26-10025, https://rscf.ru/project/23-26-10025/ in the conditions of the laboratory of preclinical research and vivarium of the Institute of Veterinary Medicine and Biotechnology of Stavropol State Agrarian University.

The maintenance, feeding, and organization of work with laboratory animals and poultry corresponded to Russian and international standards [3, 8, 9, 17, 18, 20].

According to the methodological recommendations for conducting toxicological studies, as well as taking into account differences in the metabolism of mammals and birds, acute toxicity is determined on two types of laboratory animals, as well as on target animals. Thus, the following species were involved in the experiment: non-linear white mice, white rats, and broiler chickens. The design of the study assumed the formation of five experimental groups of 10 individuals each. The first group served as a control and received an equivalent volume of drinking water, without the addition of a feed additive, groups 2 – 5 feed additive was administered orally intragastrically once in a dosage according to the data in the Table 1.

Table 1. Design for determining the acute toxicity of a chromium-based feed additive, n = 10

Group number	The dose of the applied feed additive, mg/kg of body weight		
	White mice	White rats	Broiler chickens
1	control	control	control
2	4000	4000	4000
3	4500	4500	4500
4	5000	5000	5000
5	5500	5500	5500

The feed additive is a powdered pharmacological substance, lilac in hue, with a specific amino acid odor, soluble in water (Fig. 1). Before application, the specified volume of feed additive was mixed with an equivalent volume of water for dissolution and applied individually.

The observation period was 14 days, the overall activity, the physiology of behavioral reactions (reaction to light, stimuli), feed and water consumption were evaluated. Body weight accounting was carried out by an individual method using precision Vibra laboratory scales before the start of the experiment, as well as on the 7th and 14th days.

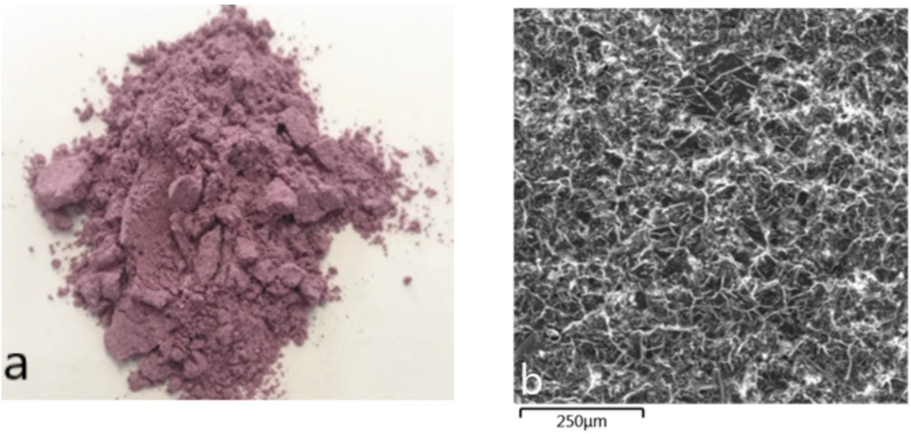

Fig. 1. Chromium-based feed additive (a - actual, b – electronic)

3 Results

During the 14 days of observation, animals and poultry showed no signs of intoxication, and no deaths were recorded. The condition of the experimental animals and poultry remained satisfying for 14 days with a well-expressed appetite, the animals were mobile, and the reaction to external stimuli remained the same as before the use of the feed additive. There were no disturbances in the functional activity of the digestive and urinary systems, as well as the appearance of other toxic phenomena. It is important to note that the dosages used according to the scheme of Table 1 are not therapeutic, but exceed it at times.

Despite the fact that the methodology for determining acute toxicity is based on the registration of animal deaths or their absence, an assessment of the dynamics of body weight changes was included in the design of the study. The data shown in Tables 2, 3 and 4 indicate that there is no negative impact on the body weight gain parameter. Thus, the weight change in white mice over two weeks ranged from 7.5 to 12% compared to body weight at the start of the study and corresponded to the parameters of the physiological norm (Table 2). At the same time, the maximum difference in body weight on the 14th day of observations between the experimental and control groups was 1.0 g and was observed in group 5, the dose of the feed additive in which was 5500 mcg of body weight.

Table 2. Body weight dynamics of white nonlinear mice, n = 10

Group number	The dose of the applied feed additive, mg/kg of body weight	Body weight, g		
		0 day of the experiment	7th day of the experiment	14th day of the experiment
1	control	18,3 ± 0,1	19,4 ± 0,2	19,7 ± 0,2
2	4000	18,7 ± 0,2	19,7 ± 0,1	20,5 ± 0,2
3	4500	18,1 ± 0,1	19,5 ± 0,3	20,1 ± 0,1
4	5000	18,5 ± 0,1	19,9 ± 0,1	20,5 ± 0,2
5	5500	18,5 ± 0,3	20,1 ± 0,2	20,8 ± 0,2

Body weight changes in white non-linear rats also did not exceed the limits of physiological values during the entire observation period (Table 3). On the 14th day of observation, the body weight change in the control group was 7.8% compared to day zero, in group 2 - 9.2%, in groups 3, 4 and 5 – 8.4, 10.2 and 10.4%, respectively. At the same time, at the final stage of the experiment, the maximum difference was observed between the control group and group 2: the deviation was 7.8 g or 2.7%.

Broiler chickens, being a meat-producing bird, are characterized by an active metabolism and a fairly pronounced rate of muscle gain. Changes in the dynamics of body weight gain are reflected in Table 4. Despite the fact that the changes recorded during the two-week follow-up do not exceed the limits of the physiological norm, it is worth paying attention to the dynamics of changes: after 14 days, the body weight of broilers in control and experimental groups increased 2.7–2.9 times. At the end of the experiment, the maximum body weight was recorded in group 2 and amounted to 2261.5 g, the minimum value was 2101.0 g in the control group, and the difference between the groups was 160 g or 7.6%.

Table 3. Body weight dynamics of white nonlinear rats, n = 10

Group number	The dose of the applied feed additive, mg/kg of body weight	Body weight, g		
		0 day of the experiment	7th day of the experiment	14th day of the experiment
1	control	262,1 ± 1,4	271,5 ± 1,8	282,7 ± 1,9
2	4000	266,0 ± 1,1	278,2 ± 1,4	290,5 ± 1,7
3	4500	267,1 ± 1,9	280,5 ± 2,1	289,5 ± 1,9
4	5000	260,4 ± 1,1	274,1 ± 1,7	287,1 ± 1,4
5	5500	262,5 ± 1,5	275,9 ± 1,9	289,9 ± 2,0

Table 4. Dynamics of body weight of broiler chickens, n = 10

Group number	The dose of the applied feed additive, mg/kg of body weight	Body weight, g		
		0 day of the experiment	7th day of the experiment	14th day of the experiment
1	control	756,0 ± 2,5	1300,5 ± 5,0	2101,0 ± 7,8
2	4000	760,7 ± 2,9	1407,7 ± 5,9	2261,5 ± 7,0
3	4500	773,2 ± 3,3	1452,1 ± 7,4	2136,2 ± 5,5
4	5000	762,5 ± 2,8	1399,5 ± 5,9	2214,2 ± 7,8
5	5500	767,4 ± 2,6	1138,3 ± 3,3	2142,0 ± 6,2

4 Discussion

The experimental data obtained indicate that a single oral application does not have a toxic effect and does not cause the death of experimental subjects – the developed feed additive based on chromium and an amino acid complex in a dosage exceeding 5,500 mg/kg of body weight in a study on laboratory animals and poultry. At the same time, even such a significant excess of therapeutic doses does not have a negative effect on metabolic processes, as indirectly evidenced by the parameters of body weight gain.

However, in the works of H. Gibb et al. information is provided on the presence of carcinogenic effects of chromium. However, it is fair to note that the noted undesirable activity is characteristic of trivalent and hexavalent forms of chromium [10]. Studies by M. Figgitt et al. reported that high concentrations of chromium can lead to increased oxidative stress and, as a result, cause DNA damage during long-term exposure [7]. H. Staniek et al. informed that the consumption of chromium by rats at a dose of 1000 mg/kg of body weight leads to the development of genotoxic damage in vitro, however, it is important to note that this damaging effect is observed with daily consumption of these doses of the drug for four weeks or more. At the same time, the team of authors found that the animals showed no signs of toxicity, that is, there were no cases of mortality, weight loss, hepatotoxic and nephrotoxic lesions [23].

In turn, in the research of V. Bampidis et al. information is reflected that toxicological examination of chromium propionate in the experiment on pregnant rats did not reveal acute toxicity and teratogenic properties when using a dose of 7.2 mg/kg body weight [4]. In the research of I.M.I. Youssef et al. no toxic effects of chromium methioninate were detected in experiments on broiler chickens when applied orally in combination with feed at doses of 50 and 100 g/t [26]. Studies on the acute toxicity of chromium methioninate in mice conducted by H.Y. Tang et al. showed a low toxicity potential and a high safety margin: the average lethal dose exceeded the value of 10 g/kg of body weight [25].

Based on the analysis of literature data, it can be concluded that the toxicity of chromium-based compounds largely depends on the form of the compound (oxide, chelate form, methioninate, propionate, etc.), the valence of chromium, and the experimental dose of use. In addition, the information is heterogeneous and requires experimental clarifications.

Thus, based on the authoritative opinion of foreign colleagues and the experimental data obtained, we consider it advisable to further study the subchronic, chronic, and embryotoxic activity of the developed feed additive.

5 Conclusion

Thus, according to GOST (state technical standards) and international standards, the developed feed additive based on chromium and a complex of amino acids belongs to substances of hazard class 4, that is, low-hazard substances. In addition, the design of the experiment did not allow determining the average lethal dose due to the fact that no animal deaths were recorded, which suggests a high potential for toxicological safety. In this regard, we consider it advisable to further study the developed feed additive both in experiments to study the parameters of chronic toxicity and in studies of the effectiveness of its use as a tool for correcting metabolic processes.

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Mechanisms for Applying Pattern Recognition Algorithms in Animal Husbandry

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Abstract. The development and global use of computer technologies make it possible to recognize the information being processed depending on the set of tasks. In this paper the problem of the use of modern technologies in animal husbandry is considered, allowing not only to simplify and reduce some daily operations, but also to increase the demand and quality of livestock products in general. The authors set the task of developing algorithms for pattern recognition based on the definition of external object parameters using software.

The article describes the mathematical apparatus of finding the number of individuals in a herd, determining the calculation with a given error of the power of the set of elements. The main content of the study is devoted to the description and construction of the method of controlling the number of animals in the field of animal husbandry with the help of the software SimInTech, allowing to simulate in a mode «real time». The work focuses on a topical topic in animal husbandry, and further research in this area will broaden the scope of work.

Keywords: animal husbandry · computer technology · mathematical model · pattern recognition algorithms · narrowing mask

1 Introduction

Today, animal husbandry is one of the significant industries in agriculture and not only. A large increase in demand for dairy and meat products is associated with a change in the quality of life of the population.

Livestock plays an important role in various food systems and acts as a major source of income, welfare and employment, and determines the rate of change and growth in agriculture as a whole.

In many large and small farms, it is the number of livestock owned by the entrepreneur that determines the degree of development of a given agricultural enterprise.

Continuous control and increase of production in livestock farming is possible only with the help of innovative solutions and modern information technologies that simplify many daily routine activities.

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The following trending technologies are currently being considered in animal husbandry for use in large companies: functional additions of satellite navigation systems, partial and full automation of some animal care processes, robotics, artificial intelligence, cloud technologies, cyber security [1, 2].

The unique livestock technology of some cattle breeds is year-round grazing. This is the case, for example, with the Kalmyk wall of cows, reindeer, or year-round grazing of sheep in the southern regions. Livestock products produced in such natural conditions are characterized by high ecological and gastronomic qualities.

Improving the way of maintenance, grazing and cultivation of the breed under conditions of development of applications of modern information technologies guarantees high profitability of business and quality of existence of natural ecosystems.

Large farms existing in the Stavropol Territory, engaged in year-round grazing, have a herd of up to 4000 animals, territorially distributed in gurts, each of which has 500–600 heads.

The existence of the herd within the boundaries of the herd is related to the need to move it continuously, and given the high physical strain on herders, an important consideration is the continuous exploration and counting of the herd.

Visually, given the similarity of many individuals belonging to a single breed, it is difficult to ensure continuous monitoring and accounting of the location of both herds and small groups of animals, while the specificity of herd behaviour needs constant evaluation.

The aim of the work is to develop an algorithm for recognizing, quantitative and qualitative features of objects in an image, by finding certain external parameters of objects using extensions of the Video Processing library in SimInTech software.

The main tasks are:

– Development of an image processing algorithm with an image with animals as input;
– Construction of an algorithm for imposing a mask on the original image;
– Automatic counting of the number of animals on the image.

2 Materials and Methods

Let us formulate the problem of determining the number of individuals in a herd as a calculation of the power of a set of elements with a given error. The error of calculations will be present due to the similarity of animal silhouettes on the images, so the analysis of pixel polygons characteristic for each individual should be performed with the scanning frequency (frame updates) allowing to classify the difference of two similar animals [3].

1 Hypothesis of image decomposition into components of pixel polygons in the wavelet transform basis (bursts). Each set of coefficients of basis functions forms a mask (mask symbol) convolution with which approximates some boundary of the set [4].

If we consider the power of the set of constituent pixel polygons as:

$$\left\{\lambda_{iM}, \omega_j\right\} = \sum_{i=1}^{n} \lambda_i C_i \sum_{j=1}^{m} \omega_j C_j \tag{1}$$

where λ_i – pixel element brightness in the line, ω_j – frame refresh frequency, C_i – wavelet transform mask coefficient, C_j – frequency resolution coefficient.

The selected zone of interest in each frame, advising the silhouette contour, is estimated by the normalized power spectral density index

$$0.707 \leq ||\mathrm{M}\{\lambda_i, \omega_j\}|| \leq 1 \tag{2}$$

where

$$\|\mathrm{M}\{\lambda_i, \omega_j\}\| = \frac{\mathrm{M}\{\lambda_i, \omega_j\}}{P\{C_i, C_j\}} \tag{3}$$

$$P\{C_i, C_j\} = \sum_{i=1}^{n} C_i \sum_{j=1}^{m} C_j \tag{4}$$

expression (4) is the power of the frame pixel field spectrum taken at each moment of time (within one frame).

With this approach it is necessary to get a good index of ω_j scanning frequency, which would be desirable to equal the frame rate. The implementation of the latter condition may be difficult:

– first, the frequency of streaming video to the buffer has a significant value of up to 2000 frames per second;
– second, the calculations (1–4) for each decomposition sample in the filter will require $n = \lambda_i \cdot (\lambda_i - 1)^2$ multiplication and addition operations, caused by the need to perform a set of zeros addition procedure;
– third, the density calculation process will be iterative, as it is necessary to decompose the filter coefficients of masks suitable for the condition (2), therefore, at each stage there will be a decimation of wavelet decomposition coefficients functions in case of redundancy, or interpolation in case of insufficient decomposition order.

It is about forming a filter bank on a set of decimation coefficients or interpolation for each frame of a video image scan.

2 The reduction in the amount of computation can be obtained by knowing the size of the polygon to estimate the power of the spectrum, knowing the approximate size of the object, it is possible to find the distance to it and estimate the set of bicubic surfaces. In our case, it's supposed to be bicubic Koons surfaces.

Considering that the animals coloring has the character of arbitrary curves, the difficulties of specifying the coordinates of bicubic curves can be overcome using approximation of surfaces by Bezier curves.

The Bézier tensor product is given as [19].

$$Q(\lambda, \omega) = \sum_{i=1}^{n} \sum_{j=1}^{m} B_{i,j} J_{n,i}(\lambda) K_{m,j}(\omega), \tag{5}$$

where $J_{n,i}(\lambda)$ – is the basis function in the parametric direction of the video frame scan,
$K_{m,j}(\omega)$ – basis function of the frame scale.

Correspondingly

$$J_{n,i}(\lambda) = \binom{n}{i} \lambda^i (1-\lambda)^{n-i} \tag{6}$$

$$K_{m,j}(\omega) = \binom{m}{j} \omega^j (1-\omega)^{m-j} \tag{7}$$

where

$$\binom{n}{i} = \frac{n!}{i!(n-i)!}, \quad \binom{m}{j} = \frac{m!}{j!(m-j)!} \tag{8}$$

$B_{i,j}$ – forms a polygonal grid, respectively indices n and m must be one less than the number of vertices of the polyhedron expanded in the direction λ and ω.

In matrix form, the Bézier surface is given as

$$Q(\lambda, \omega) = [\Lambda][N][B][M]^T[W] \tag{9}$$

Where

$$\begin{aligned} [\Lambda] &= \left[\lambda^n \lambda^{n-1} \cdots 1\right] \\ [W] &= \left[\omega^m \omega^{m-1} \cdots 1\right] \\ [B] &= \begin{bmatrix} B_{0,0} & \cdots & B_{0,n} \\ \vdots & \ddots & \vdots \\ B_{m,0} & \cdots & B_{m,n} \end{bmatrix} \end{aligned} \tag{10}$$

The animal's silhouette is not a regular polyhedron, so an approximation to a certain arbitrary form can be obtained by differentiation where the first and second derivatives

[17, 18]:

$$
\begin{aligned}
Q_{\lambda}(\lambda, \omega) &= \sum_{i=1}^{n}\sum_{j=1}^{m} B_{i,j}J'_{n,i}(\lambda)K_{m,j}(\omega)\\
Q_{\omega}(\lambda, \omega) &= \sum_{i=1}^{n}\sum_{j=1}^{m} B_{i,j}J_{n,i}(\lambda)K'_{m,j}(\omega)\\
Q_{\lambda,\omega}(\lambda, \omega) &= \sum_{i=1}^{n}\sum_{j=1}^{m} B_{i,j}J'_{n,i}(\lambda)K'_{m,j}(\omega)\\
Q_{\lambda,\lambda}(\lambda, \omega) &== \sum_{i=1}^{n}\sum_{j=1}^{m} B_{i,j}J'_{n,i}(\lambda)K_{m,j}(\omega)\\
Q_{\omega,\omega}(\lambda, \omega) &= \sum_{i=1}^{n}\sum_{j=1}^{m} B_{i,j}J_{n,i}(\lambda)K'_{m,j}(\omega)
\end{aligned}
\tag{11}
$$

Ratio of Bezier and Kuns surfaces

$$Q_{Kuns}(\lambda, \omega) = Q_{Bezier}(\lambda, \omega)$$

$$[\Lambda][N][B][N]^{T}[W] = [\Lambda][M][B][M]^{T}[W] \tag{12}$$

The mathematical models described here are based on the classical image representation models [5–7] and are suitable for filtering and segmenting images in pattern recognition.

3 Results

The use of modern technology also comes to the aid in this matter [8–11]. The use of special software applications or technical devices allow tracking every animal in the herd. Constant monitoring of the number and movement of animals allows for absolutely accurate and timely counting of animals.

We use SimInTech software developed by a team of scientists of Bauman Moscow State Technical University. And LLC «3B Service» [12, 13].

SimInTech software platform is designed for creating mathematical models, modeling physical and technical objects, and designing control algorithms. The advantage of using this platform is the fact that this version has an open interface and also has the ability to model in "real time" mode.

Modeling using SimInTech is done through programming based on blocks contained in various libraries. When designing circuits, the following sequence of steps should be followed:

– Filling the schematic window with blocks;
– Entering block properties;

– Connection of blocks by communication lines;
– Design of appropriate explanatory inscriptions;
– Setting the necessary parameters of the scheme calculation;
– Run the simulation process.

With the help of the library “Video processing” the module of counting objects is considered. This function allows to count people, vehicles, or as in our application case - animals, in real time and the specified area of the frame.

In the case of counting animals, the main task is to determine the external parameters of the object (e.g., by color or shape) to recognize the image in the image using segmentation (by brightness and narrowing).

Basic image recognition systems are based on the following typical functional schemes:

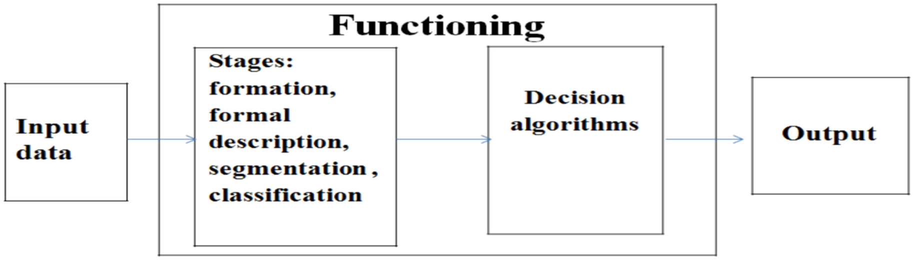

Fig. 1. Image recognition scheme

In this case, image recognition in image processing is determined by the characteristic features of objects and their video data, determining whether they meet the specified conditions.

The development of an algorithm for counting contours in an image mask is shown in Fig. 2.

Consider the task of developing an algorithm for object recognition based on color filtering, relying on the main selected tones from any range of color tones, is shown in Fig. 3.

One of the main statistical tasks in animal husbandry is to determine the system of indicators: the number of livestock, reproduction rates and productivity. Accounting and reporting in livestock breeding plays an important role, because only in one reporting period, when gaining weight, young animals are transferred to the main herd, and some animals can be rejected and transferred to fattening for further slaughter. Therefore, continuous recording and monitoring of indicators with proper management, helps to ensure the increase in livestock numbers. The proposed algorithm for the conversion of an image into a color model according to the highlighted color tone is very convenient for use in quantitative calculation

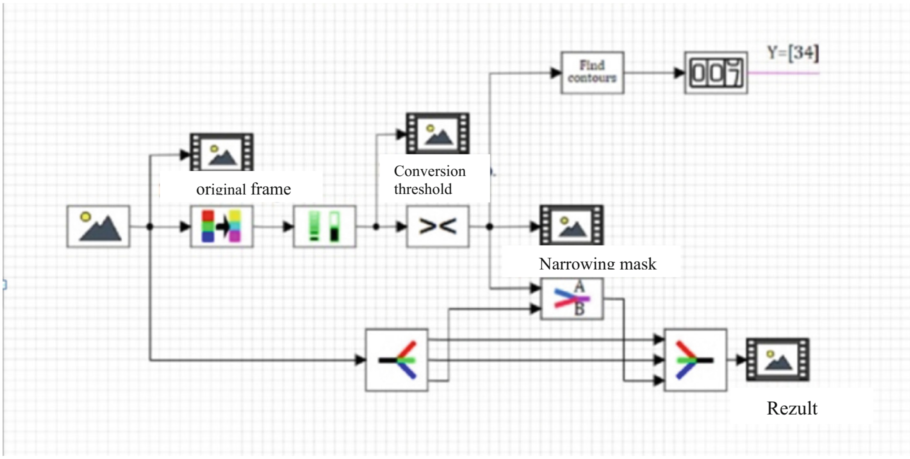

Fig. 2. Structural diagram of the algorithm with contour counting in the image mask

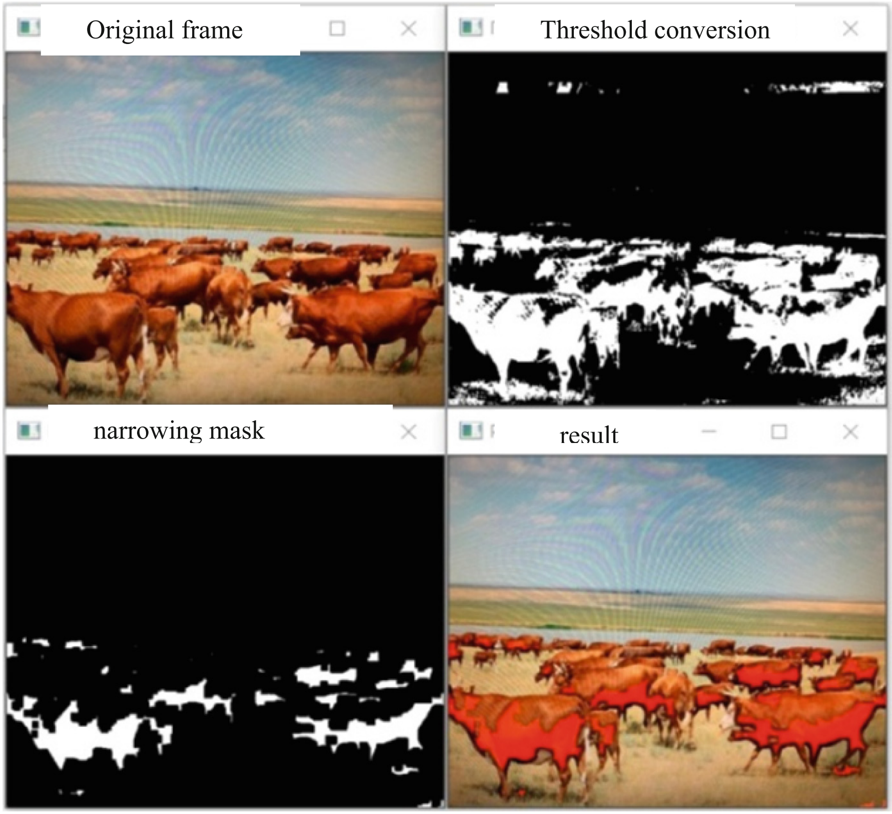

Fig. 3. Image of the objects mask

4 Conclusion

At present, a sufficiently large number of methods have been developed in various fields of research to solve recognition problems [14–16]. The considered technique relies on the possibility of classifying recognized objects by some characteristic features. The presented algorithm for controlling the number of animals in the field of animal husbandry, poultry farming is effective from the point of view of its technical solution.

The key functions are:

– The speed and accuracy of counting the same objects;
– Change and save results for subsequent access;
– Analysis of the results and their statistical processing.

This module of possibilities expands the range of tasks considered, promotes video analysis and statistics of objects studied.

The SimInTech software is an indispensable tool to save time for those who need to count objects daily, such as cattle, sheep, pigs, chickens, etc.

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Grinding Husks of Agricultural Waste in a Hammer Crusher

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Abstract. The disposal of waste obtained after processing agricultural crops (sunflower husks, buckwheat, millet, etc.) is a crucial problem in Russia. Recycling husks for usage in various types of production will help to solve the global environmental problem. An important operationsin the technological process of recycling husks is its grinding. The most common crushing machines in agricultural production are hammer crushers. However, their design and organization of the work process include a number of deficiencies, which leads to a decrease in productivity and significant energy consumption when crushing crop husks. The purpose of the article is to analyze the influence of design and technological factors influencing the process of grinding husks of agricultural crops through the development of a new perspective design of a hammer crusher. The developed perspective design and technological scheme of a hammer crusher with a feeding device permits the crushed material to be uniformly supplied to the hammer rotor of the crusher, thereby reducing the dynamic load on the crusher rotor shaft. In addition, the energy intensity of the grinding process was reducing and productivity was rising. To ensure stability of crushed material flow, a feeding device is used, which is a cylinder with four gutters, the opposite sides of which are rotated relative to each other. During the research, theoretical dependencies were obtained that made it possible to determine the influence of the design, operating and technological parameters of the hammer crusher on the productivity and energy intensity of the grinding process. The experimental hammer crusher allows obtaining the size of grinding 0.15… 0.4 mm at a feed rate 300 kg/h and a peripheral speed of the hammers 40 m/s.

Keywords: husks of agricultural crops · hammer crusher · hammer deflection angle · peripheral speed of the hammer · feeding device · uniform supply of crushed material · loading of crushed material

1 Introduction

Currently, one of the important problems in Russia is the disposal of waste obtained after processing agricultural crops (sunflower husks, buckwheat, millet, etc.). On the territory of the Russian Federation, according to Rosstat, after processing of agricultural crops, a significant share is husk: millet - 12–25% (up to 180 thousand tons / year),

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buckwheat - 18–28% (up to 400 thousand tons / year), sunflower - 35–78% (up to 7 million tons/year) [1]. This waste accumulates locally in landfills, dumps and decomposes under the influence of natural and temporary factors, which in turn leads to deterioration of the environmental situation. Also, large material costs are required for loading, transportation and disposal of these wastes due to their low bulk density.

Recycling husks for usage in various types of production will help solve the global environmental problem. For example, husks can serve as an alternative source of energy, additives to feed mixtures for cattle and poultry, various fertilizers and soil protectants, and sorbents for eliminating emergency oil and petroleum product spills [1, 4].One of the most important operations in the technological process of preparing husks for usage in the presented types of production is its grinding.

The most common crushing machines in agricultural production are hammer crushers. However, their design and organization of the work process have a number of disadvantages, which leads to a decrease in productivity and significant energy consumption when husks of agricultural crops is grinding [4, 9, 10]. In this regard, increasing the efficiency of the process of grinding husks of agricultural crops with hammer crushers, by improving their design, operating and technological parameters, is an actual task.

Both domestic and foreign scientists dealt with the issue of the grinding process: Melnikov S.V., Roshchin P.M., Aleshkin V.R., Syrovatka V.I., Kirpichnikov F.S., Plokhov F.G., Revenko I. I., Eliseev V.A., W. Kruger, A. Hendrix and others [1–11].

When analyzing existing designs of hammer crushers, as well as a literature review of theoretical studies, it was revealed that the problems inherent in hammer crushers, namely: the uneven supply of crushed material with low bulk density to the working bodies, as well as the fairly high energy intensity of the grinding process and low productivity require further research.

The purpose of the article is to analyze the influence of design and technological factors influencing the process of grinding husks of agricultural crops through the development of a new perspective design of a hammer crusher. During the study, the following results were obtained:

– the working processes of feeding and grinding husks of agricultural crops have been studied and justified, ensuring the production of the finished product with minimal energy consumption;
– analytical dependencies were obtained that make it possible to determine the nature and degree of influence of the design, technological and operational parameters of the hammer crusher on the performance of the grinding process;
– results of studies of the proposed design of a hammer crusher in laboratory conditions were obtained.

Theoretical and experimental studies were used in the work. Theoretical studies were carried out on the basis of generally accepted laws of classical mechanics, mathematics and mathematical statistics. Experimental studies were carried out in accordance with generally accepted experimental methods, current standards and regulations.

2 Materials and Methods

Based on the research carried out, a perspective design and technological scheme of a hammer crusher was developed [1–5] with a feeding device that allows the crushed material to be uniformly supplied to the hammer rotor of the crusher [6–11], thereby reducing the dynamic load on the crusher rotor shaft. In addition, the energy intensity of the grinding process was reducing and productivity was rising.

A laboratory model was created in order to verify the operability of the proposed design and technological scheme of the hammer crusher, shown in Fig. 1. To conduct experimental studies, we created the laboratory model with a longitudinal and transverse arrangement of the feeding device relative to the chopper rotor shaft.

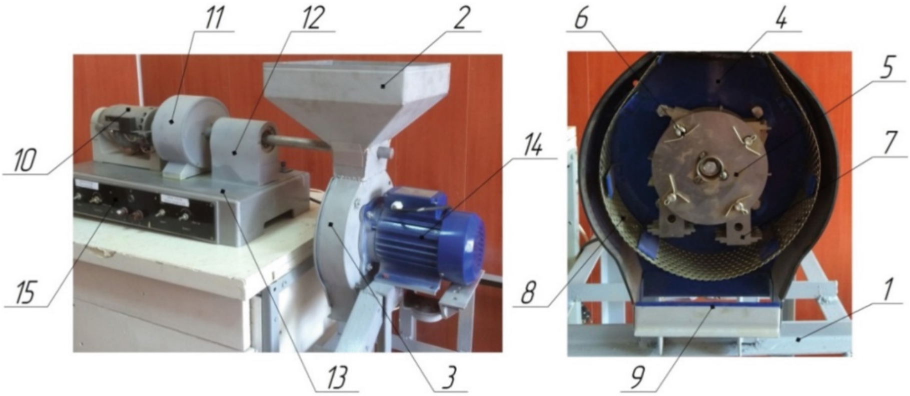

Fig. 1. General view of the laboratory installation.

The hammer crusher is located on frame 1 and consists of a loading hopper 2, a housing 3 with a crushing chamber 4, inside which a rotor 5 is installed with hammers 7 hinged on its axes 6, a sieve 8 and a discharge window 9. A feeding device is installed in the neck of the loading hopper (Fig. 2), which has an individual drive from an electric motor 10 through a gearbox 11 and a bearing support 12, mounted on a frame 13. The material is supplied against the direction of rotation of the rotor 5, and the drive of the hammer grinder shaft is carried out from an electric motor 14 mounted on the end wall of the crusher housing cameras.

The laboratory model is made with the ability to change the rotation speed of the feeder shaft and the rotor shaft of the hammer grinder using regulators installed on the control panel 15.

The working process of grinding husks of agricultural crops proceeds as follows. The crushed material is poured into the loading hopper 2, from where, by means of a feeding device against the direction of rotation of the rotor shaft 5, it is fed into the crushing chamber 4. In the crushing chamber 4, the crushed material is subjected to the impact of hammers 7 and is partially destroyed. In addition to destruction from impact with hammers 7, particles are crushed when hitting the surface of the sieve 8, as well

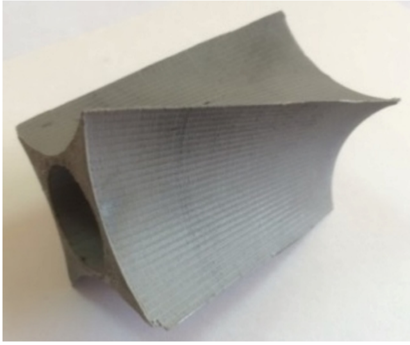

Fig. 2. Power supply.

as a result of interaction with each other. The crushed product are removed from the crushing chamber through the discharge hole 9.

The following types of crushed material were selected for experimental studies: sunflower, buckwheat and millet husks, as the most common agricultural waste. The crushed material was selected in production shops after peeling the corresponding type of cereal. A mixture of all three types of husks was also used.

3 Results

To ensure stability of the flow of crushed material, a feeding device is used (Fig. 2), which is a cylinder with four gutters, the opposite sides of which are rotated relative to each other.

The productivity of the proposed design of the power supply device has been determined:

$$Q_n = 60 l_l R_n^2 \left(\frac{\pi \varphi}{180^\circ} - \sin \varphi \right) z_g n_n \rho K_V K_p \tag{1}$$

where l_l=1.2l, l - length of the rotor shaft of the power supply device, m;

l_l - working length of the blade of the feeding device, m;

R_n – radius of the power supply, m;

φ – central angle of the feeder trough, degrees;

z_g– number of gutters;

n_n – rotation speed of the power supply shaft, min^{-1};

ρ – bulk density of the crushed material, kg/m^3;

K_V – filling factor of the feeder gutter volume, characterizing the degree of utilization of the gutter volume, $K_V = 0.97$;

K_p - coefficient of pre-pressing of the crushed material, depending on the type of crushed material, $K_p = 1.5\ldots\ 3$.

The main parameters influencing the feeding process are: the speed of input of the crushed mass to the working parts of the hammer grinder, the angle of input and the trajectory of the mass of crushed material from the blade of the feeding device.

The working process of the power supply device can be divided into three stages.

The first stage is the entry of the feeding device blade into the mass of the crushed material and its simultaneous loosening.

The second stage is the movement of a portion of the crushed material by the blades of the feeding device relative to the wall of the hopper neck to the unloading window.

The third stage is the unloading of the crushed material from the blade of the feeding device to the working parts of the hammer grinder.

Let us consider the moment when the process of unloading the mass of crushed material from the blade of the feeding device begins. At the moment, the mass element of the crushed material is moving in the vertical plane of the blade and the following forces will act on it (Fig. 3):

$\overline{G} = m\overline{g}$ - gravity;

$\overline{F_c} = m\omega_n^2 \cdot \overline{r_0}$ - centrifugal force of inertia;

$\overline{F_K} = 2m\omega_n \overline{\upsilon}_r$ - Coriolis inertial force;

$\overline{F_{fr}} = fN$ - friction force (ω_n - angular velocity of the feeder shaft; r_0 - distance from the axis of rotation to the particle of the crushed material; f - friction coefficient of the mass of crushed material on the blades of the feeding device).

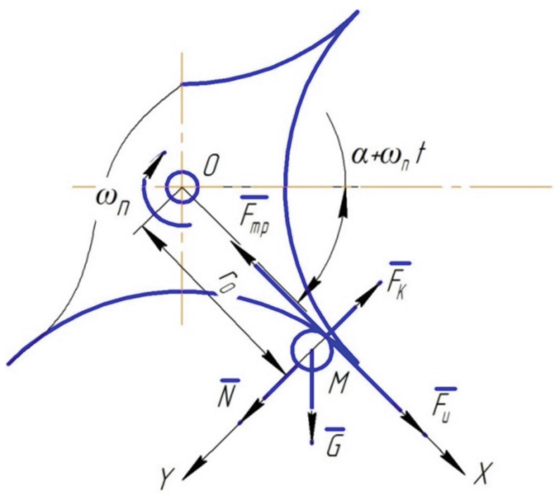

Fig. 3. The process of unloading the crushed material from the blade of the feeding device.

The condition for dropping particles of crushed material from the blade of the feeding device has the form:

$$\sum_X^F \geq F_{\text{fr}}, \tag{2}$$

where $\sum_X^F$ - the sum of all forces acting on a particle of crushed material along the axis of the blade of the feeding device.

Let us present condition (2) in expanded form and obtain:

$$m\omega_n^2 r_0 + mg\sin(\alpha + \omega_n t) \geq f(2m\omega_n \upsilon_r - mg\, cos(\alpha + \omega_n t)). \tag{3}$$

After transforming expression (3), we obtain an expression for determining the angle of rotation of the chute blade at which it is completely unloaded from the mass of the crushed material:

$$\alpha = arcsin\left[\frac{cos\,\psi\left(\omega_n^2 r_0 - 2f\,\omega_n \upsilon_r\right)}{g}\right] + \psi, \tag{4}$$

where ψ - angle of friction of the mass of crushed material on the blade of the feeder chute, degrees.

From expression (4) it is clear that the unloading angle of the feeder blade depends on the angular speed of rotation of the feeder shaft ω_n, the coefficient of friction of the mass of the crushed material on the blade of the feeder chute f and the friction angle of the mass of the crushed material on the blade of the feeder chute ψ.

To determine the relative speed υ_r of the movement of material particles, we draw up a differential equation for the movement of material particles along the surface of the chute blade, which, taking into account all the external forces acting on it, has the form:

$$m\overline{a} = \overline{F}_c + \overline{F}_K + \overline{G} + \overline{F}_{fr}. \tag{5}$$

After transformation, Eq. (5) can be written as:

$$ma = m\omega_n^2 \cdot r_0 + mg\,\sin(\alpha + \omega_n t) - 2fm\omega_n \cdot \upsilon_r + fmg\,cos(\alpha + \omega_n t) \tag{6}$$

Equation (6) is composed of the conditions under which the movement of the mass of crushed material along the blade of the feeding device will occur in a vertical plane, that is, in this case there is a flat system of forces.

Transforming the Eq. (6), we obtain:

$$\ddot{r} + 2f\,\omega_n \dot{r} - \omega_n^2 r = g(sin(\alpha + \omega_n t) + f\,cos(\alpha + \omega_n t)). \tag{7}$$

This equation is a linear inhomogeneous differential equation of the 2nd order.

The general solution of a linear inhomogeneous differential equation will have the form:

$$r = C_1 e^{k_1 t} + C_2 e^{k_2 t} + A\,sin(\alpha + \omega_n t) + B\,cos(\alpha + \omega_n t) \tag{8}$$

Having differentiated Eq. (8), we obtain a formula for calculating the relative speed of movement of material particles along the blade of the feeding device:

$$\upsilon_r = \dot{r} = C_1 k_1 e^{k_1 t} + C_2 k_2 e^{k_2 t} + A\omega_n\,cos(\alpha + \omega_n t) - B\omega_n\,sin(\alpha + \omega_n t). \tag{9}$$

The values of the coefficients C_1 and C_2 are determined by solving a particular system consisting of Eqs. (8) and (9) and satisfying the initial conditions at $t = 0$, $\dot{r} = \upsilon_r = 0$.

Finally, the law of particle motion to the working surface of the hammer will have the form:

$$s = \frac{m}{k_n} \ln \frac{e^{\sqrt{\frac{k_w g}{m}}t} + e^{-\sqrt{\frac{k_w g}{m}}t}}{2}. \tag{10}$$

where k_w - windage coefficient, for sunflower husks $k_w = 3{,}16 - 4{,}13\ m^{-1}$, for buckwheat husks $k_w = 3{,}69 - 5{,}8\ m^{-1}$, for millet husks $k_w = 2{,}45 - 8{,}1\ m^{-1}$.

To ensure an effective technological process of grinding husks, a hammer design was developed (Fig. 4) with three protrusions, the radii from the tops of which to the suspension point are equal, i.e. $r_0 = r_1 = r_2$.

To ensure optimal working conditions, hammers hinged on the rotor must be in a radial position during operation. To do this, let us depict the hammer in a position deviated from the radial one, and present all the main forces that interact with it during operation (Fig. 4) [1].

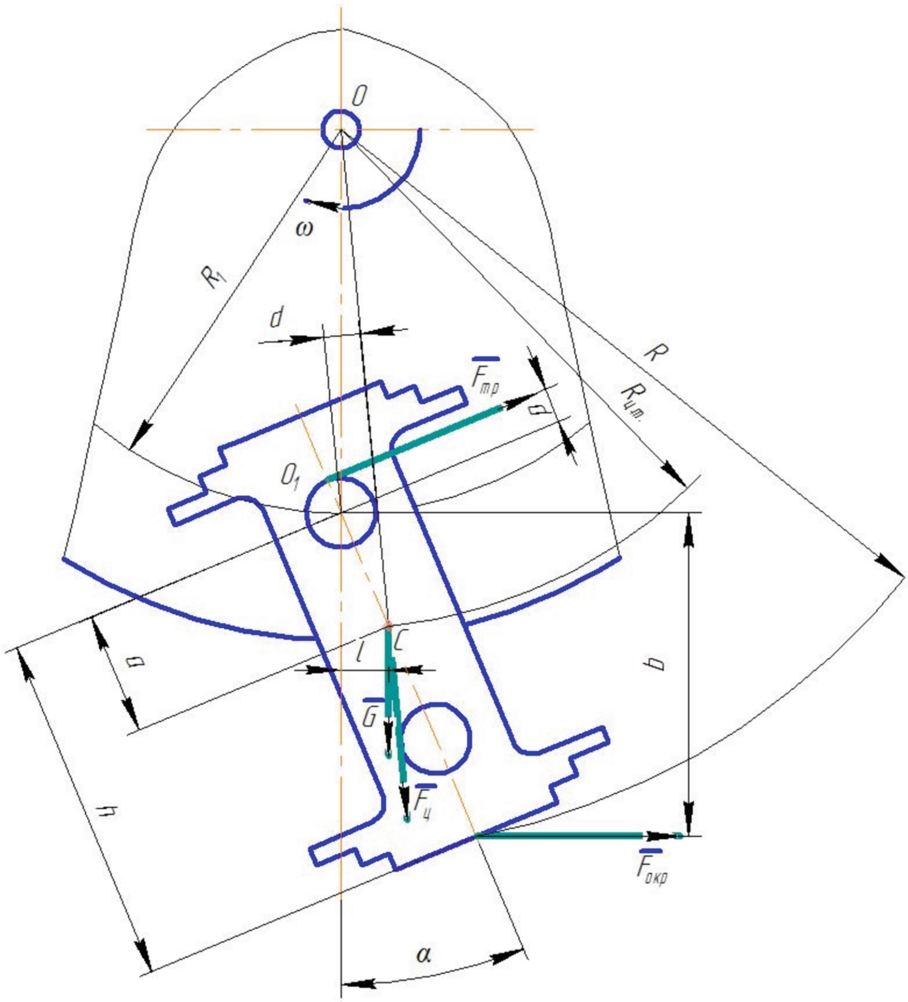

Fig. 4. Scheme of the action of forces on a hammer during its operation.

For the presented scheme, let us create an equation of moments:

$$F_{\mathrm{cir}} b = Gl + F_{\mathrm{fr}} p + F_c d, \tag{11}$$

where F_{cir} – circumferential force exerted by the hammer on the material, N;
b– circumferential force arm, m;
G– hammer gravity, N;
l– gravity force arm, m;
F_{fr}– frictional force of the hammer relative to the hinge surface, N;
p– friction force arm, m;
F_c– centrifugal force of inertia, N;
d– arm of centrifugal force of inertia, m.
After transforming expression (11), we obtain:

$$\frac{k_r Phcos\alpha}{R\omega_r z_h} = m_h g a \sin\alpha + f m_h \omega_r^2 R_h p + m_h \omega_r^2 R_1 a \sin\alpha, \tag{12}$$

where k_r – coefficient of resistance of hammer movement in the air-product layer of husks, $k_r = 2, 5 \ldots 3$;
P– required rotor drive power, W;
h- distance from the hinge axis to the point of application of force F_{cir}, m;
α– hammer deflection angle, degrees;
R– distance from the axis of rotation of the rotor shaft to the point of application of force F_{cir} m;
ω_r– angular velocity of rotor with hammers, s^{-1};
z_h– number of the hammers;
m_h– mass of hammer, kg;
g– acceleration of gravity, m/s^2;
a– distance from the hammer hinge axis to the center of the gravity, m;
f– coefficient of joint friction ($f = 0{,}15$);
R_h- distance from the axis of rotation of the rotor to the center of gravity of the hammer, m;
R_1– distance from the axis of rotation of the rotor shaft to the axis of the hammer hinge, m.
Under condition that the hammer is not deviated from the radial position, i.e. $\alpha = 0$, the following condition must be met:

$$\frac{k_r Ph}{R\omega_r z_h} < f m \omega_r^2 R_h p,$$

where

$$\omega_r \geq \sqrt[3]{\frac{k_r Ph}{f R z_h m R_h p}}. \tag{13}$$

$$m \frac{k_r Ph}{f R z_h \omega_r^3 R_h p}_{min} \tag{14}$$

Fulfillment of conditions (13) and (14) will ensure stable equilibrium of the hammer, in which it will not deviate from the radial position.

The productivity of a hammer crusher when crushing husks is determined by the formula:

$$Q = 0,06 k_i k_{sh} k_e \rho D_{rh}^2 L_r n_r, \tag{15}$$

where Q – hammer grinder productivity, kg/h;

k_i– impact factor, $k_i = 2.5 \ldots 3$;

k_e– empirical coefficient depending on the type and size of the sieve cells, for smooth sieves with a hole diameter of 3 mm $k_e = (1,3 \ldots 1,7) \cdot 10^{-4}$ (according to S.V. Melnikov);

k_{sh}– coefficient depending on the shape of the working surface of the hammers, $k_{sh} = 1,2 \ldots 1,5$;

ρ– density of the crushed material, kg/m^3;

D_{rh}– rotor diameter around the circumference of the ends of the hammers in working position, m;

L_r– length of the rotor, m;

n_r– speed of the rotor, min^{-1}.

The energy intensity of the working process of a hammer grinder, taking into account the degree of grinding and the quality of the finished product, is calculated by the formula:

$$E = \frac{PK_q}{Q\lambda}, \tag{16}$$

where P – power spent on the working process of a hammer grinder, taking into account energy costs for the entire technological process, kW;

Q– the productivity, t/h;

λ. – degree of the grinding;

K_q– finished product quality factor.

Tensure the grinding process, the flow of material leaving the feeding device must have the necessary uniformity. As can be seen from Fig. 5, the proposed design of the feeding device ensures a uniform flow of crushed material to the working parts of the hammer grinder at lower rotation speeds compared to a feeder with straight gutters.

The working parts of the grinder significantly influence on the productivity of a hammer grinder, in addition to the influence of physical and mechanical properties and the amount of feed of the crushed material.

Figure 6 shows the results of the influence of the shape of the working surface of the hammer on the productivity of the hammer grinder. From this dependence it is clear that hammers with a stepped working surface provide a hammer grinder productivity that is approximately 1.5 times greater compared to standard hammers at a peripheral speed of the hammers of 40 m/s.

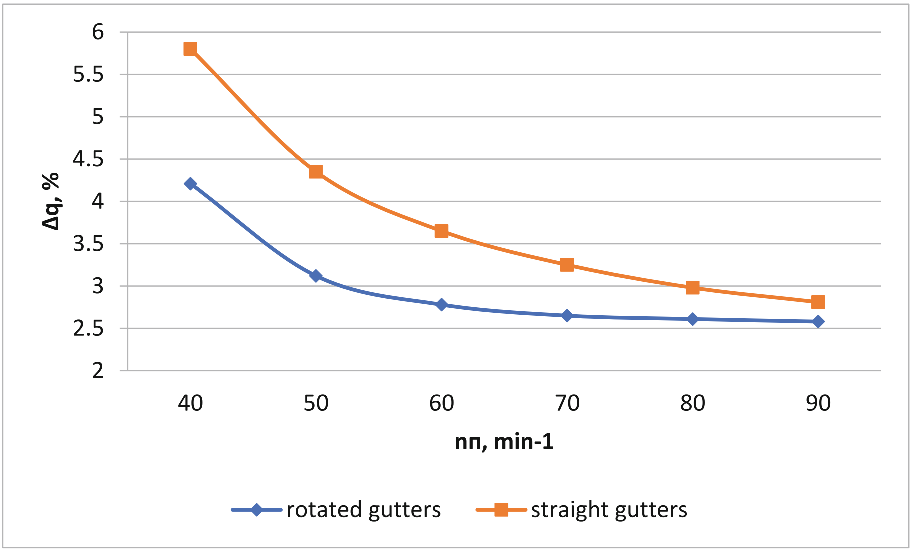

Fig. 5. Dependence of uneven supply of crushed material on the rotation speed n_n of the feeding device, buckwheat husk.

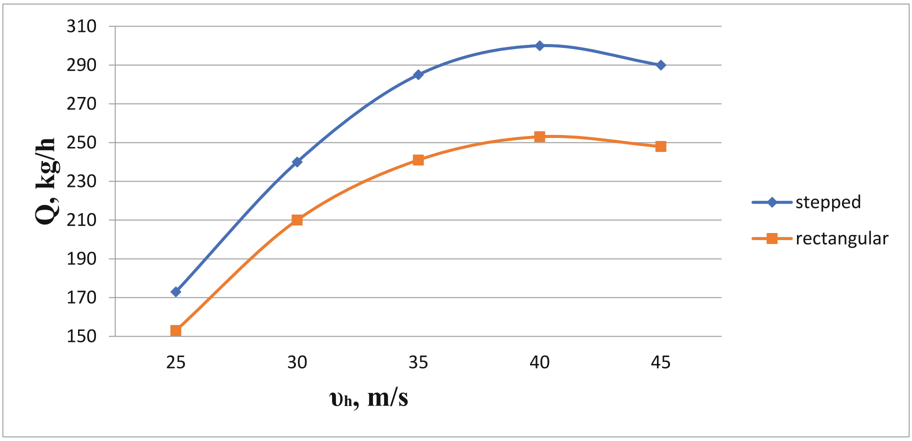

Fig. 6. Dependence of the productivity of a hammer chopper on the peripheral speed of the hammers υ_h, buckwheat husks.

Based on the results of the research, a regression Eq. (17) was obtained and a corresponding graphical dependence of the productivity of the hammer grinder on the feed rate of the crushed material and the peripheral speed of the hammers (Fig. 7).

$$Q = 291,915 + 0,449 \cdot Q_n - 8,267 \cdot \upsilon_n + 0,0004 \cdot Q_n^2 - 0,007 \cdot Q_n \cdot \upsilon_n + 0,14 \cdot \upsilon_h^2 \tag{17}$$

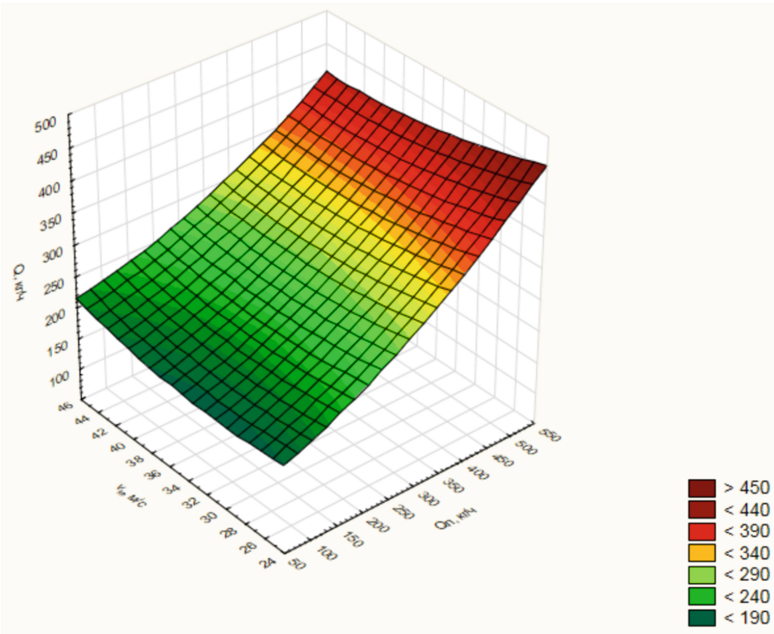

Fig. 7. Dependence of the productivity of a hammer grinder on the feed rate Q_n of the crushed material and the peripheral speed of the hammers υ_h.

As can be seen from Fig. 7 at optimal values of the supply of crushed material Q_n equal to 250… 300 kg/h and the peripheral speed of the hammers υ_n 30… 40 m/s, the productivity of the hammer grinder is achieved 250… 300 kg/h.

Based on the results of the research, a regression Eq. (18) was obtained and a corresponding graphical dependence of the energy intensity of the process of grinding husks of cereals and oilseeds on the feed rate of the crushed material and the peripheral speed of the hammers (Fig. 8).

$$E = 1,4865 - 0,0008 \cdot Q_n - 0,006 \cdot \upsilon_n + 3,6792\mathrm{E}^{-6} \cdot Q_n^2 - 3,7716\mathrm{E}^{-5} \cdot Q_n \cdot \upsilon_n + 0,0002 \cdot .\upsilon_h^2 \tag{18}$$

As can be seen from Fig. 8, the energy intensity of the grinding process at a small supply of crushed material Q_n up to 250 kg/h increases, but as the supply of material to the working parts of the hammer grinder increases, the energy intensity begins to decrease, since the power supplied to the grinder rotor remains constant. With a feed rate of 250…300 kg/h, the optimal energy intensity value of 1.23…1.35 kWh/kg is achieved. A further increase in feed leads to an increase in the energy intensity of the grinding process and when the value is greater than 300 kg/h, the grinder operates in blockage mode.

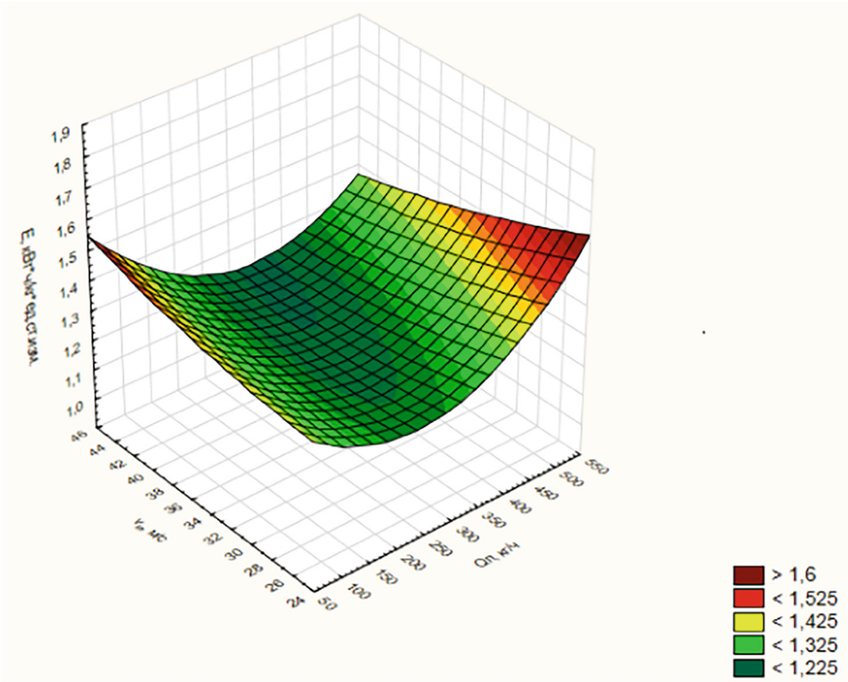

Fig. 8. Dependence of the energy intensity of the process of grinding husks of agricultural crops on the feed quantity Q_n of the crushed material and the peripheral speed of the hammers υ_h.

4 Discussion

The theoretical and experimental studies presented in the article are devoted to improving the technological process of grinding the husks of agricultural crops, as a result of which the finished product can be used as a feed additive for cattle. The developed hammer crusher can be used for crushing husks by enterprises associated with the production of grains and oilseeds.

The developed design and technological scheme of the hammer crusher, in comparison with previously known hammer crushers, makes it possible to increase the yield and reduce the energy intensity of grinding using new designs of the hammer and feeding device.

5 Conclusion

As a result of theoretical and experimental studies of the working processes of feeding and crushing agricultural crop husks with a hammer crusher, it was found that the main factors determining the uniformity of supply of the crushed mass and the degree of crushing with a hammer crusher are the rotation frequencies of the feeder shaft and the rotor shaft with hammers, respectively.

Equations (18) and (19) obtained as a result of experimental studies make it possible to determine the productivity of a hammer crusher and the energy intensity of the process of grinding husks of agricultural crops with optimal design and operating parameters of the hammer crusher.

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Microbiological Approaches to Reducing the Use of Antibacterial Drugs in Fish Farming as a Tool to Improve Ecology in Aquaculture Systems

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Abstract. The novelty of the work is confirmed by the trends in the search and study of microorganisms with probiotic potential that can have a positive effect on fish health and the sustainability of aquaculture systems, and are aimed at improving environmental friendliness in aquaculture. The aim of the research was a comparative study of the antagonistic activity of symbiotic lactobacilli isolated from the intestinal canal of fish and the antibiotic sensitivity of pathogenic aeromonads. The material for the study was microorganisms isolated from the internal organs of fish species: Russian sturgeon, silver Prussian carp, carp, silver carp and amber trout. The bacteria were studied using bacteriological methods by seeding intestinal contents onto nutrient media and subsequent species identification using the MALDI-TOF MS time-of-flight mass spectrometry method. Pathogenic aeromonads of the species *Aeromonas hydrophila, Aeromonas veronii, Aeromonas ichthiosmia, Aeromonas salmonicida* were obtained and their sensitivity to antibacterial drugs was determined. The degree of bactericidal action of ciprofloxacin, imipenem and cefaclor was established. Amoxicillin had moderate antimicrobial activity. *Aeromonas ichthiosmia* culture showed the least sensitivity to antibiotics compared to other aeromonads. Species-specific bacteria of their intestinal contents of silver Prussian carp and amber trout belonging to the species *Enterococcus faecium, Pediococcus acidilactici, Lactococcus lactis* were obtained. The antagonistic activity of lactobacilli was studied in relation to pathogenic aeromonads. A high degree of bacteriostatic action was expressed in the inhibition of microbial growth of indicator cultures of pathogenic aeromonads. Prospects for the use of species-specific lactobacilli of fish were established as new environmentally friendly probiotic feed additives for an alternative to antibiotics.

Keywords: Aquaculture · Ecology · Fish Farming · Aeromonas · Lactobacillus · Probiotics · Antibiotics

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1 Introduction

Aquaculture, as a sector of the food industry, is becoming increasingly important in the context of a growing population and increasing demand for fish products. However, at the same time, the risk of negative impacts of aquaculture on the environment and ecology increases. The use of antibiotics in fish farming, aimed at disease control and growth stimulation, leads to serious problems such as the development of antibiotic resistance and disruption of the biodiversity of aquatic ecosystems [1, 2].

In addition, it should be borne in mind that keeping and growing fish in industrial production conditions other than their natural habitat inevitably leads to disorders on the part of the body, including behavioral changes, as well as the development of new, previously unobserved diseases. Thus, violation of the technology of maintenance, feeding with concentrated feeds – provoke the occurrence of stress, which ultimately leads to a violation of protective mechanisms, weakening of the immune system, and as a result, the emergence of various pathological processes and diseases. The causes of fish diseases are often opportunistic microorganisms, including pathogenic bacteria of the genus *Aeromonas*. The strategy of treatment and prevention of aeromonosis and other infectious diseases of fish is primarily aimed at the destruction of pathogens. For this reason, when carrying out therapeutic measures, preference was given to chemotherapeutic and antimicrobial drugs of artificial origin [3].

In this context, there is a growing interest in finding more environmentally sustainable methods of conducting aquaculture activities. One of the promising approaches that attracts the attention of researchers and practitioners is the replacement of antibiotics with probiotics. This decision is justified by its high environmental friendliness and direct impact on both the immune system and the causative agent of the disease directly [4].

One of the first probiotic preparations in fish farming was based on live microorganisms of the species *Bacillus subtilis*. These microorganisms have an antagonistic effect against a large number of pathogenic and opportunistic microorganisms. In this case, the choice of a bacterium of the genus *Bacillus* as a probiotic strain was due to the peculiarities of its biology. Bacteria of this genus are widespread in soil and water, where they are active participants in various biological processes, fermentation of organic compounds [5]. The functional capabilities of representatives of the genus *Bacillus* are very diverse. They actively produce enzymes, amino acids and other biologically active substrates and secrete bacteriocins (antimicrobial peptides) that help suppress the growth of pathogenic bacteria in the digestive system of hydrobionts, provide immunostimulation, and are used to reduce metabolic waste in the aquatic system [6, 7].

Limiting the use of antibiotics in aquaculture and increasing the use of a range of probiotic biological products has now given rise to a new industry in the production of aquaculture products – organic aquaculture. This new, extremely promising, rapidly developing market niche meets the growing demands of people for safe, environmentally friendly products in conditions of stagnation in the global fisheries [2, 4].

In these new developing conditions, drugs containing species-specific bacteria come to the fore. When studying modern research data, it was found that species-specific microorganisms can be successfully used as feed additives and have a beneficial effect on the body of hydrobionts, which is an urgent area of research [11–14].

The aim of the work was to study the prospects of using species-specific microorganisms isolated from the intestinal canal of fish as an alternative to antibacterial drugs used in fish farming.

2 Materials and Methods

The research was carried out based on the laboratories of microbiology and industrial fermentation of the Center for Biotechnology of the Federal State Budgetary Educational Institution of Higher Education «Kuban State Agrarian University named after I.T. Trublin».

The microorganisms of the genus *Aeromonas* participating in the study were isolated from the parenchymal organs of fish (kidneys, liver) of the following species: Russian sturgeon (*Acipenser gueldenstaedtii*), silver Prussian carp (*Carassius gibelio*), carp (*Cyprinus carpio*), and silver carp (*Hypophthalmichthys*).

Microorganisms of the genus *Aeromonas* were isolated in the laboratory from pathological material suspected of fish disease. To obtain pure bacterial cultures from pathological material, we used breeding ground belonging to selective and differential ones: meat-peptone agar, meat-peptone broth, Endo breeding ground manufactured by Laboratorios CONDA, Spain. Incubation was performed in a Binder FD53 thermostat manufactured in Germany. Meat peptone broth was used as a storage breeding ground. Cultivation was carried out for 24 h. Further, the material was transplanted onto the breeding ground Endo and meat-peptone agar, in order to further identify the isolated microorganisms. The identification of isolated microorganisms was carried out using the MALDI-TOF MS time-of-flight mass spectrometry method on a BactoSCREEN spectrometer manufactured by Limited Liability Company Scientific and Production Company «Litech», Russia.

Sensitivity to antibacterial drugs was determined in identified microorganisms: *Aeromonas hydrophila, Aeromonas veronii, Aeromonas ichthiosmia, Aeromonas salmonicida* by serial dilution on Mueller-Hinton agar using antibiotic discs, produced by Hi-MEDIA, India. The interpretation of the obtained research results was carried out based on the recommendations of the Institute of Clinical and Laboratory Standards (CLSI). The study involved antibacterial drugs ciprofloxacin, imipenem, amoxicillin, cefaclor, manufactured in India. The choice of drugs for assessing the sensitivity of isolated bacteria was because they are approved for use in aquaculture in countries belonging to the World Organisation for Animal Health [9, 10].

To study the antagonistic activity to pathogenic bacteria of the genus Aeromonas, species-specific microorganisms were used, which were isolated from the gastrointestinal tract of the following fish: *Enterococcus faecium* and *Pediococcus acidilactici* – from the gastrointestinal tract of crucian carp (*Carassius*), bacteria of the species *Lactococcus lactis* were isolated from the intestines of amber trout (*Oncorhynchus mykiss*). Their antagonistic activity was determined against microorganisms *Aeromonas hydrophila, Aeromonas veronii, Aeromonas ichthiosmia, Aeromonas salmonicida.*

For the cultivation of probiotic microorganisms, breeding ground were used: Bifidum breeding ground, Enterococcagar, produced by HiMedia Laboratories, India. The thermostating of breeding ground was carried out in an anaerobic incubator manufactured by

SBt Smart BioTherm, Biosan, Latvia. Culture of nutrient media was carried out for 48 h. The identification of microorganisms was carried out using the MALDI-TOF MS time-of-flight mass spectrometry method on a BactoSCREEN spectrometer manufactured by Limited Liability Company Scientific and Production Company «Litech», Russia. The study of antagonistic activity was carried out using Mueller-Hinton nutrient agar produced by Hi-MEDIA, India.

3 Results

As a result of the conducted studies, it was established that the culture of *Aeromonas hydrophila* is highly sensitive to antibiotics such as ciprofloxacin, impinem and cefaclor, while the bacterial growth retardation zone was 30.4, 28.2 and 29.1 mm, respectively. *Aeromonas veronii* showed high sensitivity to the antibiotic impinem (24.5 mm). *Aeromonas salmonicida* was highly sensitive to ciprofloxacin and cefaclor (25.2 and 24.3 mm, respectively). The average degree of antibiotic sensitivity was recorded in the *Aeromonas ichthiosmia* microorganism, in our studies the growth retardation zone ranged from 15.5 to 19.6 mm, depending on the type of antibacterial drug. *Aeromonas hydrophila* had an average degree of sensitivity to amoxicillin (21.0 mm). *Aeromonas veronii* gave growth retardation zones of 16.4, 18.3 and 20.0 mm to the antibiotics ciprofloxacin, amoxicillin and cefaclor, which allows it to be attributed to an average sensitivity to these antibacterial drugs. *Aeromonas salmonicida* was moderately sensitive to amoxicillin (17.8 mm) and impinem (19.0 mm). Thus, most of the indicator cultures of microorganisms of the genus *Aeromonas* have medium or intermediate sensitivity to the most common antibiotics used in fish farming, and treatment of which will not always be appropriate and effective.

In turn, species-specific microorganisms of the species *Enterococcus faecium*, *Pediococcus acidilactici* and *Lactococcus lactis* showed antagonistic activity to pathogenic species of aeromonads. Thus, *Enterococcus faecium* restrained the growth of *Aeromonas hydrophila* with a value of 9.5 mm, which was the maximum for this type of lactobacilli. At the same time, the minimum delay in bacterial growth was 7.8 mm to *Aeromonas ichthiosmia*. *Pediococcus acidilactici* inhibited the growth of pathogenic aeromonads in the range from 7.5 to 9.2 mm. *Lactococcus lactis* showed minimal antagonistic activity to *Aeromonas hydrophila* (7.0 mm), and maximum activity to *Aeromonas salmonicida* (10.2 mm) (Table 1).

As a result, it was found that the use of species-specific microorganisms as an alternative to antibacterial drugs seems more promising, since each type of lactobacilli has a high antagonistic activity, restraining pathogenic aeromonads with a delay in antibacterial growth of 7 mm or more. Microorganisms belonging to the species-specific autochthonous microflora of freshwater fish, due to their antagonistic properties, have a depressing effect on conditionally pathogenic and pathogenic microflora living in natural and artificial reservoirs. The peculiarity of these types of bacteria is their ability to show their activity at temperatures below +15 °C. These properties of feed additives used on their basis can contribute to the preservation and improvement of the quality of fish farming products.

Thus, the practical application of beneficial probiotic species-specific microorganisms that can be added to fish food in order to maintain a healthy intestinal microflora,

Table 1. Comparison of the results of the sensitivity of bacteria of the genus *Aeromonas* to antibacterial drugs and the antagonistic activity of species-specific microorganisms isolated from fish

Antibacterial drugs and microorganisms	Indicator cultures of microorganisms of the genus *Aeromonas*			
	A. hydrophyla	*A. veronii*	*A. ichthiosmia*	*A. salmonicida*
Sensitivity of microorganisms to antibacterial drugs, mm*				
Ciprofloxacin	30.4 ± 0.12	16.4 ± 0.27	18.0 ± 0.32	25.2 ± 0.17
Imipenem	28.2 ± 0.3	24.5 ± 0.09	15.5 ± 0.15	19.0 ± 0.24
Amoxicillin	21.0 ± 0.17	18.3 ± 0.31	17.2 ± 0.23	17.8 ± 0.32
Cefaclor	29.1 ± 0.22	20.0 ± 0.2	19.6 ± 0.11	24.3 ± 0.18
Species-specific microorganisms exhibiting antagonistic activity (bacterial growth retardation, mm)				
Enterococcus faecium	9.5 ± 0.2	8.0 ± 0.31	7.8 ± 0.28	9.3 ± 0.43
Pediococcus acidilactici	8.3 ± 0.13	9.0 ± 0.28	7.5 ± 0.16	9.2 ± 0.23
Lactococcus lactis	7.0 ± 0.3	9.4 ± 0.17	8.7 ± 0.41	10.2 ± 0.31

* bacterial growth suppression zone of more than 24 mm – high sensitivity to antibacterial drugs; 15–24 mm – medium (intermediate sensitivity); up to 15 mm – antibiotic resistance.

contributes to the formation of a balanced intestinal microbiome, improves nutrient absorption, increases disease resistance and fish productivity.

4 Discussion

Taking into account the peculiarities of industrial technology of fish keeping, the influence of adverse environmental factors is not excluded, which leads to a decrease in the resistance of the fish body and the spread of pathogens among all farmed fish. A number of authors note this problem and define the main role of representatives of the genus *Aeromonas* as an indicator of the biological well-being of reservoirs [3, 15].

With increased exploitation of fishery reservoirs, there is a need for scientifically sound environmental approaches to their use.

Ecological approaches consist in carrying out an assessment of aquatic systems with subsequent correction of biocenotic communities, including microbial ones. Correction with the use of chemicals and antibiotics often does not lead to the expected result. On the contrary, such measures are capable of shifting the balance of the microbial community towards an increase in the number of pathogenic bacterial forms while simultaneously reducing the microbial landscape of a useful aquatic ecosystem, which will inevitably lead to a violation of its balance. The scientific idea of developing alternatives to antibiotic drugs is based on the formed reserve of researchers [4, 7, 8, 12, 13]. The use of drugs of biological origin as means of stimulating immunity in fish farming makes it possible to solve this problem. The use of vaccine preparations in aquaculture and probiotics makes it possible to control the environmental situation and increase the immune status of aquatic organisms [4, 6, 15].

We have established that the bacteria of the genus Aeromonas of the species *A. hydrophila, A. veronii, A. ichthiosmia, A. salmonicida* have a high and intermediate degree of sensitivity to antibacterial drugs: ciprofloxacim, impinem, amoxicillin and cefaclor. In addition, during the microbiological study, it was found out that the studied species of probiotic microorganisms, including *Enterococcus faecium, Pediococcus acidilactici*, *Lactococcus lactis,* have antagonistic activity against pathogenic aeromonads.

The choice of the used indicator microorganisms of the genus *Aeromonas*, antibacterial drugs and types of biological models were determined by scientific data and the available experimental research groundwork. The use of species-specific bacteria with high antagonistic activity was the main search task that meets modern scientific demands. In turn, the literature notes the positive experience of using *Enterococcus faecium, Pediococcus acidilactici* and *Lactococcus lactis* bacteria in the development of feed additives in fish farming [11–14].

The results obtained during the research and the methodology used to study the antibiotic sensitivity of aeromonads and the antagonistic activity of lactobacilli isolated from the intestinal canal of fish are consistent with previous work in this area [2–8].

5 Conclusion

The conducted studies have established the presence of varying degrees of sensitivity in the studied species of bacteria of the genus *Aeromonas* to antibacterial drugs such as amoxicillin ciprofloxacim, impinem, and cefaclor. The study of the antagonistic activity of representatives of lactobacilli isolated directly from the intestines of fish made it possible to establish its significant degree in such species as *Enterococcus faecium, Pediococcus acidilactici, Lactococcus lactis*, which determines the practical significance of the study. The prospect of further scientific research is the development of feed additives containing species-specific microorganisms that can have a beneficial effect on fish productivity, contributing to the formation of a natural intestinal microbiome, completely or partially reduce the use of antibacterial drugs in aquaculture, contributing to the improvement of the environmental situation in the industry.

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The Importance of Humus in the Fertility of Irrigated Gray-Earth Soils and the Effectiveness of Mineral Fertilizers

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Abstract. Humus is an important component of the soil that plays a crucial role in the agricultural ecosystem. A comparative assessment of the current humus state of typical, light gray and meadow-gray soils is given. The study presents the influence of natural factors (altitude above sea level, depth of groundwater) and anthropogenic factors (duration of irrigation, type of agricultural crop) on the quality of humus (group composition) in the studied soils. The influence of the humus state of the soil on the effectiveness of mineral fertilizers was studied in separate observation sites. We revealed that the content and quality of humus in gray-earth soils increases with the height of the soil above sea level. In terms of humus state, typical serozems are superior to light serozems. Moreover, the difference between the group composition of humus of automorphic and semi-hydromorphic soils was studied. We noted the high content of humic acids in the group composition of humus of meadow-gray soils, which provides a better quality of humus compared with light and typical gray soils. As the irrigation prescription increased, an improvement in the quality of humus was observed in all the studied soils. Long-term cultivation of gray-earth soils with irrigated green farming affects not only the accumulation of organic matter, but also an increase in soil fertility, including the effectiveness of the use of nutrients by cotton from mineral fertilizers introduced into these soils. This is especially evident in aphthomorphic soils. The research showed that the utilization rate of nitrogen from nitrogen fertilizers improves with an increase in soil hydromorphism, which indicates the need for differential use of nitrogen fertilizers, taking into account the genetic characteristics of the soil. It is recommended to reduce the norms of nitrogen fertilizers by applying a correction factor.

Keywords: gray-earth belt · typical gray soils · light gray soils and meadow-gray soils · irrigation prescription · altitude above sea level · depth of groundwater · tillage · cultivated crops · group composition of humus · quality of humus · crop yield · effectiveness of mineral fertilizers

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1 Introduction

Humus is the main component of the soil that affects the productivity of the ecosystem and controls processes such as the circulation of nutrients and their retention in the productive soil layer [1, 2]. Humus has a significant effect on the dynamics of soil water, nutrient supply and plant growth [3].

Today, the state of humus in the soil is determined by many factors, the most important of which is anthropogenic. The attraction of land for agricultural use and their intensive use leads to a deterioration of the humus state of soils and loss of productivity [4–14].

Reducing the rate of soil dehumification and increasing the efficiency of agricultural production is an urgent problem of land management, especially in regions with unfavorable climatic or relief conditions. Non-compliance with agro-technical, agro-reclamation and hydro-reclamation measures when using land in arid climates leads to a deterioration of the humus state of the soil [15].

The most favorable for agriculture are river valleys, where agriculture is traditionally conducted on irrigated alluvial gray-earth and meadow-gray-earth soils [16]. The study of the causes of dehumification of gray-earth and meadow-gray-earth soils, which make up the bulk of the land resources of irrigated agriculture in the studied region, and the factors affecting the reduction of humus reserves and the deterioration of the humus state of these soils is of particular interest. In this regard, our research was aimed at studying the mutual influence of natural and anthropogenic factors on the humus state of gray-earth soils common in the Khatyrchinsky district of Navoi region. The influence of the humus state of the soil on the effectiveness of mineral fertilizers was studied in separate observation sites.

2 Research Methodology

In order to study the humus state of gray-earth soils, expedition studies were conducted. Irrigated meadow-gray soils formed on alluvial deposits located on the II-terrace of the Zarafshan River, irrigated typical gray soils formed on loess deposits located on foothill slopes and irrigated northern gray soils located on the foothill slopes and lower reaches of the mountains of the Central Asian province of the subtropical mountain-semi-desert zone of the gray belt were studied.

Soil maps with a scale of 1:10000, land use plans and agrochemical maps of agricultural lands were used. With the help of these maps and by direct examination of the soils in each farm, soil types and subtypes and their boundaries were determined.

The areas characterizing these sites were determined by digging in the studied soils. To study the entire soil profile, the main sections were laid in the most typical places. Soil samples from each genetic horizon were taken from the sections. Soil samples and their preparation for analysis were carried out by a generally accepted method.

The humus content was determined by the Tyurin method and Nikitin modification, the fractional and group composition of humus by the Tyurin method and modification by Ponomareva and Plotnikova.

To study the effectiveness of mineral fertilizers, observation sites with an area of 262 ^{m2} similar in agrochemical indicators were selected on four soil subtypes. New and old-irrigated soils of light gray soil and new and old-irrigated meadow-gray soils were selected as observation sites. At each observation site of these types and subtypes of soils, the same norms recommended for cotton crops in this region were applied (in the ratio of 1.0:0.7:0.5, 200 kg of nitrogen, 140 kg of phosphorus and 100 kg of potash per hectare) fertilizers based on the active substance. As a control, one section was separated and left without fertilization. Nitrogen was introduced in the form of ammonium nitrate (N - 34%), phosphorus - ammophos (N - 14–11%, P_2O_5 - 46%), potassium - potassium chloride (K_2O - 60%).

The removal of nutrients from the soil by cotton was calculated by determining plant biomass and NPK content. The amount of NPK in plants was determined by the Ginzburg method in one sample.

The yield was determined biologically in each plot, and then recalculated per hectare. The effectiveness of mineral fertilizers was calculated using the difference method. The observations were carried out in 2022.

3 The Results of the Study

The group and fractional composition of the humus of the studied soils largely depends on natural and anthropogenic factors. Compared with aphthomorphic soils, it was found that the accumulation of humus and the quality of humus in conditions of hydromorphic soil formation are relatively high (Table 1).

Among hydromorphic soils, semi-hydromorphic meadow-gray soils are the most common, they have a relatively high humus content, and humic acids predominate in the ratio C_{ha}:C_{fa}. The humus state of meadow-gray soils also depends on the level of their cultivation. The high quantity and quality of humus is noted in old-irrigated meadow-gray soils. It was found that the quality of humus in newly irrigated meadow-gray soils is lower compared to the above-mentioned meadow-gray soils. The quality of humus of meadow soils also depends on its mechanical composition. As the mechanical composition becomes heavier, not only the amount of humus increases, but also its quality improves, that is, the percentage of humic acids in humus increases and the percentage of fractions associated with calcium and colloidal particles increases.

Studies have shown that with an increase in the prescription of irrigation, the content and quality of humus increased significantly, and accordingly the duration of irrigation affected the yield of cotton. For example, the yield of cotton on newly irrigated light gray soil averaged 26.8 c/ha, and on old-irrigated light gray soil - 31.9 c/ha. This indicator is on meadow gray soil, respectively, with an increase in irrigation prescription of 33.3, 36.1 c/ha. It is noted that the yield of cotton on old-irrigated meadow gray soil is higher than on new-irrigated ones.

In addition, with the transition from automorphic soils to semi-hydromorphic ones, with an improvement not only in quantitative but also in qualitative indicators of humus, the yield of cotton has increased significantly (Table 2).

In addition, with the transition from automorphic soils to semi-hydromorphic ones, with an improvement not only in quantitative but also in qualitative indicators of humus, the yield of cotton has increased significantly. For example, it was observed that the yield of cotton on newly irrigated meadow gray soil was 6.5 c/ha higher than the yield

Table 1. The group composition of humus of gray-earth soils, of total carbon, %.

Soil type and subtype	Horizon depth, cm	C, %	The content of the general C, %	Humus			$C_{ha}:C_{fa}$
				Humic acids	Fulvic acids	Non-hydrolyzable residue	
Newly irrigated typical serozem	0–30	0,89	0,515	28,5	33,8	37,7	0,84
	30–50	0,61	0,354	11,6	29,7	58,8	0,39
	50–70	0,58	0,338	8,6	26,7	64,9	0,32
	70–100	0,48	0,278	5,7	23,3	70,8	0,24
Old-irrigated typical serozem	0–30	1,08	0,626	31,1	36,4	32,4	0,85
	30–50	0,89	0,516	16,7	32,9	50,4	0,51
	50–70	0,80	0,464	9,7	28	62,3	0,35
	70–100	0,56	0,326	6,7	24,2	69	0,28
Newly irrigated light gray soil	0–30	0,81	0,470	26,4	31,3	42,4	0,84
	30–50	0,57	0,331	10,6	30,2	59,3	0,35
	50–70	0,53	0,307	8,1	27,3	64,4	0,3
	70–100	0,45	0,262	5,3	23,6	70,9	0,22
Old-irrigated light gray soil	0–30	0,93	0,541	28,3	35,5	36,3	0,8
	30–50	0,80	0,464	15,9	32,5	51,5	0,49
	50–70	0,64	0,371	9,2	27,2	63,6	0,34
	70–100	0,50	0,290	6,2	24,1	69,7	0,26
Newly irrigated meadow-gray soil	0–30	0,85	0,493	31,8	31,8	36,3	1,0
	30–50	0,59	0,342	17,2	27,8	54,9	0,62
	50–70	0,53	0,307	9,8	27	63,1	0,36
	70–100	0,47	0,274	6,9	24,1	69	0,29
Old-irrigated meadow-gray soil	0–30	1,24	0,720	33,5	33	33,5	1,02
	30–50	1,00	0,580	18,6	28,4	52,9	0,65
	50–70	0,87	0,506	11,3	27,3	61,5	0,41
	70–100	0,69	0,399	7,8	24,1	68,2	0,32

of cotton on newly irrigated light serozem. In the old-irrigated typical serozem, this indicator was higher by 4.2 c/ha compared with the old-irrigated light serozem.

It is noted that the coefficient of use of mineral fertilizers and the yield of cotton depend on the genetic characteristics of the soil, the duration of irrigation, the content and quality of humus. The coefficient of use of nitrogen fertilizers in the cultivation of cotton on newly irrigated light gray soil is 29.8%, in old-irrigated - 36.1%, on newly irrigated typical gray soil - 42.8%, old-irrigated - 44.8%, i.e. as the content and quality of humus increases, the coefficient of nitrogen use by cotton from nitrogen fertilizers increases.

The utilization rate of nitrogen fertilizers by cotton was higher than that of phosphorous fertilizers, but less than that of potash fertilizers. With an increase in the humus

Table 2. The effect of fertilizers on cotton yields on gray-earth crops soils (c/ha).

Number of the observation area	Soil type and subtype	Duration of irrigation	Mechanical composition	Yield without fertilizers, kg/ha	Yield with fertilizers, c/ha	Crop increase from fertilizers	
						c/ha	%
23rd	Light gray	New-	Light-loamy	12,9	26,8	13,9	107,8
22's		Old-	Medium loamy	13,4	31,9	18,5	138,1
41's	Meadow-gray-earth soil	New-	Light-loamy	13,5	33,3	19,8	146,7
46's		Old-	Medium loamy	14,9	36,1	21,2	142,3

$F_f > F_{05}$

content of the soil, the utilization rate of phosphorus from phosphorus fertilizers by cotton was higher in meadow-gray soil than in light gray soil. At the same time, as the irrigation prescription increases, the utilization rate of phosphorus from fertilizers also increases (Table 3).

Table 3. The effect of irrigation duration and groundwater level on cotton yield on gray-earth soils (c/ha)

Number of the observation area	Type and subtype Soils	Duration of irrigation	Mechanical composition of the soil	Yield c/ha	Crop increase	
					c/ha	%
23rd	Light gray	New-	Light-loamy	26,8	-	-
22's		Old-	Medium loamy	31,9	-	-
41's	Meadow-gray-earth soil	New-	Light-loamy	33,3	6,5	20,38
46's		Old-	Medium loamy	36,1	4,2	12,61

HCR05 = 1.54

The utilization rate of phosphorus from fertilizers by cotton on newly irrigated light gray soil was the lowest - 16.6%, and the highest - 18.7% on old-irrigated meadow-gray soil (Table 4).

The same pattern was observed with the application of potash fertilizers: the coefficient of use of potassium by cotton from potash fertilizers on light gray soil was 68.2–75.8%, on meadow-gray soil 77.9–79.8%. As the irrigation period increases, the utilization rate of potash fertilizers in cotton increases, that is, as the content and quality of humus decrease, the utilization rate of potash fertilizers decreases. Studies have shown that the utilization rate of nitrogen from nitrogen fertilizers improves with an increase in soil hydromorphism, which indicates the need for differential use of nitrogen fertilizers, taking into account the genetic characteristics of the soil. It is recommended

Table 4. The influence of the humus state of gray-earth soils on the coefficient of fertilizer use by cotton, %

The number of the observation area	Type and subtype soils	Duration irrigation	Mechanical composition	Yield c/ha	Content humus, %	$C_{ha}:C_{fa}$	The coefficient of use of batteries by cotton from fertilizers, %		
							N	P_2O_5	K_2O
23rd	Light gray	New-	Light-loamy	26,8	0,75	0,72	29,8	16,6	68,2
22's		Old-	Medium loamy	31,9	0,84	0,8	36,1	17,8	75,8
41's	Meadow-gray-earth soil	New-	Light-loamy	33,3	0,88	0,93	42,8	18,2	77,9
46's		Old-	Medium loamy	36,1	1,12	1,02	44,8	18,7	79,6

to reduce the norms of nitrogen fertilizers by applying a correction factor of 0.8, obtained on the basis of the correlation coefficient of nitrogen fertilizer norms with cotton yields on semi-hydromorphic soils. When calculating the correlation coefficient between the yield of cotton and the coefficient of use of mineral fertilizers, a reliable correlation was established between the effectiveness of fertilizers and the genesis of the soil.

The efficiency indicators of nitrogen fertilizers are more correlated with yield than potash and phosphorus fertilizers.

4 Conclusion

The effectiveness of mineral fertilizers, the absorption of nutrients by plants and their utilization rate from mineral fertilizers, including crop yields, depend on the type of soil, its genesis, the content and quality of humus in the soil. With an increase in soil hydromorphism, the utilization rate of nitrogen fertilizers and the amount of nitrogen in the soil increases. This makes it possible to reduce the norms of nitrogen fertilizers without harming cotton crops and the ecological state of the soil.

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The Effect of Neutralized Phosphogypsum on the Productivity and Safety of Winter Wheat Grain

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Abstract. The aim of the study was to study the application of a fertilizer system with the inclusion of phosphogypsum neutralized on the yield and quality of winter wheat on slightly saline chernozems of the Central Caucasus. For this purpose, field experience was laid on the territory of the Stavropol Territory of the Russian Federation. The observation dates were 2022–2023. The scheme of the experiment includes variants with dosages of phosphogypsum neutralized in 5, 10, 15 and 20 t/ha using the agrochemical background N30P52K30. The estimated reclamation dose is 10 t/ha. The effect of phosphogypsum on crop yields increases over time. So in 2022, a positive increase was detected only on the variant with the addition of neutralized phosphogypsum 10 t/ha, in 2023 all variants showed a significant increase in the range of 0,3–0,38 t/ha. The quality of agricultural products has not yet been systematically affected. A chemical analysis of winter wheat grain was carried out according to the content of nitrogen, phosphorus, potassium and calcium. The content of toxic elements such as mercury, arsenic and cadmium in the grain is within the maximum permissible concentration. Since the use of chemical ameliorants has a long-term effect, observations will continue. The next stage of observations will be carried out on sunflower crops.

Keywords: winter wheat · fertilizer system · saline soils · neutralized phosphogypsum · agroecosystems · yield · grain quality · chernozem · heavy metals · chemical reclamation

1 Introduction

In the 21st century, food security is still an unsolved problem [1]. Science strives with all its might to provide the Earth's population with environmentally friendly products. It is impossible to expand the acreage indefinitely, therefore it is necessary to increase the efficiency of the lands already involved in agricultural use while preserving their fertility [2].

But the increased intensity of soil use increases the anthropogenic load on it. Human activity is becoming the main source of pollution, which is why the issue of chemicalization of agricultural production should be treated as carefully as possible.

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Chemical reclamation of saline soils can be used as a way to increase the efficiency of agricultural lands [3–5]. In the Stavropol Territory of the Russian Federation, they account for about 855.4 thousand hectares of arable land [6], which is about 20% of the total area. The best meliorant for this is phosphogypsum, but when using it, all necessary precautions must be taken.

Phosphogypsum at excessive concentrations can lead to pollution of the ecosystem [7, 8]. Phosphogypsum is the waste of processing phosphorites and appatites, and they may contain a significant amount of heavy metals, strontium and fluorine. Therefore, when tens of millions of tons of phosphogypsum are stored in ovals, they begin to pose a danger to the human environment for tens of kilometers around [9]. The greatest danger is the surrounding aquatic environment, where toxicants enter through water drains [10, 11].

To prevent this from happening, phosphogypsum dumps must be disposed of [12]. It is most rational to dispose of it as a reclamation agent of saline soils. At the same time, the use of ameliorants should be carried out with systematic monitoring of the accumulation of fluorine, strontium and periodic monitoring of the content of Cd, Hg, As.

The aim of the study was to determine the effect of different doses of neutralized phosphogypsum on the yield and quality of winter wheat grain in the conditions of the Central Caucasus. To evaluate the chemical composition of the products, as well as the content of heavy metals, arsenic and strontium.

To achieve this goal, field experience was laid down. The observations were carried out during 2022–2023. Biological accounting of winter wheat yield was carried out annually. The content of protein, gluten, nitrogen, phosphorus, potassium, calcium, mercury, arsenic, cadmium and strontium was determined in winter wheat grain.

2 Materials and Methods

The experience was laid down in the conditions of the Central Pre-Caucasus of the Russian Federation on the territory of the Stavropol Territory. The coordinates of the pilot site are 44.566807, 42.730295.

The site is located in an unstable humidification zone. 450–550 mm of precipitation falls per year. The hydrothermal coefficient is 0.9–1.1. The sum of temperatures is 3000º-3200ºC. Winter is moderately mild, the average monthly temperature in January is -3.0 °C…-0.5 °C minimum - 32°…-34 °C.

The soil of the experimental site is ordinary chernozem, slightly saline, deep-saline, low-humus, medium-thick. On average, the arable horizon of the experimental site contains 5.1% organic matter, 32 mg/kg of mobile phosphorus, 423 mg/kg of mobile potassium. The pH of the aqueous solution is 7.7. Methods of analysis:

- pH of the water extract according to GOST 17.5.4.01–84;
- mobile forms of phosphorus and potassium according to the Machigin method in the modification of TSINAO, GOST 26205–91;
- organic matter according to the Tyurin method in the modification of the TSINAO, GOST 26213–91.

Before laying the experiment, a site survey was conducted and calculations of the volume of gypsum necessary to ensure the reclamation effect were carried out. Then the dose was recalculated to phosphogypsum neutralized by EuroChem – Belorechenskiye Fertilizers LLC. The calculated dose was 10 t/ha of neutralized phosphogypsum, an experimental scheme was selected on a full mineral background of N30P52K30:

1. Background N30P52K30 (control).
2. Background N30P52K30 + phosphogypsum 5 t/ha.
3. Background N30P52K30 + phosphogypsum 10 t/ha.
4. Background N30P52K30 + phosphogypsum 15 t/ha.
5. Background N30P52K30 + phosphogypsum 20 t/ha.

Increased doses of neutralized phosphogypsum were selected to determine a possible negative environmental effect. The observations were carried out three times.

The introduction of neutralized phosphogypsum was carried out on February 09, 2021 using a UMEGA PI 20 spreader. The reclamation was carried out to a depth of 20 cm for the main tillage using a steam precursor. Sowing of winter wheat was carried out on November 08, 2021. The variety of winter wheat is Adel. The seeding rate is 220 kg/ha. The Amazone DMC 9000 seeder. The tractor is New Holland 5670.

The determination of the quality of winter wheat grain was carried out according to the methods adopted for mass research:

– the mass fraction of the quantity and quality of gluten of winter wheat and winter barley grains according to GOST R 54478–2011;
– protein content in winter wheat and winter barley grains according to GOST 10846–91;
– determination of nitrogen in winter wheat and winter barley grains, sunflower seeds according to GOST 13496.4–2019;
– determination of phosphorus in winter wheat and winter barley grains, sunflower seeds according to GOST 26657–97;
– determination of potassium in winter wheat and winter barley grains, sunflower seeds according to GOST 30304–97;
– determination of calcium in winter wheat and winter barley grains, sunflower seeds according to GOST 26570–95;
– determination of mercury in winter wheat and winter barley grains, sunflower seeds according to GOST 26927–86;
– determination of arsenic in winter wheat and winter barley grains, sunflower seeds according to GOST 26930–86;
– determination of cadmium and lead in winter wheat and winter barley grains, sunflower seeds according to GOST 30178–96;
– determination of strontium by the method of measuring the mass fraction of metals, M-MVI-80–2001 St. Petersburg, 2001, p.8.3.2.2, 9.

3 Results

We have been conducting research on the use of a **fertilizer system** with the inclusion of neutralized phosphogypsum for two years. According to the results of each year of observations, biological accounting of yields was carried out and the quality of agricultural products was determined (Table 1).

Table 1. The effect of neutralized phosphogypsum on biological yield and grain quality of winter wheat

Experience variants / indicators	Yield, t/ha		Yield increase, t/ha		Protein content, %		Increase in protein content, %		Gluten content, %		Increased gluten content, %	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
1. Background N30P52K30 (control)	5,01	4,18	-	-	10,5	10,7	-	-	17,3	16,1	-	-
2. Background N30P52K30 + phospho-gypsum 5 t/ha	5,06	4,48	0,05	0,30	10,9	10,7	0,4	-0,07	16,5	16,6	-0,8	0,47
3. Background N30P52K30 + phospho-gypsum 10 t/ha	5,24	4,49	0,23	0,31	11,5	10,3	1,0	-0,45	17,6	16,0	0,3	-0,13
4. Фон N30P52K30 + фосфогипс 15 т/га.4. Background N30P52K30 + phospho-gypsum 15 t/ha	4,87	4,55	-0,14	0,38	9,5	10,9	-1,0	0,16	15,5	16,1	-1,8	-0,03
5. Background N30P52K30 + phospho-gypsum 20 t/ha	4,51	4,51	-0,49	0,34	11,1	11,0	0,6	0,29	16,1	16,8	-1,2	0,63
The smallest significant difference 05	-	-	0,22	0,25	-	-	0,82	0,48	-	-	1,78	0,71
F05	-	-	3,48	3,48	-	-	3,48	3,48	-	-	3,48	3,48
Ff	-	-	15,46	3,61	-	-	8,56	3,5	-	-	5,41	2,30

To assess the effect of neutralized phosphogypsum on the chemical composition of winter wheat grain, the content of nitrogen, phosphorus, potassium and calcium in the grain was determined (Table 2).

To assess the possible contamination of agricultural products, an analysis of the content of toxicants in grain was carried out (Table 3).

Table 2. The effect of neutralized phosphogypsum on the chemical composition of winter wheat grain

Experience variants / indicators	Content N, %		Content P, %		Content K, %		Content Ca, %	
	2022	2023	2022	2023	2022	2023	2022	2023
1. Background N30P52K30 (control)	1,68	1,89	0,62	0,98	0,68	0,53	0,09	0,06
2. Background N30P52K30 + phosphogypsum 5 t/ha	1,74	1,87	0,43	0,87	0,70	0,53	0,05	0,06
3. Background N30P52K30 + phosphogypsum 10 t/ha	1,84	1,81	0,61	0,93	0,66	0,54	0,04	0,06
4. Background N30P52K30 + phosphogypsum 15 t/ha	1,52	1,91	0,53	0,93	0,69	0,51	0,03	0,05
5. Background N30P52K30 + phosphogypsum 20 t/ha	1,78	1,94	0,43	0,89	0,67	0,55	0,05	0,05
The smallest significant difference 05	0,16	0,08	0,07	0,05	0,018	0,025	0,03	0,009
F05	3,48	3,48	3,48	3,48	3,48	3,48	3,48	3,48
Ff	6,14	3,69	18,58	7,62	7,64	3,72	4,76	3,68

Table 3. The effect of neutralized phosphogypsum on the content of toxicants in winter wheat grain

Experience variants / indicators	Content Pb, mg/kg		Content As, mg/kg		Content Cd, mg/kg		Content Sr, mg/kg	
	2022	2023	2022	2023	2022	2023	2022	2023
1. Background N30P52K30 (control)	< 0,005	0,005	< 0,025	< 0,025	0,04	0,04	1,07	2,13

(*continued*)

Table 3. (*continued*)

Experience variants / indicators	Content Pb, mg/kg		Content As, mg/kg		Content Cd, mg/kg		Content Sr, mg/kg	
	2022	2023	2022	2023	2022	2023	2022	2023
2. Background N30P52K30 + phosphogypsum 5 t/ha	< 0,005	0,006	< 0,025	< 0,025	0,03	0,02	1,55	2,26
3. Background N30P52K30 + phosphogypsum 10 t/ha	< 0,005	0,005	< 0,025	< 0,025	0,04	0,03	1,07	2,92
4. Background N30P52K30 + phosphogypsum 15 t/ha	< 0,005	0,006	< 0,025	< 0,025	0,04	0,03	2,08	2,65
5. Background N30P52K30 + phosphogypsum 20 t/ha	< 0,005	0,005	< 0,025	< 0,025	0,03	0,02	1,33	2,79
Maximum permissible concentration	0,03	0,03	0,2	0,2	0,1	0,1	-	-
The smallest significant difference 05	-	-	-	-	0,02	0,01	0,55	0,37
F05	-	-	-	-	3,48	3,48	3,48	3,48
Ff	-	-	-	-	0,61	0,01	5,77	8,37

4 Discussion

In 2022, the use of a fertilizer system with the inclusion of neutralized phosphogypsum had a positive effect on the yield of winter wheat was achieved in variants with the addition of 5 and 10 t/ha (Table 1). The increase in these variants was 0.05 and 0.23 t/ha, respectively, compared with the control variant.

In 2023, all options demonstrated a positive effect on yields. The increase compared to the control variant ranged from 0.30 to 0.38 t/ha, the result is statistically significant.

In 2022, only the variant with 10 t/ha had a positive effect on the protein content, the difference with the control variant was 1% with the smallest significant difference of 0.82%. In 2023, none of the variants for this indicator showed a significant difference.

None of the variants had a significant effect on the gluten content over 2 years of observation.

We also examined the effect of neutralized phosphogypsum on the chemical composition of winter wheat grain(Table 2). For all elements, the Fisher criterion exceeds the tabular values of the criterion for a 5% significance level.

In 2022, the nitrogen content in grain varied in variants from 1.52 to 1.84%. A statistically significant positive result was shown by the variants, an increase of 0.17%. In 2023, the nitrogen content in grain ranged from 1.81 to 1.94%. There was no significant difference in this indicator.

In terms of the effect on the phosphorus content in winter wheat grain in 2022, all options had a negative impact, although the option with the addition of neutralized phosphogypsum 10 t/ha does not statistically differ from the control. In 2023, in relation to the control, all options showed a negative result, the difference value exceeds the smallest significant difference.

In terms of the effect on potassium content in 2022, a statistically reliable result in relation to the control was shown by the option with the addition of 5 t/ha of neutralized phosphogypsum, where the increase in potassium content was 0.023%. The remaining options did not reveal significant differences from the control. In 2023, the potassium content in the experiment varied from 0.51 to 0.55%. There was no statistically significant difference in relation to the control between the variants.

In 2022, the calcium content in the variants ranged from 0.03 to 0.09%. All variants showed a significant decrease in relation to the control. In 2023, the calcium content in the variants varied from 0.05 to 0.06%. Only the variant with 20 t/ha of neutralized phosphogypsum showed a statistically significant decrease in the content of this element.

For the agroecological assessment of agricultural products, an analysis of toxicants in winter wheat grain was carried out (Table 3). The safety assessment was carried out using standards adopted on the territory of the Russian Federation.

The data for 2022 on the content of lead and arsenic go beyond the scope of the chosen method and are below the values of 0.005 and 0.025 mg/kg, respectively. In 2023, the arsenic content is also below 0.025 mg/kg in all variants, and the lead content is in the range of 0.005–0.006 mg/kg. According to these indicators, the products are completely safe.

The cadmium content for 2 years, according to the variants, ranges from 20 to 40% of the maximum permissible concentration. According to the results of statistical data processing, there were no significant differences between the variants.

According to the content of strontium, statistical processing showed the reliability of the experience. In 2022, only the variant with the addition of 15 t/ha of neutralized phosphogypsum showed a significant difference compared to the control, where the strontium content was higher by 1.01 mg/kg. In 2023, the strontium content increased in all variants relative to 2022. In relation to the control, variants 3, 4 and 5 showed a significant increase.

The maximum permissible concentration of stable phosphorus in soil and plants in the territory of the Russian Federation has not been established. To assess the safety of crop production for this element, it is customary to use the Ca/Sr ratio. Thus, for a dietary diet, a ratio of 140:1 and higher is accepted [13]. Despite a slight increase in this indicator in 2023, all experience options are safe for humans.

5 Conclusion

Thus, the positive effect of the use of a fertilizer system with the inclusion of neutralized phosphogypsum on the productivity of winter wheat was noted by the second year of the study. According to the results of the second year of our research, an increasing reclamation effect was noted.

The maximum positive effect of the calculated dose of 10 t/ha of phosphogypsum neutralized on slightly saline chernozems in an unstable humidification zone has been established according to the research results:

– the increase in winter wheat yield compared to the control in 2022 was 0.23 t/ha, which is 5% higher than the control. In 2023, the increase amounted to 0.31 t/ha, which is 7% higher than the control;
– also, the best quality indicators of winter wheat grain were noted on variants using phosphogypsum neutralized at a calculated dose of 10 t/ha: grain of class 4 with quality indicators exceeding the control variant was obtained;
– according to the results of 2 years of research, the content of toxicants in winter wheat grain did not exceed the maximum permissible concentration, and therefore, from an agroecological point of view, the products are safe.

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Diagnostics of Seeding Qualities of Agricultural Crops Seeds Based on Their Electrical Indicators

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Abstract. The article presents a brief overview of relevant works on the measurement and study of bioelectric signals of plant organisms. The methodology and research methods proposed by authors from different countries are explored. Based on the literature studied, a technique for measuring electrical signals of plant organisms is proposed by piercing the shells of various seeds of agricultural crops. Our experiment measures the potential difference between the surface of the seed and the base of the seedling. The results obtained do not allow us to analyze changes in the biopotential of individual cells, but show the general physiological state of the object under study. The development and creation of measuring equipment for studying the biopotentials of plant tissue enable to diagnose seed germination using the express method, both before sowing and when determining the rational regime for treating seeds with physical and chemical factors. Additionally, this technique provides monitoring of the plant organism at various stages of ontogenesis. The results may be the basis for a model of optimal growth and development of plants in various conditions. Further experiments need to be conducted in several types of environments and at different times of the year to identify optimal performance when treated with chemical, biological and physical factors.

Keywords: biopotential · cell membrane · potential difference · physiological state · germination energy · germination

1 Introduction

In recent years, the study of bioelectric potentials in plants and swelling or germinating seeds has acquired great practical importance. Scientists from various countries are discussing the possibility of using data on their nature and changes under the influence of stimuli to determine by express method: seed germination, injury, stunting, plant infestation with fungal and viral diseases, to assess the frost and heat resistance of plants, viability and productivity, as well as to determine rational regimes for treating seeds with electrophysical factors in order to increase sowing qualities, reduce the time to emerge from dormancy, and suppress pathogenic mycoflora.

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The electrical signals of plants are less studied than the signals of animal cells and tissues. But the fact that a bioaction potential arises when a plant is irritated indicates that the nature of electrogenesis in plants and seeds is, in all likelihood, the same as in the cells of an animal organism. Along with this, an analysis of literary sources shows that the response of plant tissue to a stimulus differs from the behavior of animal tissue, primarily in the period of distribution of biopotential.

There are known copyright certificates and patents for inventions on devices and methods for measuring the bioelectric potentials of plants in laboratory and field conditions. The results presented are numerous and contradictory. There are numerous copyright certificates and patents, but the mechanisms of transient changes in membrane potential and their ionic basis remain unclear [21–24] .

Many scientists have worked and are working on the study of the biopotentials of plant tissue [1–4, 2, 7–13]. Numerous experiments carried out in the study of cell membranes have shown that the membrane of plant cells, like the membrane of an animal cell, is polarized. Polarization is due to the different ability of the membrane to transmit potassium, sodium ions and other chemical elements. Just like the membrane of animal cells, a plant cell is negatively charged on its inner surface, and positively charged on its outer surface, and this determines the ability of permeability.

In response to the action of a variety of stimuli (heating, cooling, illumination, mechanical action, electric current, chemical reagents, and so on), depolarization of the membrane occurs, accompanied by the generation of propagating oscillations of electrical potentials. However, the speed of propagation through plant tissue is significantly lower than the speed of propagation of the excitation wave in the nerve fibers of animal tissues and is usually measured at several centimeters per minute [10, 11].

The results of literature and patent searches showed increasing interest in studying the biopotentials of plant tissues.

A large number of works have been devoted to studying the effect of the environment on the biopotentials of cell membranes. The bioelectrical activity of plants to a light stimulus has been studied in detail. It has been established that the transition of illumination from dark to light leads to hyperpolarization of the cell membrane, and when light changes to darkness, the cell membrane is depolarized, which changes the principle of operation of potassium channels; they become inactive.

V.L. Uspenskaya claims that the magnitude of the potential difference depends to the same extent on the light intensity as the intensity of the photosynthesis process depends on it [10, 11].

S.V. Kacheishvili, N.V. Ksenz made an attempt to connect the sowing qualities, germination energy and germination of seeds, the dependence of the rate of specific water absorption by seeds, the magnitude of the membrane potential when an electric field acts on the seeds [7].

Barysheva N.N. proposed a methodology for diagnosing the sowing qualities of seeds, germination, as well as the presence of injured, hollow and infected wheat seeds by changing the membrane potential when moistened seeds are exposed to a mechanical stimulus and electric current [1].

T. Gun-Aazhav and others used new biophysical methods to assess the physiological states and developmental characteristics of plant organisms to determine heat and frost resistance and carbon dioxide content in wheat seeds [9].

A.V. Dubrovin, Yu.Kh. Shagen considered a method for economically optimal growing of plants in protected soil with additional electrical influence of a deterministic level on their biological and electrical potential along the plant stem.

According to N.G. Kholodny and F. Venta, the electrical potentials of plants are closely related to growth processes [11].

D. L. Rubinstein, having once proposed a classification of bioelectric potentials, identified a special group of potentials, which he called metabolic. By metabolic potentials, he understood the potential difference that arises between sections of plant or seed tissue with different levels of metabolic processes [11].

These data suggest the role of electrical potentials in plants.

A change in biopotential, an electrical signal that occurs on a membrane cell, causes physiological changes in plants (for example, respiration, water absorption, decreased turgor, and so on) [14–17]. It is very likely that, as in an animal organism, electrical potentials in plants are not just a "by-product" of ongoing biochemical and physico-chemical processes, but also carry out a functional connection between different parts of the plant, and can even act as a regulator of metabolic processes [11].

In our opinion, metabolic biopotential can be used to monitor the physiological state of both individual parts of the plant and the plant as a whole. Despite the significance of the research conducted by various scientists, some aspects of this problem have not been sufficiently studied.

As far as we know, the influence of a pulsed electric field on the bioelectrical activity of seeds and plants has not been studied, so these studies are currently relevant.

The development and transformation into production of new technologies, taking into account advanced digital systems and breeding innovations, both for diagnosing and improving the sowing qualities of agricultural seeds, is necessary. This is primarily due to the growing demand for organic products and the acute shortage of quality seeds of our own production.

Therefore, the research, development and application of new biophysical methods for assessing the physiological state, growth characteristics, and development of plant organisms is relevant.

Goal of the work - study of the electrical properties of plant objects.

2 Materials and Methods

During the experiment, a destructive method was used to measure biopotentials caused by depolarization-repolarization processes in a group of cells and to monitor the whole plant. The electrical signal was measured in germinating seeds. It is known that seeds of different crops sprout at different times. The seeds of sunflower, barley, peas and potatoes were chosen for the experiment. During the experiment, the results of measuring the electrical parameters of seeds were compared with the readings obtained using standard methods for determining the sowing qualities of seeds described in state standard No. 52325-2005 (RU).

Previously, potato seeds were treated with a pulsed electric field in various modes. This procedure was carried out to study the influence of various pulsed field modes on the electrical potential of seeds. The method for measuring biopotentials to determine rational treatment modes with a pulsed electric field is as follows: samples of seeds of the crop under study are taken from the general batch according to state standard No. 12036-85 (RU), in accordance with the number of planned experimental options. The parameters of the pulsed electric field for processing botanical potato seeds are presented in Table 1.

Table 1. Pulsed electric field parameters for processing botanical potato seeds

Tension, V/m	Pulse duration, mks	Pulse frequency, Hz	Time of processing, min	Exposure time, day
$1–5*10^5$, in increments $1*10^5$	150	20	60	1

After treating the seeds with a pulsed electric field, the seeds were placed in prepared Petri dishes on a moistened bed, 50 pieces each. Cups with seeds are placed in a thermostat for germination at temperatures corresponding to state standard No. 52325-2005 (RU).

The sprout of potato seeds appears 5–6 days after the start of germination. Next, seeds with seedlings from the batch under study are removed from the thermostat to measure their biopotentials. Control Petri dishes for studying seeding qualities according to the state standard remain in the thermostat.

When working with potato seeds that are small in size and have a small sprout, we additionally used a stand with X10 magnification and built-in lighting for precise puncture of the sprout. The seeds are placed on a bed electrode and pierced at the base of the seedling with a needle electrode. The entire installation is covered with a Faraday cage for the purity of the experiment; the seeds have an electrical value from 5 to 50 mV. When measuring a seed with a sprout, the maximum peak value of the biopotential is measured, since the indicators of the seeds vary, we take the average value of the biopotentials of 10 seeds. In batches where the number of sprouted seeds does not exceed 60% on days 5–6 after the start of the experiment, germination continues for another 3 days with this fact recorded in the test report.

Figure 1 shows a block diagram of a device for measuring the biopotentials of plant tissues.

1 – mechanism for fixing the change, 2 – common wire of the circuit, 3 – seed with sprout, 4 – first electrode-needle, 5 – second electrode-needle, 6 – electrode-bed, 7 – amplifier block, 8 – signal level matching block, 9 – microcontroller, 10 – liquid crystal screen, 11 – personal computer, 12 – power supply, 13 – power supply.

Two types of measurements can be carried out on the proposed device, due to the fact that the clamps of the mechanism are connected to the electrode-bed (6), which in turn is connected to the common wire (2) of the device. The common wire of the device

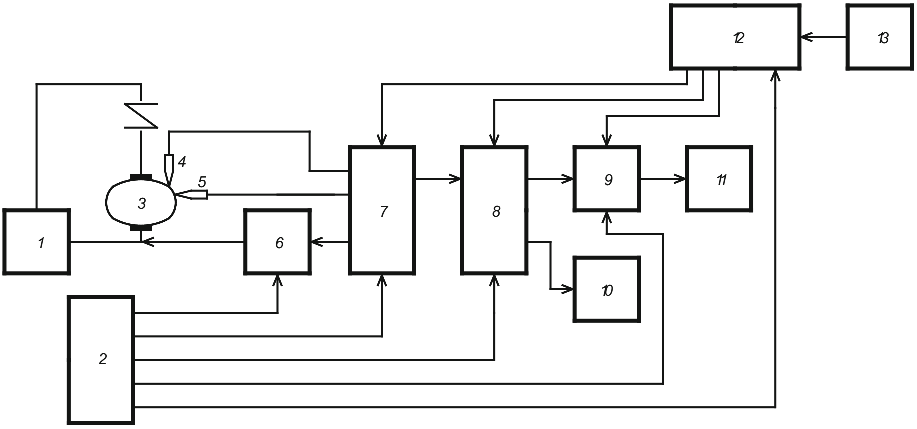


Fig. 1. Block diagram of a device for measuring biopotentials in germinating seeds and vegetative plants

(ground, body wire) is the point whose potential is taken to be zero. All other potentials and voltages are measured relative to this potential, that is, the common wire.

The seed is fixed motionless using the fixation mechanism (1). When measuring the biopotentials of vegetative plants, needle electrodes 4 and 5 pierce the plant at the required points, and the needle electrode (5) is connected by a conductor to the electrode bed. The device is equipped with removable non-oxidizing needles of various diameters for piercing seedlings and plants of different crops, with different depths of penetration into the tissue, thanks to the presence of limiters on the needles. The needle electrode is free, but the clamp has a replaceable holder for taking electrical characteristics between the bed electrode (6) and any point of the seed with the sprout (3). A replaceable conductor is made to the needle electrode (5), as well as to the needle electrode (4). In both cases, the signal passes through the matching block (8) and then goes to the amplifier block (7) with a gain factor k = 8, after the amplifier block the signal goes to the ADC of the microcontroller, the image is transmitted to the liquid crystal screen (10) and is duplicated on a personal computer (11). Power supply (9V) is provided through the power supply (12) and is connected to the mains supply (13).

The device, developed in 2022, works as follows: on an electrode made of non-oxidizing material, which is located on a dielectric base, a seed with a sprout is located, which is clamped using a dielectric plate, then a needle electrode (mechanical stimulus) pierces the seed sprout at the base for a certain depth adjusted by notches on the needle. The biopotential value taken from the electrodes is fed to a signal amplifier with a high input resistance (200 MΩ) and gain (k = 8), since plant cell membranes have a high resistivity - about 50,000 Ohm cm. After amplification, the signal is transmitted to the microcontroller, then to the analog-to-digital converter, and then to the recorder or oscilloscope on the display, from which we can observe the electrical signal. Laboratory experiments to determine the sowing qualities of seeds were carried out in the traditional way according to state standard No. 52325-2005 (RU) and using the method using the values of the biopotentials of germinating seeds.

The applied method for measuring biopotentials in plant tissue includes several main stages:

Stage I: seed selection using well-known methods described in state standards. Placing seeds in Petri dishes, following the methods described in state standards.

Stage II: measurement of biopotentials.

Stage III: analysis of the results obtained and comparison with laboratory experiments.

A block diagram of connecting a seed to a device for collecting an electrical signal from a plant is shown in Fig. 2.

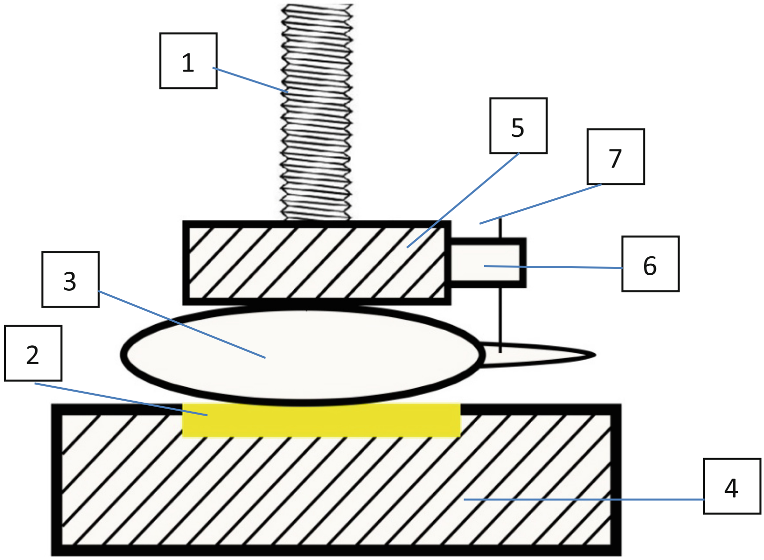


Fig. 2. Block diagram of a device for fixing seeds when measuring biopotentials of germinating seeds.

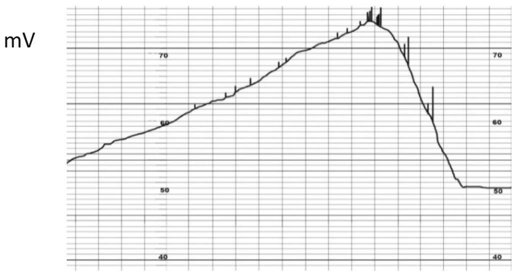
1-threaded regulator; 2 – non-oxidizing electrode bed; 3 – seed with sprout; 4 – dielectric platform; 5 – movable dielectric block; 6 – needle electrode holder; 7 – needle electrode.

When measuring the biopotentials of the seed, a device was used containing: a threaded fixation regulator to control the pressure on the seed (1), a pressure dielectric plate (5), a non-oxidizing bed electrode (2) located on a dielectric base (4), a non-oxidizing needle electrode (7).

3 Findings

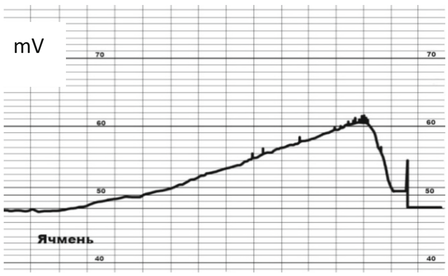
In an experimental laboratory measurement setup, the metabolic biopotentials of various crops were determined: sunflower seeds of the Peredovik variety, pea seeds of the Truzhenik variety and spring barley seeds of the Bogatyr variety. The results were recorded on a recorder.

The results obtained led to the conclusion that the electrical parameters of seeds depend on the crop. The results are presented in Figs. 3, 4, 5.



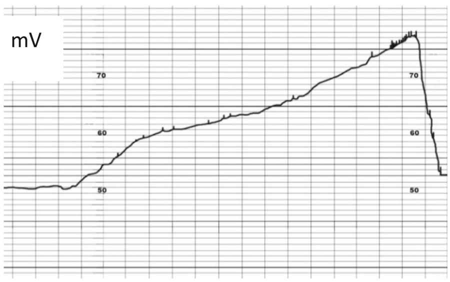
Maximum change in metabolic potential from resting potential – 24 mV

Fig. 3. Indicators of the metabolic potential of sunflower seeds of the Stepnoy variety



Maximum change in metabolic potential from resting potential – 11 mV

Fig. 4. Indicators of metabolic potential of spring barley seed variety Perelom



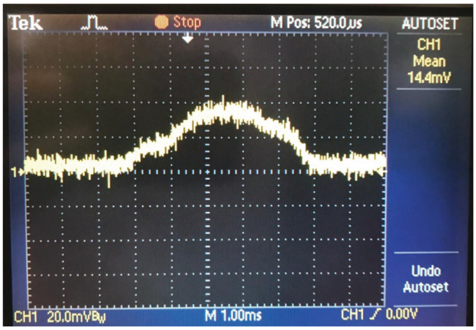
Maximum change in metabolic potential from resting potential – 26 mV

Fig. 5. Indicators of metabolic potential of pea seed variety Truzhenik

After experiments on measuring biopotentials carried out on an experimental installation, with registration on a recorder, we found that different cultures have different maximum changes in metabolic potential from the resting potential.

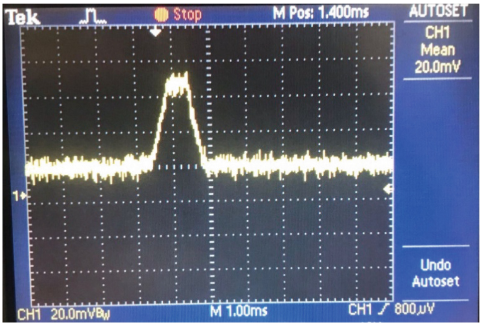
In subsequent experiments, we decided to use an oscilloscope as a recording device. Botanical potato seeds pre-treated with a pulsed electric field were chosen as the object of research (Figs 6, 7, 8, 9, 10 and 11).

Table 2 shows the dependence of the sowing qualities and biopotentials of potato seeds on the IEP intensity on the 28th day after sowing according to state standard No. 52325-2005 (RU) and on the 6th day according to the determination of biopotentials.



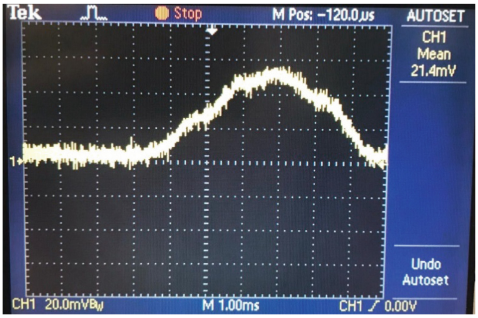
The maximum change in metabolic potential from the resting potential is 14.4 mV, control.

Fig. 6. Electroplantagram of the metabolic potential of potato seed of the Ballada variety, control variant.



The maximum change in metabolic potential from the resting potential is 20.0 mV, at a voltage of $1*10^5$ V/m.

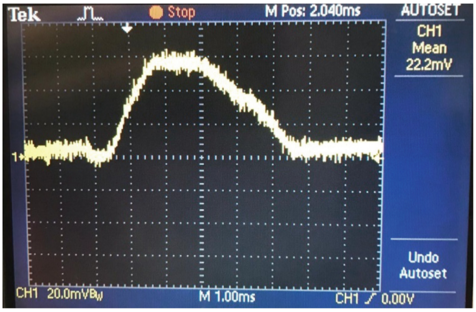
Fig. 7. – Electroplantagram of the metabolic potential of potato seed of the Ballada variety treated with tension $1*10^5$ V/m.



The maximum change in metabolic potential from the resting potential is 21,4 mV, at a voltage of $2*10^5$ V/m.

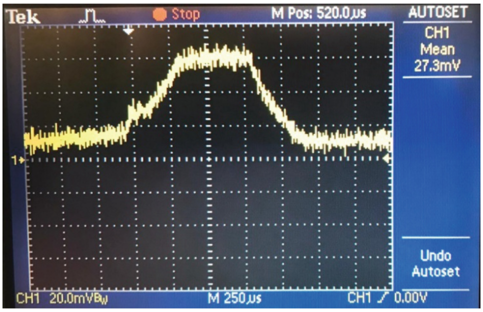
Fig. 8. Electroplantagram of the metabolic potential of potato seed of the Ballada variety treated with tension $2*10^5$ V/m.

From the data presented in the table it can be seen that the maximum increase in sowing qualities, germination energy and germination was observed when seeds were treated with IEP with a tension of 4 * 105 V/m. The germination energy is 16.0%, germination is 25.5% higher than that of the seeds of the control untreated variant and



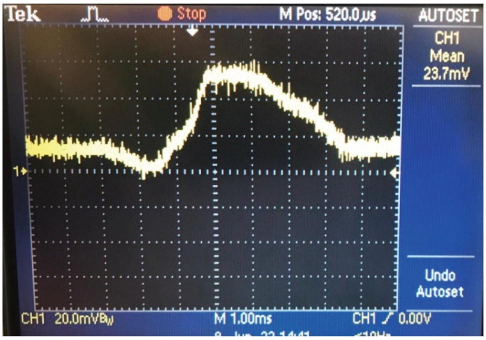
The maximum change in metabolic potential from the resting potential is 22,2 mV, at a voltage of 3*10^5 V/m.

Fig. 9. Electroplantagram of the metabolic potential of potato seed of the Ballada variety treated with tension 3*10^5 V/m.



The maximum change in metabolic potential from the resting potential is 27,3 mV, at a voltage of 4*10^5 V/m.

Fig. 10. Electroplantagram of the metabolic potential of potato seed of the Ballada variety treated with tension 4*10^5 V/m.



The maximum change in metabolic potential from the resting potential is 23,7 mV, at a voltage of 5*10^5 V/m.

Fig. 11. Electroplantagram of the metabolic potential of potato seed of the Ballada variety treated with tension 5*10^5 V/m.

the maximum change in metabolic potential from the resting potential in this variant is 12.9 mV higher than that of the control variant. These data confirm that the values of changes in biopotentials correlate with the values of sowing qualities according to state standard No. 52325-2005 (RU).

Table 2. Dependence of the sowing qualities of potato seeds on the intensity of the pulsed electric field

Option	Tension	Germination energy	Germination	Relationship of experiences	Biopotentials
	V/m	%	%	%	mV
Control	0	42,1	49,7	100,0	14,4
1	$1*10^5$	45,7	65,2	131,1	20,0
2	$2*10^5$	41,9	66,0	132,7	21,4
3	$3*10^5$	52,3	72,1	145,0	22,2
4	$4*10^5$	58,1	75,2	151,3	27,3
5	$5*10^5$	59,2	70,5	141,8	23,7

4 Conclusions

Since during plant growth, biopotentials can change due to insufficient light, humidity, lack of potassium and other nutrients, causing changes in the physiological state of the plant, which can be used to automatically control and regulate these parameters in greenhouses.

The results obtained led to the conclusion that the values of electrical indicators depend on the culture. Different crops have different metabolic potentials. It was experimentally revealed that the biopotential of sunflower seedlings is 24 mV (Fig. 3); in barley - 10 mV (Fig. 4); in peas – 28 mV (Fig. 5). Different crops have different metabolic potentials.

Also, experiments conducted with botanical potato seeds led to the conclusion that the value of biopotential affects sowing qualities. At the same time, the study revealed that a pulsed electric field affects the electrical parameters of seeds. Knowing the value of the biopotential, you can select the optimal mode of the pulsed electric field, which will be most favorable for a particular crop.

For complete confirmation, it is necessary to conduct a large number of experiments in order to identify the most rational degree of processing and optimal conditions for growing certain agricultural plants.

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Safety of Food Products of Animal Origin After the Use of Benzimidazole Drugs

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Abstract. Obtaining raw materials and products of high quality animal origin is an urgent and strategic task that ensures the food security. However, animals on farms are often susceptible to various diseases, including invasive ones, which are treated by various drugs of benzimidazole group. The purpose of the study was to study the effectiveness of the drug Rikazohit and the nutritional value of animal meat after treatment. Based on the study of the effectiveness of Rikazohit, we found that subcutaneous administration of the drug in a dose of 1 ml per 25 kg provided 100% extensive and intensive effectiveness against nematodes of the gastrointestinal tract common in the Stavropol region of Russia. The study of organoleptic quality assessment of raw meat, smoked and boiled lamb products was carried out in accordance with the requirements of GOST 9959-91 "Meat products. General conditions for conducting organoleptic assessment." The chemical indicators of sheep meat dewormed with Rikazohite are higher than meat of infested animals. According to the veterinary and sanitary characteristics obtained during the study, the meat of sheep dewormed with ricobendazole is characterized as a benign, highly nutritious product that can be released for free sale without restrictions.

Keywords: sheep farming · benzimidazole · chemical analysis · organoleptics · safety

1 Introduction

One of the important tasks of restoring sheep farming in Russia is to protect animals from parasitic diseases. Economic damage from mixed forms of parasitic diseases of sheep is expressed in the death of young animals, a decrease in growth and development rates, a decrease in weight gain, and a deterioration in product quality [2, 4].

Determining the quality of food products and human nutrition issues affect a complex of aspects related to economics, politics, social sphere, environment and the development of the agro-industrial complex. When producing food products, the issue of human health, on which the quality of life and well-being depends, should come first [1].

The concept of state policy in the field of healthy nutrition of the Russian population provides for a significant expansion of domestic food production and ensuring their safety. That is why the veterinary and sanitary assessment of products obtained by using new pharmacological drugs and their combinations in the treatment of animals and poultry is an urgent task of veterinary and sanitary examination [3].

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2 Materials and Methods

A study of the effectiveness of the drug "Rikazohit" was carried out on the basis of the Toloknevo Clinical Clinical Complex, Grachevsky District, Stavropol Territory. For this purpose, 20 sheep spontaneously infested with gastrointestinal nematodes, M. expansa and D. lanceatum, were selected using double helminth oovoscopy. The animals are 1.5 years old. The selected sheep were marked with individual numbers and divided into 2 groups ($n = 10$).

The animals were individually injected subcutaneously with the drug "Rikazohit" at a dose of 1 ml per 25 kg of animal weight. Sheep in the control group were not administered the drug.

The study of organoleptic assessment of the quality of raw meat and smoked and boiled lamb products was carried out in accordance with the requirements of GOST 9959-91 "Meat products. General conditions for conducting organoleptic assessment." The mass fraction of moisture (%) was determined by drying the samples at a temperature of 150 °C to constant weight. The mass fraction of moisture (%) of adipose tissue was determined by drying samples at a temperature of 103 ± 2 °C to constant weight. The mass fraction of intramuscular fat (%) was determined by the Soxhlet method (GOST 23042–86 "Meat and meat products. Method for determination of fat"). The mass fraction of protein (%) was determined by the Kjeldahl method. The mass fraction of ash (%) was determined by burning a sample of meat in a muffle furnace at 550 °C. The energy value was calculated using a formula based on the actual protein and fat content in meat (due to their low content in meat, carbohydrates were not taken into account).

$E = Bx4.0 + Zx9.0(1)$,

where E is the energy value of meat, kcal/100 g of product;

B - mass fraction of protein, g/100 g of meat;

F - mass fraction of fat, g/100 g of meat.

The fatty acid composition of internal fat was carried out on a chromatograph using gas-liquid chromatography. Determination of the number of mesophilic aerobic and facultative anaerobic microorganisms - according to GOST 10444.15 - 94 "Food products. Methods for determining the number of mesophilic aerobic and facultative anaerobic microorganisms." Determination of the number of coli bacteria - according to GOST R 52816-2007 "Food products. Methods for identifying and determining the number of coliform bacteria (coliform bacteria)." The vitamin composition of the samples was determined by chromatographic and fluorimetric methods.Moisture-binding capacity - % of tightly bound moisture to total moisture was determined according to the method of R. Grau and R. Hamm, modified by V.M. Volovinskaya and Kelman. The pH value was determined by the potentiometric method using a portable meter "Zamer-1". Statistical processing of the obtained data and plotting of graphs were carried out using the Microsoft Excel computer program. The significance of the statistical difference between the average values was determined using the Student's method.

3 Results

After introduction drug Rikazohitin all tested doses, the general condition and behavior of the animals did not change; no signs of intoxication were observed.

Days after using the drug, 3 animals, typical for their groups, were selected from each group for control slaughter.

For a detailed assessment of the quality of sheep meat, a study of the chemical composition of meat was carried out (Table 1).

Table 1. Chemical analysis of sheep meat

Index	Group	
	rikazohite	control
Chemical composition of meat		
Total moisture, %	61.07	62.99
Raw ash, %	0.92	0.88
Crude protein, %	22.94	21.83
Crude fat, %	15.07	14.30
Calorie content of meat, kcal	2270.4	2173.5

The Table 1 indicate that the meat of control animals contains slightly more moisture, and those dewormed with ricobendazole have more fat and protein. The calorie content of meat from dewormed sheep was 4.5% higher compared to crossbred peers.

The study of the organoleptic evaluation of meat broth was carried out in accordance with the requirements of GOST 9959-91 [GOST 9959-91 "Meat products. General conditions for conducting organoleptic assessment"].

It is known that during heat treatment of meat (cooking), so-called extractive substances pass into the broth, which give it a certain taste and aroma, which accordingly increases its attractiveness to the consumer. As a result, it is also advisable to carry out an organoleptic assessment of the quality indicators of the meat broth obtained by cooking the meat of the studied groups of animals

To determine the transparency and aroma of the broth, about 70 g were cut out. Muscles and chopped. Weighed 20 gr. placed in a conical flask with a capacity of 100 ml., poured 60 ml. Distilled water, covered with glass and left for 10 min. to a water bath. The aroma of the meat broth was determined during heating to a temperature of 80–85 °C. The degree of transparency was determined visually by examining 20 ml. Broth poured into a 25 ml measuring cylinder with a diameter of 20 mm.

When the meat was cooked, the broth in both groups was clear and aromatic. The taste of fat and broth in both groups corresponded to the indicators of a benign product. There were no foreign odors.

Meat in general is known to be a source of B vitamins.

Vitamins enter the human body primarily through food or are synthesized by bacteria living in the intestines. The main vitamins, the source of which is meat, are found in muscle tissue. These are B vitamins - thiamine (B1), riboflavin (B2), choline (B4), etc. The results of studies of the vitamin composition of meat are presented in Table 2.

Table 2. Content of B vitamins in meat

Group	Vitamins, mg/100 g				
	IN 1 thiamine	AT 6 riboflavin	AT 4 choline	AT 5 pantothenic acid	AT 9 folic acid
control	0.15	0.47	56.23	8.41	17.57
experienced	0.21	0.49	58.59	8.59	15.81

Analyzing the data obtained, we can conclude that dewormed animals are superior in vitamin content to infested ones, with the exception of folic acid, the amount of which in the meat of control animals is 1.26–1.84 mg less than in the meat of experimental animals. Vitamin B1 (thiamine) ensures the absorption of carbohydrates, the content of which in the meat of experimental animals is up to 0.21 mg. Thiamine functions in the body as an essential coenzyme, or assistant, in the metabolism of proteins, carbohydrates and fats to produce energy. This vitamin is also necessary to copy the genetic material that must be passed from one cell to another during cell division. Finally, thiamine is essential for normal transmission of electrical nerve signals. A lack of this vitamin in the human body leads to loss of appetite, fatigue and vitamin deficiency. The daily requirement of thiamine is 0.10–0.12 mg, which is fully satisfied by the consumption of 100 g of meat of the studied animals per day.

Meat and meat products as sources of vitamin B2 (riboflavin) for humans occupy third place after dairy and grain products. The daily requirement for riboflavin is 1.5–2.5 mg, which most fully satisfies the consumption of meat from dewormed animals. Vitamin B2 intensifies metabolic processes in the body, participating in the metabolism of proteins, fats and carbohydrates. Riboflavin is necessary for the formation of red blood cells and antibodies, cell respiration and growth. It facilitates the absorption of oxygen by skin, nail and hair cells.

It improves the condition of the visual organ, taking part, along with vitamin A, in the processes of dark adaptation, reduces eye fatigue and plays an important role in the prevention of cataracts. Vitamin B2 has a positive effect on the mucous membranes of the digestive tract.

Riboflavin minimizes the negative effects of various toxins on the respiratory tract. Riboflavin is necessary for the metabolism of tryptophan, which is converted into niacin in the body.

One of the most valuable qualities of riboflavin is its ability to accelerate the conversion of pyridoxine - vitamin B6 - into its active form in the body.

Vitamin B4 (choline) is a structural part for the structure of other important substances such as lipoproteins, phospholipids, acetylcholine. Takes an active part in cholesterol metabolism, providing an anti-sclerotic effect, participates in the production of acetylcholine, which is necessary for the normal functioning of the entire nervous system and prevents diseases of the nervous system. The daily requirement of the human body for choline is 0.5 g, the most complete satisfaction of which is achieved by eating the animal meat under study.

Vitamin B5 (pantothenic acid), entering the body, is converted into pantethine, which is part of coenzyme A, which plays an important role in the processes of oxidation and acetylation. Pantothenic acid is required for the metabolism of fats, carbohydrates, amino acids, the synthesis of vital fatty acids, cholesterol, histamine, acetylcholine, and hemoglobin. The daily requirement is 5–10 mg, which can be satisfied by consuming 100g of the lamb under study, since the content of this vitamin in sheep meat ranges from 8.41–8.59 mg/100g.

Vitamin B9 (folic acid) is a water-soluble vitamin necessary for the growth and development of the circulatory and immune systems. The daily requirement of the human body for this vitamin is 0.2 g, which is fully covered by eating 100 g of the meat under study.

Thus, the studies of sheep pulp tissues confirmed the positive effect of animal deworming on the formation of the biological value of meat.

The changes that occur in meat after poultry slaughter are characterized by different intensities of autolytic processes, which subsequently determine the quality of the meat. To assess it, mainly physicochemical and microbiological research methods are used.

Muscle samples from carcasses and internal organs of sheep in the experimental and control groups were subjected to physicochemical analysis. The control consisted of samples of meat and offal from carcasses of clinically healthy sheep, selected according to the principle of analogues from the same flock. At the same time, in a comparative aspect, pH, water-binding capacity, reaction with a 5% solution of copper sulfate, reaction to peroxidase, content of volatile fatty acids and amino-ammonia nitrogen, acid and peroxide numbers of fat were determined. Additionally, the ammonia content in the Nessler reaction was determined. The results of the study are presented in Table 3.

Table 3. Physico-chemical parameters of sheep meat

No p/p	Physico-chemical indicators of meat	Group of animals	
		Control	Experienced
1	pH value		
	12 h	5.84 ± 0.08	5.83 ± 0.04
	24 h	5.89 ± 0.07	5.85 ± 0.06
2	Reaction with 5% CuSO4	–	–
3	Peroxidase reaction	+	+
4	AAA, mg%	1.05 ± 0.03	0.99 ± 0.07
5	VFA mg/CON	52.25 ± 0.18	52.17 ± 0.51
6	Water binding capacity	50.42 ± 0.32	52.13 ± 0.37
7	Acid number of fat	1.24 ± 0.05	1.21 ± 0.04
8	Peroxide value of fat	0.01 ± 0.001	0.01 ± 0.002

One of the important indicators that determine the stability of meat in relation to the impact and development of putrefactive microflora, shelf life and processing technology is the pH value. In the meat of animals of both groups during 12 h of meat ripening, this indicator did not have significant differences. Similar studies of meat, carried out after 24 h, showed naturally changing values compared to the previous period of meat ripening, both in sheep of the control and in the experimental group of animals. From the data in Table 3 it is clear that the pH of meat 24 h after slaughter of sheep dewormed with rikazohite was 5.85, and the pH of meat of control animals was 5.89, that is, 0.04 units lower, which indicates normal intensity ripening of meat.

The water-binding capacity of meat depends on the concentration of hydrogen ions in muscle tissue, which, according to the results of the study in the muscle tissue of turkeys of both groups, was at the level of standard values.

More intense processes of muscle tissue protein breakdown are characterized by the accumulation of ammonia and amino acids, the level of which was determined by the amount of amino-ammonia nitrogen. In the meat of sheep from the experimental group, this indicator was at the level of control values, within the limits of fresh meat. The amount of aminoammonia nitrogen in the muscles of dewormed and healthy animals during storage was 52.25–52.17 mg/KOH, respectively.

Autolytic processes occurring in muscle tissue contribute to the proteolytic transformation of proteins, leading to an increase in the tenderness of meat and the accumulation of primary products of its breakdown - peptones and polypeptides, the concentration of which should not exceed the maximum permissible standards for fresh meat. Control of these substances was carried out using a reaction with a 5% solution of copper sulfate. At the same time, in the compared groups, the broth, when adding the appropriate reagent, remained transparent without the presence of flaky sediment, which corresponds to fresh meat. The reaction indicators of meat extract with 5% copper sulfate and to peroxidase had no visible differences and remained within normal limits.

Studying the state of adipose tissue, which, like muscle tissue, undergoes changes in the post-slaughter period of poultry, is of no small importance for characterizing the freshness of meat. Thus, the acid number of fat, which changes during its hydrolysis, did not have significant differences in the compared groups. As a result of fat hydrolysis, polyunsaturated fatty acids are easily oxidized when exposed to air, forming peroxides, which can be determined using a chemical method based on the peroxide value. Studies of internal fat in terms of the amount of peroxide value in a group of experimental animals indicated insignificant differences in comparison with samples obtained from healthy sheep.

There were no significant differences in the content of volatile fatty acids in the meat of animals of both groups.

Physico-chemical parameters of tissues of internal organs (offal) were also determined in sheep killed 30 days after deworming and control healthy animals (Table 4).

Table 4. Physico-chemical indicators of sheep by-products

No p/p	Physico-chemical indicators of meat	Group of animals	
		Control	Experienced
1	heart		
1.1	pH	5.79 ± 0.03	5.81 ± 0.05
1.2	AAA, mg%	0.95 ± 0.03	0.98 ± 0.02
1.3	VFA mg/CON	52.25 ± 0.18	52.17 ± 0.51
2	liver		
2.1	pH	5.86 ± 0.06	5.85 ± 0.03
2.2	AAA, mg%	1.15 ± 0.08	1.18 ± 0.06
2.3	VFA mg/CON	53.15 ± 0.18	51.27 ± 0.32
3	lungs		
3.1	pH	5.64 ± 0.08	5.63 ± 0.06
3.2	AAA, mg%	1.11 ± 0.03	1.12 ± 0.07
3.3	VFA mg/CON	46.15 ± 0.08	45.12 ± 0.54
4	kidneys		
4.1	pH	5.81 ± 0.09	5.80 ± 0.07
4.2	AAA, mg%	1.15 ± 0.06	0.99 ± 0.05
4.3	VFA mg/CON	52.15 ± 0.28	52.17 ± 0.31

From the data presented in Table 4, it is clear that the physicochemical parameters of sheep by-products of the compared groups do not have significant differences in pH, aminoammonium nitrogen and volatile fatty acids. The reaction indicators of meat extract with 5% copper sulfate and to peroxidase had no visible differences and remained within normal limits.

The data we obtained allows us to conclude that the meat and offal of sheep dewormed with the drug Rikazohit do not differ in physical and chemical properties from the meat and offal of healthy animals.

The biological safety of meat is determined, first of all, by the level of contamination with various microorganisms, including pathogenic pathogens for humans.

A comprehensive microbiological study made it possible to establish that in the muscle tissue of chickens the amount of mesophilic aerobic and facultative anaerobic microflora (CMAFanM) and the presence or absence of coliform bacteria did not show significant differences (Table 5).

In the studied samples of all experimental groups, no opportunistic and pathogenic microflora were found. The results obtained indicate the absence of disturbances in autolytic and oxidative processes in the muscle tissue of sheep of the experimental groups.

Table 5. Results of microbiological studies of muscles and internal organs of sheep

Group	Try	KMAFAiM CFU/g	coliform
Control	muscles	0.4 × 102	0
	liver	1.1 × 102	0
	heart	0.2 × 102	0
	lungs	0.7 × 102	0
	kidneys	0.3 × 102	0
Experienced	muscles	0.5 × 102	0
	liver	1.0 × 102	0
	heart	0.1 × 102	0
	lungs	0.8 × 102	0
	kidneys	0.4 × 102	0

4 Conclusion

1. The chemical indicators of meat from sheep dewormed with rikazohite are higher than those of infested animals. In the average sample of meat from experimental animals, in contrast to meat from control animals, there is more protein, fat, and less moisture. In terms of physicochemical properties and biological safety, the meat of sheep dewormed with rikazohite does not differ from the meat of healthy animals.
2. According to veterinary and sanitary characteristics, meat from sheep dewormed with ricobendazole is characterized as a benign, highly nutritious product that can be released for free sale without restrictions.

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Systematization and Assessment of the Settlement Network and Settlement System of Rural Territories of the Subjects if the North Caucasus Federal District

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Abstract. The North Caucasus Federal District unites seven federal subjects with extremely differentiated potential and territorial and economic systems. 5.5% of Russia's agricultural land is located here, 13.7% of the country's rural population lives, 15.1% of those employed in the agricultural sector work, and 9.6% of agro-industrial enterprises are concentrated. The contribution to the total gross output is 8.2%, the net financial result is over 4.1% of the national total. 8.2% of cereals and legumes, 15.6% of vegetables, 27.6% of fruits and berries, 6.1% of livestock and poultry meat, 8.9% of milk and 48.6% of wool are produced in the district. The rural population makes up half of the inhabitants of the North Caucasus Federal District - these are residents of rural areas. At the same time, in the subjects there is a lag in key indicators from the national average in terms of key indicators of economic activity, low returns on the use of existing potential, subsidized budgets and uneven development of its subjects themselves. Most of the subjects of the district are in a state of stable unstable socio-economic development and do not have the ability to independently exit it. The increasing importance of the agricultural sector in the functioning of territorial production systems and processes requires an assessment of the potential of rural areas and an analysis of its socio-economic efficiency. It is precisely this systematization and assessment of the settlement network and the settlement system of rural territories of the subjects of the district that is the purpose of the study, during which the main integral socio-economic indicators were analyzed. The results obtained are of great importance for the development and implementation of effective socio-economic strategies for the development of the region, taking into account the identified features, which will contribute to the development and strengthening of economic and social stability in the North Caucasus Federal District as a whole.

Keywords: municipalities · sustainable development · settlement · rural areas · settlement network · agriculture

1 Introduction

The dynamic socio-economic development of rural areas of the North Caucasus Federal District largely depends on the agricultural and industrial complex, which ensures economic development, food self-sufficiency and social well-being of the territory and the

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population. The current economic state of agricultural activity is due to the presence of both potential conditions: historical, cultural, demographic, natural, climatic, settlement systems, etc., and the ability to make the most effective use of these factors in production and economic activities [1].

We believe that progressive development is a controlled process of using the entire complex of rural resources, having a cognitive and innovative vector and, ultimately, ensuring stability and sustainability. This involves the use of various assessment systems consisting of indicators that take into account not only the availability of production resources, but also reflect the efficiency of resource use. This is what forms the strategy of sustainable spatial development of agricultural regions and rural areas today [2, 3].

Rural territory is a relatively integrated socio-economic system, including territorial organization, population, production and economic functioning and economic results.

2 Materials and Methods

Within the framework of the conducted research, analytical, abstract-logical methods and methods of system analysis were used to evaluate and systematize the available information, taking into account the comparability of federal and regional information. The systematic approach made it possible to comprehensively study the socio-economic development of the North Caucasus Federal District and its individual subjects. The empirical basis of the study was the materials of periodic and operational statistical reporting generated by the Office of the Federal State Statistics Service for the North Caucasus Federal District and Stavropol Territory. These data made it possible to determine the agricultural potential of the regions, the level of its development and the effectiveness of its use. Based on this, the systematization of the regions of the North Caucasus Federal District was carried out by the method of point-rating assessment.

3 Organizational and Settlement Basis of Rural Areas

A territorial organization can be municipal or administrative-territorial. For local self-government, there is more than a sufficient variety of possibilities for organizing municipalities. The entire territory is delimited between settlements, which are divided into rural and urban. In Russia, there is a two-tier system of municipalities in urban and rural areas. Urban districts with inner-city divisions, inner-city districts, urban and rural settlements form the first or lower territorial level of municipal government. The second or upper level of the organization of local self–government is municipal districts, municipal districts, urban districts without municipal division and the inner-city territory of a city of federal significance.

The system of territorial organization of local self-government in the North Caucasus Federal District, compiled by the author on the basis of data from the Federal State Statistics Service (Rosstat) and the Office of the Federal State Statistics Service for the North Caucasus Federal District (North Kavkazstat) [4, 5], is represented by all territorial forms except for the territories of cities of federal significance (Fig. 1).

Municipalities may contain several localities (up to 15 or more). In all republics, the system of organization of local self-government is as diverse as possible and contains

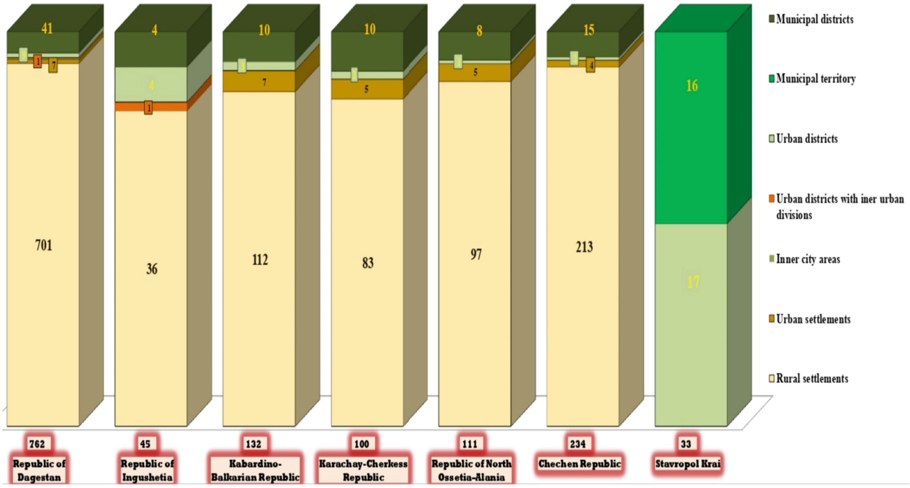


Fig. 1. Structure of municipalities

all types of territorial organization. A special system has developed in the Stavropol Territory, where only districts have been created – municipalities of the highest level. In the structure of municipalities of the North Caucasus Federal District, rural municipalities account for 88%, and in the Chechen Republic and the Republic of Dagestan their share exceeds 90% (Table 1). The extent of the asymmetry of the indicators is noteworthy. Calculated according to the indicators of Table 1 [4, 5], it was accordingly (in times): 23.1; 19.2; 19.5; 17.8. In the largest constituent entity of the district (Stavropol Territory), there are one and a half times fewer municipalities than in the smallest one (Republic of Ingushetia).

The municipal territorial system is divided into municipalities and cannot be further divided. Accordingly, some regions with unique special territorial systems cannot be analyzed below the level of the municipality. Administrative-territorial division allows you to divide administrative units into larger (regions, districts) and smaller (cities, settlements) administrative units, which leads to a more complete territorial division.

Administrative-territorial division includes the establishment of various administrative units in a certain hierarchy from top to bottom. The administrative-territorial division of the subjects of the North Caucasus Federal District also contains two levels: cities of regional significance and districts (sections), which in turn include cities, towns, rural settlements (Table 2) [4, 5].

An analysis of rural settlements in the North Caucasus Federal District subjects showed that 80% of rural settlements in the district are located in three subjects: the Republic of Dagestan, Stavropol Territory and the Chechen Republic. And the most urbanized subject of the district is Stavropol Territory, which has 19 cities, 10 of which are cities of regional importance.

Table 1. Territorial organization of local self-government in the regions as of 01.01.2023

Regions	Municipalities – total	including:		
		I territorial level	including: municipalities – rural settlements	II territorial level
Russian Federation	18402	15 815	14580	2587
North Caucasian Federal District	1 417	1 275	1 242	142
Republic of Dagestan	762	712	701	50
Republic of Ingushetia	45	37	36	8
Kabardino-Balkarian Republic	132	119	112	13
Karachay-Cherkess Republic	100	88	83	12
Republic of North Ossetia–Alania	111	102	97	9
Chechen Republic	234	217	213	17
Stavropol Krai	33	—	—	33
max/min	23,1	19,2	19,5	17,8

Table 2. Administrative-territorial organization in the regions as of 01.01.2023

Regions	II		I				TOTAL settlements
	Cities of regional importance	Districts (sections)	Cities	Urban-type settlements	Rural settlements		
					Total	including without population	
Russian Federation	599	2 062	1 118	1 179	153 157	24 751	155 454
North Caucasian Federal District	34	115	59	34	3 335	136	3 428
Republic of Dagestan	10	42	10	18	1 604	34	1 632
Republic of Ingushetia	5	4	5	—	117	66	122
Kabardino-Balkarian Republic	3	10	8	—	172	1	180
Karachay-Cherkess Republic	2	10	4	8	137	2	149
Republic of North Ossetia–Alania	1	8	6	1	211	11	218
Chechen Republic	3	15	7	—	360	12	367
Stavropol Krai	10	26	19	7	734	10	760
max/min	10,0	10,5	4,8	18,0	13,7	66,0	13,4

4 Characteristics of the Rural Settlement System

According to some scientists, the municipal and administrative-territorial systems of the organization of the settlement network are based on historically established settlement systems, including the placement of the population in space and its interrelationships [6–8]. Urban and rural areas are characterized by various settlement systems, which, as a result of the development of the territory, gradually acquired unique types of connections and, in the process of interaction, gradually reformatted into a new qualitative state, i.e. into a settlement system. At the same time, there is a single settlement system and its hierarchical and morphological structure, urban and rural settlement, etc. A standard description of the settlement of the population. The most common concepts are: average population density and settlement, topography of the population, settlement capacity (demographic capacity), morphological indicators - population density, the ratio of urban and rural settlements. Information for their calculations is presented in Table 3 [4, 5].

The North Caucasus is largely a rural federal district and contains subjects that differ as much as possible from each other. The Chechen Republic, the Karachay-Cherkess Republic and the Republic of Dagestan are the three most rural regions, with 62%, 59% and 55% rural populations, respectively. One of the key indicators in characterizing rural settlements is the average population in settlements, which is associated with the form of settlement, the production functions of the settlement and the history of its formation. This indicator objectively reflects the combined effect of a number of factors on the development of the settlement [6]. Due to geographical differences in natural conditions, the level of development and the configuration of the settlement network, the average number of residents in the subjects of the district fluctuates 2.4 times, amounting to 2,635 people in the Chechen Republic, and 1,097 people in the Republic of Dagestan.

The size of the population depends primarily on the level of research of the territory and socio-economic development. At the same time, the possibility of developing natural resources, proximity or remoteness to main transport corridors, energy lines, social facilities, and regional centers is important. Currently, in the republics of the district, the density of rural settlements is decreasing dynamically, the average population of rural settlements is increasing, and the share of large settlements in the structure of rural settlement is gradually increasing [6, 9]. A distinctive trend of rural settlement of the district is the growth of their demographic potential, the discrepancy between their numbers and the censorship of a rural locality and, in this regard, the structural redistribution of the resource component of rural areas.

Table 3. Characteristics of the regional settlement system as of 01.01.2023

Regions	Population, people		Total land area, thousand hectares		The density of the network of rural settlements, units (per 1000 km^2)	Average population of rural settlements, people
	Total	including rural	Total	including agricultural land		
Russian Federation	146 447 424	36 791 861	1 712 500,0	221 800,0	11,2	240
North Caucasian Federal District	10 205 730	5 040 439	17 043,9	12 066,9	5,1	1 511
Republic of Dagestan	3 209 781	1 759 290	5 027,0	3 348,2	3,1	1 097
Republic of Ingushetia	519 078	234 425	310,4	198,7	2,7	2 004
Kabardino-Balkarian Republic	903 266	435 622	1 247,0	695,8	7,3	2 533
Karachay-Cherkess Republic	468 444	274 642	1 427,7	664,6	10,4	2 005
Republic of North Ossetia–Alania	680 748	250 607	798,7	400,7	3,8	1 188
Chechen Republic	1 533 209	948 470	1 617,1	971,3	4,5	2 635
Stavropol Krai	2 891 204	1 137 380	6 616,0	5 787,6	9,0	1 550
max/min	6,2	7,5	21,3	29,1	3,9	2,4

5 Economic Results in Agriculture

In the North Caucasus Federal District, agriculture is of paramount importance and is the main type of economic activity in the sectoral structure of the district. The share of the added value of the industry in the gross regional product of the North Caucasus Federal District exceeds 16.1%, which is 3.6 times more than the average in Russia. According to the results of 2022, this indicator ranges from 11.0% in the Republic of Ingushetia to 19.6% in the Republic of Dagestan. Financial and economic results in agriculture are presented in Table 4 [4, 5], which reflects information about one of the most important indicators – the balanced financial result, the imbalance of which amounted to an unthinkable 954 times.

The analysis of the main relative indicator of agricultural performance (profitability) indicates the effective functioning of crop production industries in all subjects of the

Table 4. Indicators of production and economic activity and economic results in the regions for 2022

Regions	Agricultural products (in actual prices), mln rubles	Financial result in agriculture (profit minus loss), mln rubles	Profitability, %				The average annual number of people employed in agriculture, thousand people
			crop production		animal husbandry		
Russian Federation	8 563 466,0	650 318,0	34,9		11,5		4 465,7
North Caucasian Federal District	705 948,0	26 708,0	30,5		11,6		675,5
Republic of Dagestan	188 328,0	709,0	28,0	*6*	10,7	*5*	216,3
Republic of Ingushetia	20 147,0	169,0	23,8	*4*	1,7	*4*	37,2
Kabardino-Balkarian Republic	84 382,0	286,0	12,1	*2*	21,0	*7*	72,6
Karachay-Cherkess Republic	40 714,0	642,0	25,1	*5*	– 44,1	*1*	25,8
Republic of North Ossetia–Alania	43 081,0	26,0	13,7	*3*	—	*3*	23,3
Chechen Republic	50 861,0	71,0	1,6	*1*	– 43,2	*2*	122,0
Stavropol Krai	278 435,0	24 805,0	32,7	*7*	11,9	*6*	178,3
max/min	13,8	954,0	20,4		—		9,3

district. The profitability of crop production is at least three times higher than that of animal husbandry, which is profitable in almost half of the subjects of the district. The exceptions are the Chechen, Karachay-Cherkess and the Republic of North Ossetia – Alania, and the resulting loss in livestock industries is more than twice the profitability of profitable entities. The instability of economic returns indicates systemic shortcomings in understanding the processes taking place directly in rural areas, and the low effectiveness of existing agricultural development programs in individual subjects [9].

6 Systematization and Evaluation of Regions by Potential and Effectiveness

To systematize regions according to indicators of the territorial organization of settlements, population, industrial and economic functioning and economic results, we use the index method and the sum of points proposed by Russian and Belarusian scientists, adjusted for the specific features of the region [10–12]. The ranking is based on the calculation and comparison of two groups of indicators characterizing the basic foundations of rural territory (potential) and the effectiveness (efficiency) of its use. They are calculated based on data from the previous tables. Based on the logic of the study, six integral relative indicators were taken in each group. The first group (Table 5) characterizes rural territory and settlement (the proportion of municipalities – rural settlements, the proportion of rural settlements, the ratio of rural and urban population, population density, the proportion of rural population, the proportion of agricultural land).

Table 5. Indicators of the assessment of the settlement system and rural territories in the regions for 2022

Regions		Specific gravity, %								Population density, people per 1 km^2		The ratio of rural and urban population	
		municipalities – rural settlements		rural settlements		rural population		agricultural land					
Russian Federation		79,23		98,52		25,12		12,95		8,6		0,34	
North Caucasian Federal District		87,65		97,29		49,39		70,80		59,9		0,98	
Republic of Dagestan	*35*	91,99	*7*	98,28	*7*	54,81	*5*	66,60	*6*	63,9	*5*	1,21	*5*
Republic of Ingushetia	*17*	80,00	*2*	95,90	*3*	45,16	*3*	64,01	*5*	143,1	*1*	0,82	*3*
Kabardino-Balkarian Republic	*21*	84,85	*4*	95,56	*2*	48,23	*4*	55,80	*3*	72,4	*4*	0,93	*4*
Karachay-Cherkess Republic	*24*	83,00	*3*	91,95	*1*	58,63	*6*	46,55	*1*	32,8	*7*	1,42	*6*
Republic of North Ossetia–Alania	*17*	87,39	*5*	96,79	*5*	36,81	*1*	50,17	*2*	85,2	*3*	0,58	*1*
Chechen Republic	*32*	91,03	*6*	98,09	*6*	61,86	*7*	60,06	*4*	98,0	*2*	1,62	*7*
Stavropol Krai	*22*	—	*1*	96,58	*4*	39,34	*2*	87,48	*7*	43,7	*6*	0,65	*2*
max/min		1,15		1,07		1,68		1,88		4,36		2,78	

Source: compiled by the author

The second group (Table 6) – indicators of the economic efficiency of the rural sector and territory (agricultural products (in farms of all categories; in actual prices) per capita, balanced financial result per 1 resident, balanced financial result per 1 employee in the industry, balanced financial result per 1 hectare of farmland, profitability of crop production and the profitability of animal husbandry).

Based on this, the rating score of the subject of the North Caucasus Federal District was calculated for each indicator. The subject with the best indicator value gets the highest score equal to 7, and with the lowest value – 1. The scores in the tables are indicated in italics. The total for each group is defined as the sum of the scores of all indicators included in the group and is shown in Fig. 2.

According to the sum of the rating points, the regions were ranked by the level of potential, and subsequently by the effectiveness of its use. All subjects of the North Caucasus Federal District are conditionally systematized into three levels of potential and efficiency of its use: high, medium and low. It has been revealed that some regions have significant potential for rural development. It is necessary to single out the largest in

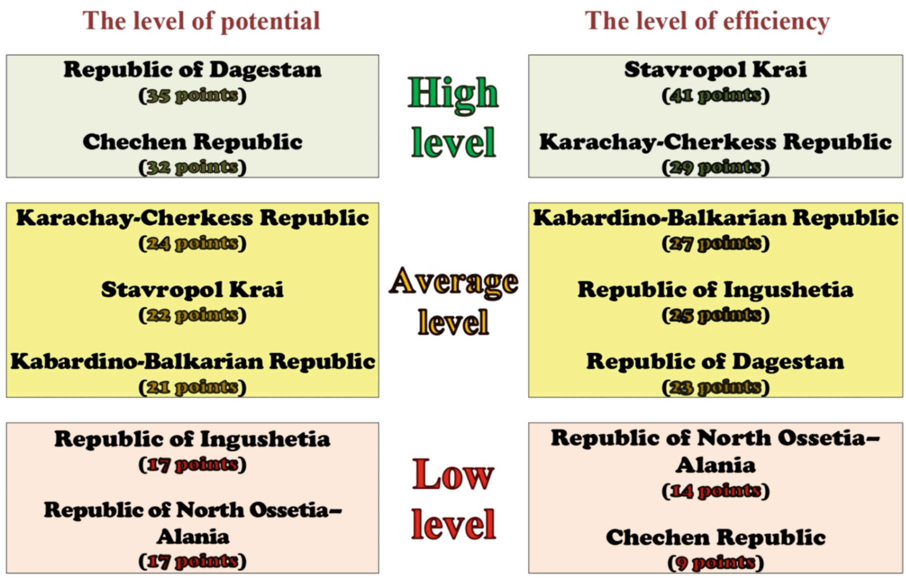
Table 6. Indicators of agricultural efficiency in the regions for 2022

Regions		Agricultural products per 1 inhabitant, mln rubles		Net financial result per 1 ha of agricultural land, rubles		The net financial result per 1 resident, rubles		Net financial result per 1 employee, rubles	
Russian Federation		58 474,7		2 932,0		4 440,6		145 625,1	
North Caucasian Federal District		69 171,7		2 213,3		2 617,0		39 538,1	
Republic of Dagestan	*23*	58 673,2	*3*	211,8	*3*	220,9	*3*	3 277,9	*3*
Republic of Ingushetia	*25*	38 813,0	*2*	850,5	*5*	325,6	*5*	4 543,0	*5*
Kabardino-Balkarian Republic	*27*	93 418,8	*6*	411,0	*4*	316,6	*4*	3 939,4	*4*
Karachay-Cherkess Republic	*29*	86 913,3	*5*	966,0	*6*	1 370,5	*6*	24 883,7	*6*
Republic of North Ossetia–Alania	*14*	63 284,8	*4*	64,9	*1*	38,2	*4*	1 115,9	*2*
Chechen Republic	*9*	33 172,9	*1*	73,1	2	46,3	2	582,0	*1*
Stavropol Krai	*41*	96 304,2	*7*	4 285,9	*7*	8 579,5	*7*	139 119,5	*7*
max/min		2,9		66,1		224,6		239,1	

Source: compiled by the author

terms of their potential: the Republic of Dagestan and the Chechen Republic, which have the highest indicators in terms of the proportion of rural settlements, rural population and agricultural land. The potential that exists in them has a holistic set of basic elements for the development of rural areas. Nevertheless, the Stavropol Territory and the Karachay-Cherkess Republic are the leaders in terms of the effectiveness of its use, more than 200 times ahead of other regions of the North Caucasus Federal District in terms of indicators.

Of course, this can be explained by natural conditions, dependence on the terrain and the climate caused by it: low–mountain (mainly steppe) with a moderately warm climate, medium–mountain - with a moderately continental climate, high-mountain - with a moderately cold climate. However, the discrepancy in the level of possibilities of reality indicates that even the subjects of the region with the same climate and topography have significant differences in the considered indicators and their ratios [13]. Thus, this is largely confirmed by this system, created and implemented by the region's strategy for the development of agricultural production through the accompanying structure of financial and economic support and rural development.



Source: compiled by the author

Fig. 2. Systematization of regions according to the characteristics of the settlement network and the settlement system of rural areas

7 Conclusion

The basic structure of the agrarian economy of the subjects of the North Caucasus Federal District is characterized by imbalance and complexity of development, its inertia and weak innovation susceptibility. As a result, it is precisely the agrarian regions that, due to the depressed socio-economic state, do not have the ability to recover and sustain growth. Nevertheless, the crucial importance of the rural lifestyle and the agricultural sector in the regional economic systems of the district confirms the importance of industrial innovations, technological and institutional changes, taking into account the existing conditions of the territory and the settlement system [14, 15].

A cross-section of the results of the subjects of the region and an analysis of the indicators allows us to conclude that the subjects are differentiated by territorial organization, settlement systems, demographic situation, and the effectiveness of the level of socio-economic development. The prevailing asymmetry of rural territories and settlement systems in conditions of differentiated socio-economic development requires an innovative and breakthrough approach in the implementation of a system of measures for the development of rural territories of the subjects of the district. State regulation and development of geographically differentiated measures to support production, economy, standard of living and social services should take into account the specific features of rural settlement and rural territory.

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Assessment of the Productive Qualities of the First Heifers of the Jersey Breed

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Abstract. For the successful development of dairy cattle breeding, it is necessary to have cows with improved milk productivity in combination with an effective herd management system. In the conditions of the North Caucasus, Jersey cattle make up 26% of the total breeding stock of cattle. The article presents the results of research, during which the following tasks were solved: the study of the main parameters of dairy productivity of controlled cows after the first completed lactation (305 days) (milk yield, milk fat and protein content and their percentage in milk, lactose content); the study of live weight indicators at 6 months and after the first calving of the first Jersey breed heifers in combination with the manifestation of productive qualities. As a result of the research work, various reliable correlation coefficients were found between the indicators of dairy productivity of cows (milk yield, milk fat and protein yield, percentage of fat and protein, percentage of lactose) and the live weight of animals at 6 months and after calving. A reliable correlation was established between the average daily gains in the period 0–6 months with the yield of milk fat and the percentage of fat in milk. The percentage of lactose in milk showed a weak but reliable correlation with the mass fraction of fat and protein.

Keywords: dairy components · productivity · live weight · lactose · average daily gains · Jersey breed · cattle · milk fat · milk protein

1 Introduction

One of the objectives of the development of dairy cattle breeding is to increase the amount of raw milk received from cows and improve its quality. Achieving positive results in this direction is possible only with the development of new breeding and technological techniques in the industry. Modern breeding methods should contribute to the full disclosure of the genetic potential inherent in animals (Pacheco, Rangel et al., 2020).

One of such methods for improving dairy productivity in cattle is an integrated approach, tested internationally and including an independent assessment of dairy productivity and the qualitative composition of raw milk, an in-depth assessment of the phenotypic parameters of animals (live weight, exterior), the use of genomic analysis in the selection of parental pairs (Oleinik, S, et al., 2022; V.L. Daley et al., 2022).

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In many scientific papers (Chuck G. M., et al., 2018; R.C. Handcock, et al., 2019; Pinto, Pollyana, et al., 2021; V. Trukhachev, et al., 2021; Surjowardojo, Puguh, et al., 2022) by to study the relationship between the live weight of repair heifers and their milk productivity, the main object of research was cows of Holstein and black-and–white breeds, which may be due to the great popularity of these breeds abroad and in Russia due to high milk productivity (9–11 thousand kg).

Jersey cattle have not been studied enough in this direction. According to ICAR (2023), Jersey cows do not really have high productivity (5.8 thousand kg) compared to cows of the same Holstein breed, but the percentage of fat and protein in milk is an order of magnitude higher than 5.43% and 3.94% versus 4.09% and 3.29%, respectively. At the same time, Jersey cattle have a higher feed conversion, good adaptive qualities and resistance to diseases. All these aspects make this breed competitive in the global dairy market.

In addition to the percentage of fat and protein, lactose may indirectly affect the economic efficiency and sales of raw milk, this is due to the fact that milk with a high lactose content can be used to produce a wide range of products, whereas milk with a low lactose content limits the choice of products (M. Haile-Mariam & J.E. Pryce, 2017). Unlike the concentrations of milk fat and protein, the lactose content in milk is not affected by the number of milking days, and its curve reflects the curve of milk yield with a peak at the beginning of lactation. Lactose is also an osmotic compound of milk, which is why its content level cannot be changed biologically, for example, using genetic selection or a feeding strategy (M.A. Olsen, et al., 2023).

Thus, the study of the relationship between live weight and milk productivity, as well as an additional study of the lactose index in milk-raw materials of Jersey cows is of scientific and practical interest and the results obtained will be relevant in organizing effective management of dairy cattle and may increase the interest of the scientific community and commercial organizations in the Jersey breed of cattle.

2 Materials and Methods

The object of the study was a controlled herd of Jersey cows with the first completed lactation (305 days) ($n = 386$) of a breeding reproducer of the Stavropol Territory.

To determine the effect of the growth of young animals on their further productivity by the method of normalized distribution (GOST R ISO 3534-1-2019), 4 groups were formed according to the average daily increase in the period from 0 to 6 months. 50 heads were included in group I with an average daily increase from 556 g to 672 g, 152 heads in group II from 678 g to 739 g, 139 heads in group III from 744 g to 806 g and 45 heads in group IV from 811 g to 911 g.

The influence of environmental factors was not taken into account in this study, since the animals were geographically located in the production buildings of one farm. The feeding ration included the following feeds: corn silage, triticale haylage, soybean meal, rapeseed cake, dry corn feed, sunflower meal, beer pellet, beet pulp, crushed barley, barley straw. The total nutritional value of the feed was at the level of 116 Mj per day, for two groups.

2.1 Milk Sampling

Milk was selected monthly by means of control milking on the farm by specialists of the assistant service. Milk sampling and transportation to the Laboratory of milk quality control were carried out in accordance with GOST R ISO 707-2010 and GOST 26809.1-2014.

2.2 Laboratory Testing

The qualitative composition of the selected milk samples was studied in the Laboratory of Milk Quality Control of the Stavropol State Agrarian University (state registration number in the Breeding Register of the Russian Federation No. 262704801000, Certificate of registration in the state Breeding Register, series PJ 77 No. 011667) by Fourier transform infrared spectrometry on the CombiFoss 7 ds milk analyzer, Foss company (Denmark), according to the indicators of the mass fraction of fat and the mass fraction of protein, lactose in accordance with GOST 32255-2013, GOST 5867-90, GOST 8218-89, GOST 25179-2014.

2.3 Live Weight

The dynamics of live weight was studied by weighing animals (GOST R 57784-2017). The intensity of the live weight gain of young animals was determined by generally accepted methods.

2.4 Data Collection and Statistical Processing

Data on daily milk yields and the results of laboratory tests of milk were automatically uploaded via the Internet to the 1C: Livestock Management software module developed on the basis of the Stavropol State Agrarian University (certificate of state registration of the computer program No. RU 2023682384). Based on the module, a database of quantitative and qualitative indicators of milk of the controlled Jersey breed was formed.

Statistical processing of the actual material and correlation coefficients was carried out using the Excel mathematical module, differences were considered statistically significant at $p < 0.05$ of the Student's t-test.

3 The Results

To assess the productive qualities of the first Jersey breed heifers, milk yield, milk fat and protein yield for completed lactation (305 days), milk fat and protein yield per 100 kg of live weight, percentage of fat and protein, percentage of lactose, live weight of animals at 6 months, live weight after the first calving, average daily the increase in the period of 0–6 months.

The analysis revealed a pattern of changes between quantitative indicators of milk productivity and live weight (Table 1).

Thus, the first heifers with an average daily increase of 811–911 g (group IV) showed the highest indicators of milk productivity. Milk fat yield index for the first completed

Table 1. Normalized distribution of cows in terms of average daily growth in the period 0–6 months, M±sem.

Indicators	Total animals (n = 386)			
	I	II	III	IV
Number of animals by group, head	50	152	139	45
Average daily increase of 0–6 months, g	556–672	678–739	744–806	811–911
Milk fat yield per lactation (305 days), kg	320.06 ± 5.55	326.96 ± 3.92	338.14 ± 4.75	347.71* ± 7.72
Milk protein yield per lactation (305 days), kg	242.57 ± 4.84	243.61 ± 3.09	250.32 ± 3.71	250.81* ± 5.21
Live weight after 1 calving, kg	387.71 ± 0.85	398.28 ± 0.38	410.53 ± 0.43	424.55* ± 0.21
Live weight at 6 months, kg	136.36 ± 1.03	150.84 ± 0.31	162.07 ± 0.41	176.55* ± 1.13
Milk fat yield per 100 kg of live weight, kg	82.54* ± 1.42	82.07 ± 0.97	82.33 ± 1.13	81.87 ± 1.81
Milk protein yield per 100 kg of live weight, kg	62.56* ± 1.25	61.15 ± 0.77	60.95 ± 0.89	59.06 ± 1.21

Note. * Reliability of values at $p < 0.05$.

lactation (305 days) It was higher by 9.57–27.65 or by 2.83–8.63% compared to peers from group I-III. The milk protein yield index for the first completed lactation (305 days) in groups III and IV was almost at the same level with a difference of 0.49 kg. In group I and II peers, its value was in the range of 242–243 kg, which is 2.82–3.26% lower than in group III and IV.

The analysis of milk fat and protein yield per 100 kg of live weight showed the opposite situation than during the completed I lactation. The highest yield of dairy components was in cows of group I (fat 82.54 kg, protein 62.56 kg) 0.21–0.67 more in milk fat and 1.41–3.5 kg more in milk protein.

The live weight index after the first calving was in a large range throughout the sample (387.71–424.55 kg). Group IV cows have the highest weight (424.55 kg) than their peers by 14.02–36.84 kg or by 3.41–9.49%. The live weight index at 6 months repeats the trend. On average, its value in group IV was 176.55 kg, which exceeds the other groups by 8.93–29.47%.

A general analysis of Table 1 showed that with an increase in body weight, milk indicators increase in different periods. From which it can be concluded that the live weight of cows at 6 months and the intensity of growth in the period 0–6 months are interrelated with the indicators of their milk productivity, which confirms the results of other researchers (R.C. Handcock, et al., 2019; Hayes C. J., et al., 2021; Han L., et al., 2021; Kramarenko A., et al., 2022).

The data on the total yield of dairy components (fat+protein) per 100 kg of live weight for all groups were also analyzed (Fig. 1).

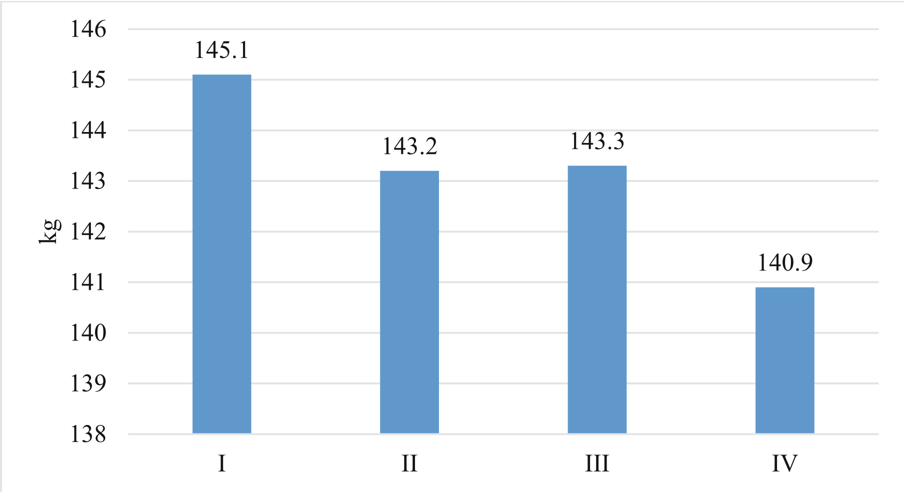

Fig. 1. The total yield of dairy components (fat+protein) per 100 kg of live weight of cows.

An analysis of the total yield of dairy components (fat+protein) per 100 kg of live weight showed that in cows from group I, this indicator had the highest value (145.1 kg) than in their peers. Compared with group IV, where this indicator was the lowest (140.9 kg), the value in group I was 4.2 kg or 2.9% higher. In groups II and III, the total yield of milk fat and protein was at the same level (143.2–143.3 kg), which is the average among the animals of the entire sample. It can be assumed that this is due to the fact that the animals in group I had the lowest live weight at 6 months and after the first calving among their peers. Comparing this analysis with the data from Table 1, we get the result that the animals of group I had the lowest milk fat and protein yields according to the results of the first completed lactation. The parameter of the total yield of milk fat and protein can be used for interbreeding comparison.

The total yield of dairy components (fat+protein) at the end of the first completed lactation (305 days) showed the opposite trend (Fig. 2).

Thus, the highest total yield of milk fat and protein was in group IV (598.6 kg), an indicator higher than that of peers in groups I-III by 10.2–36 kg or by 1.7–6.3%, where the lowest value was in cows in group I (562.6 kg).

Considering that the quantitative yield of dairy components (fat, protein) directly depends on the volume of milk obtained and the percentage of fat and protein in it, data on the milk yield level and qualitative indicators of raw milk (mass fraction of fat, mass fraction of protein, lactose) were analyzed (Table 2).

The analysis showed that the cows of group IV had an advantage over their peers of group I-III. Thus, the volume of milk received during the completed I lactation in group IV was 22.7–697.4 kg higher or 0.3–2.7% than in the other groups. It is worth

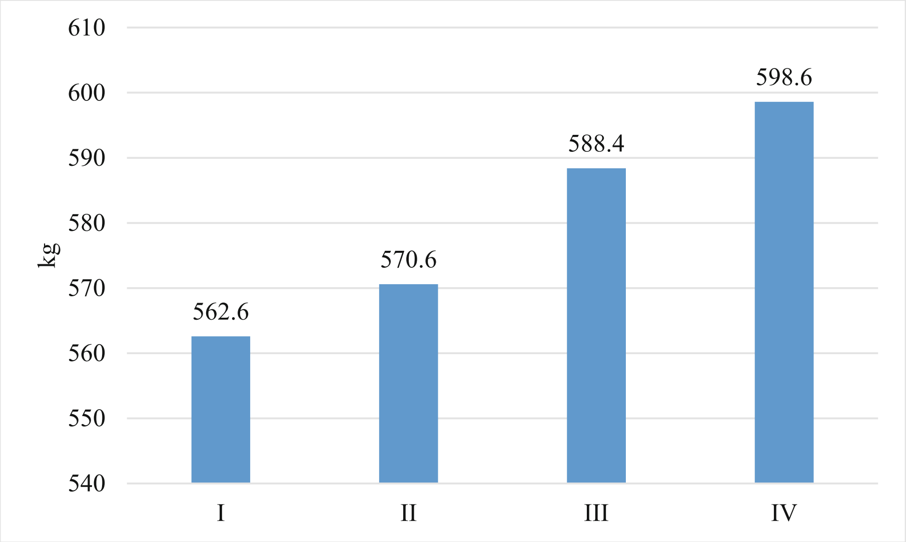

Fig. 2. Dynamics of the total yield of dairy components (fat+protein) for the completed I lactation (305 days).

Table 2. Data on milk yield, fat mass fraction, protein mass fraction and lactose in the controlled livestock (n = 386) with a normalized distribution into groups according to the average daily increase in the period 0–6 months, M±sem.

Indicators	Total animals (n = 386)			
	I	II	III	IV
Number of animals, head	50	152	139	45
Milk yield, kg	5825.61 ± 133.41	5829.75 ± 77.14	5960.29 ± 87.85	5983.02 ± 136.21
Mass fraction of fat, %	5.56 ± 0.08	5.64 ± 0.03	5.71 ± 0.04	5.84 ± 0.08
Mass fraction of protein, %	4.18 ± 0.02	4.18 ± 0.01	4.21 ± 0.01	4.21 ± 0.02
Lactose, %	4.76 ± 0.01	4.77 ± 0.01	4.75 ± 0.01	4.77 ± 0.01

Note. * Reliability of values at $p < 0.05$.

noting that the amount of milk produced in group III was almost on the same level as the leading group IV.

The percentage of fat in raw milk was also higher in group IV (5.84%) by 0.13–0.28 higher than in groups I-III. The percentage of protein in all groups was almost at the same level (4.18–4.21%), which explains the stability of the protein and the low dependence on changes in other phenotypic parameters.

The situation is similar with the percentage of lactose, the value of which was in the range of 4.75–4.77% for the entire studied livestock. The scientific literature notes that the lactose index has a stable level, which does not depend on the live weight and milk yield of the animal (M. Haile-Mariam & J.E. Pryce, 2017; A. Costa, 2019).

The study of the effect of growth intensity in the period of 0–6 months on milk productivity according to the results of the first completed lactation (305 days) showed the relationship between these parameters (Fig. 3).

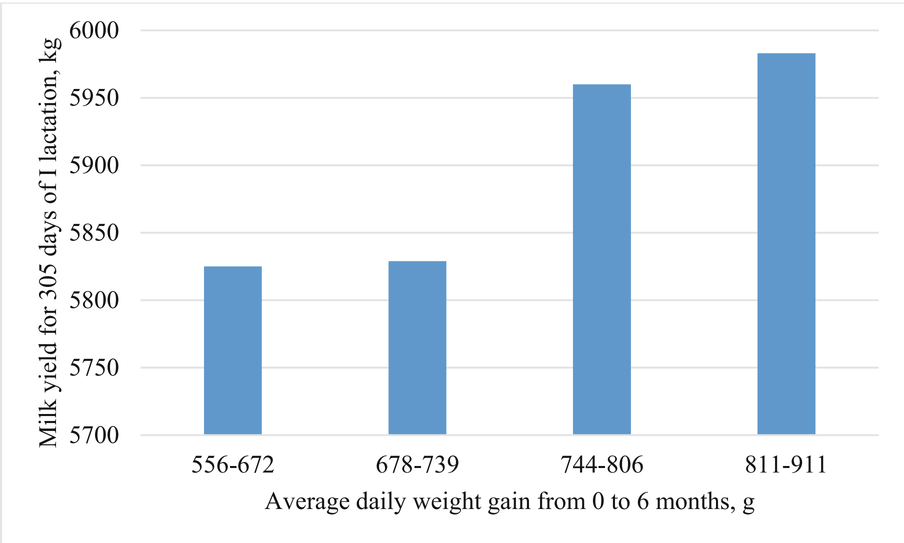

Fig. 3. The volume of raw milk obtained for the first completed lactation due to the average daily increase in the period of 0–6 months.

Thus, the first heifers, which had an average daily increase in the range of 811–911 g in the period of 0–6 months, had the highest milk yield (5983 kg). Animals with an average daily gain of 744–806 g for a similar result did not have a significant difference in the direction of a decrease in milk yield by 0.3%. Female peers with average daily gains below 744 g showed a significantly lower volume of milk received (5825–5829 kg).

To determine the relationships between the studied indicators, correlation coefficients with a high level of confidence ($p < 0.05$) were determined. The correlation relationship between 11 indicators was considered: milk fat yield per completed lactation (305 days); milk protein yield per completed lactation (305 days); live weight after the first calving; milk fat yield per completed lactation (305 days) per 100 kg of live weight; milk protein yield per completed lactation (305 days) per 100 kg of live weight; milk yield for completed lactation (305 days); mass fraction of fat; mass fraction of protein; percentage of lactose; live weight of cows at 6 months; average daily increase in the period 0–6 months (Table 3).

Table 3. Correlation coefficients between indicators of milk productivity, live weight and average daily increases of cows (n = 386), r.

Indicators**	Correlation coefficients, r										
	1	2	3	4	5	6	7	8	9	10	11
1	1.00	−0.43*	0.82*	−0.28*	0.95*	0.18*	0.20*	0.41*	0.03	0.00	0.13*
2	−0.43*	1.00	0.16*	0.46*	−0.29*	0.13*	−0.38*	−0.13*	−0.02	0.03	0.15*
3	0.82*	0.16*	1.00	−0.01	0.85*	0.28*	−0.01	0.34*	0.03	0.03	0.24*
4	−0.28*	0.46*	−0.01	1.00	0.03	0.02	−0.23*	0.03	0.00	0.04	0.03
5	0.95*	−0.29*	0.85*	0.03	1.00	0.20*	0.14*	0.42*	0.03	0.02	0.14*
6	0.18*	0.13*	0.28*	0.02	0.20*	1.00	−0.02	0.17*	0.02	0.03	0.98*
7	0.20*	−0.38*	−0.01	−0.23*	0.14*	−0.02	1.00	0.12*	0.07	0.05	−0.03
8	0.41*	−0.13*	0.34*	0.03	0.42*	0.17*	0.12*	1.00	0.05	−0.03	0.11*
9	0.03	−0.02	0.03	0.00	0.03	0.02	0.07	0.05	1.00	0.85*	−0.01
10	0.00	0.03	0.03	0.04	0.02	0.03	0.05	−0.03	0.85*	1.00	0.01
11	0.13*	0.15*	0.24*	0.03	0.14*	0.98*	−0.03	0.11*	−0.01	0.01	1.00

Note. ** Reliability of correlation values at $p < 0.05$. * 1 – milk yield per completed lactation (305 days), kg; 2 – mass fraction of fat per completed lactation (305 days), %; 3 – milk fat yield per completed lactation (305 days), kg; 4 – mass fraction of protein per completed lactation (305 days), %; 5 – milk protein yield for completed lactation (305 days), kg; 6 – live weight at 6 months, kg; 7 – lactose, %; 8 – live weight after the first calving, kg; 9 – milk fat yield for completed lactation (305 days) per 100 kg of live weight, kg; 10 – milk protein yield for completed lactation (305 days) per 100 kg of live weight, kg; 11 – average daily increase in the period of 0–6 months, g

Thus, milk yield for completed lactation (305 days) was significantly correlated with 8 indicators. High correlation coefficients were found with the yield of milk fat and milk protein during completed lactation (305 days) with values r = 0.82 and r = 0.95, respectively. Low and average correlation coefficients were established with indicators of live weight at 6 months (r = 0.18), the percentage of lactose (r = 0.20), live weight after the first calving (r = 0.41) and the average daily increase in the period 0–6 months (r = 0.13). Negative correlation coefficients, but also reliable ones, were established with indicators of the mass fraction of fat (r = −0.43) and protein (r = −0.28).

The indicator of the mass fraction of fat for the completed lactation (305) days was also significantly correlated with 8 other indicators. Positive correlation coefficients were established with the yield of milk fat for completed lactation (305 days) (r = 0.16), with a mass fraction of protein (r = 0.46), with a live weight of 6 months (r = 0.13), with an average daily increase of 0–6 months (r = 0.13). In addition to correlation with milk yield, negative correlation coefficients were noted with indicators of milk protein yield for completed lactation (305 days) (r = −0.29), lactose percentage (r = −0.38) and body weight after the first calving (r = −0.13).

The protein mass fraction indicator showed only 3 significant correlations, 2 of which are described above. The third indicator is the percentage of lactose and the correlation coefficient was r = −0.23.

The yield of milk fat and protein, except for the above coefficients, were significantly interrelated (r = 0.85). With a live weight index at 6 months, the milk fat index was significantly correlated with a value of r = 0.28, and the milk protein index had a coefficient of r = 0.20. Also, milk fat and protein significantly correlated with the live weight index after the first calving r = 0.34 and r = 0.42, respectively, and with the average daily gain r = 0.24 and r = 0.14, respectively. Separately, the milk protein parameter was significantly correlated with the percentage of lactose (r = 0.14).

The obtained data of average daily increases over a period of 0–6 months, as described above, showed reliable correlation coefficients with 4 indicators of milk productivity: milk yield per lactation (r = 0.13), mass fraction of fat (r = 0.15), milk yield fat (r = 0.24) and milk protein (r = 0.14).

Analyzing the correlation coefficients between the studied indicators, it can be concluded that there are reliable relationships between the dairy components in most cases and each of the indicators shows dependence on the other in both positive and negative ways. The correlation between milk productivity and live weight in the studied periods is present and the information obtained can be used for further study.

4 Discussion

The topic of the influence of live weight parameters in different age periods on the dairy productivity of cows, both in general and on individual milk quality indicators, is widely studied in the world (R.C. Handcock, et al., 2019; Hayes C. J., et al., 2021; Han L., et al., 2021; Kramarenko A., et al., 2022), but there are practically no studies on the Jersey breed.

According to the results of studies on the effect of the live weight of repair young animals on future dairy productivity, the opinions of some authors differ. Thus, Australian scientists Chuck G. M., Mansell P. D. (2018) noted that heifers with a large live weight do not always show high results in milk production, which is confirmed in studies by Irish scientists Boyle L., Conneely M. (2022). But Han L., Heinrichs A. J., De Vries A. (2021) noted that heifers with a large live weight gave more milk during the first lactation, but at the same time lost more body weight.

To achieve high efficiency of herd reproduction, it is necessary to find new developments and improve old methods for targeted rearing of young animals, the authors Salte R., Storli K. S., Sommerseth J. K. (2020) note, in which calves will form stable immunity, growth intensity will be stimulated, which will eventually lead to the development of future high productivity.

Thus, manipulating the growth rate of heifers can provide a real opportunity to improve the efficiency of dairy enterprises.

In addition, several authors confirm correlations between the amount of milk received and the percentage of fat and protein in it. The higher the productivity of cows, the lower the mass fraction of fat and protein in their milk (Shetty A., et al., 2020; Lefler, T., et al., 2021).

Scientists have noted observations that the percentage of lactose decreases with an increase in the number of lactation, and the correlation coefficients between milk yield and lactose yield were close to 1, which is not confirmed in this work (r = 0.20)/ At the same time, no negative effect of lactose on other milk quality indicators has been found to date, such as and a significant reverse effect, which is reflected in this study (A. Costa, et al., 2019; Tsenkova, R. & Muncan, J., 2022)

Also, a number of scientists note that the lactose index is inversely correlated with the number of somatic cells. Therefore, the use of this indicator as an additional parameter can contribute to the early detection of cow mastitis (M. Caccamo, et al., 2008; Sneddon, Nicholas, et al., 2015) These observations can be used in the future in an in-depth study of this indicator.

5 Conclusion

Thus, the application of the method of ranking repair young animals according to the level of average daily gains in the period of 0–6 months showed that the growth rate of over 744 g. allows you to get highly productive heifers with a dairy productivity of 5960–5983 kg, which is 2.3–3.6% higher than that of their peers.

Analysis of the total yield of dairy components (fat+protein) following the results of completed I lactation showed that in animals with a live weight of 6 months not less than 176 kg and after the first calving at 424 kg, it is within 598 kg, which is 1.7–6.3% higher than in their peers.

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Aerospace Technologies in Grazing Livestock

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Abstract. Remote monitoring systems find practical application in various branches of science. Recent research shows the interest and practical significance of the agricultural sector in the use of aerospace technologies to assess the quality of agricultural land. The purpose of this work was to identify the relationship between the NDVI (Normalized Difference Vegetation Index), obtained by remote sensing, and the nutritional value of natural pastures. The research was carried out in an arid region of the Stavropol Territory on the territory of a breeding farm for breeding and raising fine-wool sheep of the Dzhalginsky Merino breed. To obtain data obtained remotely, a unique scientific installation (UNU) "Vega-Science", which is part of the Center for Collective Use "IKI-Monitoring", was used. The chemical composition of pasture feed was carried out in the laboratory of the Scientific and Technical Center "Forage and Metabolism" according to generally accepted methods. The data obtained revealed a relationship between NDVI and the chemical composition of plants. The superiority of pasture plants with an NDVI index of 0.60 over grass stands with an NDVI index of 0.23 and 0.41 in terms of crude protein content by 1.3 percentage points and 2.35 percentage points. An analysis was also carried out on the amino acid composition of forage plants, where the result was better in grass with an NDVI of 0.60.

Keywords: pasture livestock breeding · satellite service · remote monitoring · productivity · vegetation index · nutritional value · pasture feed

1 Introduction

In modern agricultural practice, aerospace monitoring is actively used using satellite imagery systems and data obtained from unmanned aerial vehicles. Remote methods using satellite systems allow you to quickly and in real time obtain up-to-date information about the composition, condition and development of agricultural crops, build predictive models of their yield, as well as identify plant diseases and damage from pests. In addition, these data are used to account and control land resources, and study the dynamics of their use for agricultural purposes. Recently, remote techniques have found practical significance in assessing the biomass and productivity of pastures [7].

The use of aerospace monitoring can significantly increase the efficiency of agricultural production by optimizing the use of resources, timely identification and elimination

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of problems associated with the condition of crops. The data obtained allows us to develop and implement measures to increase productivity. In general, aerospace monitoring is a key tool for ensuring sustainable development of the agricultural industry and ensuring food security at the global level [2, 3].

One of the key advantages of remote sensing data obtained from aerospace surveys is their scale, uniformity and the ability to compare results obtained over large areas. In addition, they are distinguished by high visibility, relevance and continuity, which makes them extremely useful for solving a number of formed problems. The formation of an innovative livestock farming system based on the use of digital aerospace technologies represents a new, modern approach to the development of pasture livestock farming [6].

In most studies, the assessment of the quality of vegetation cover is studied by different vegetation indices, one of them is NDVI, calculated by analyzing spectral characteristics, namely in the infrared regions of the spectrum. In the works of scientists, this index and the method of its calculation using remote methods are informative for assessing vegetation cover [5, 13].

This is confirmed by many conclusions obtained and tested in practice that open ground in spectral space is in the near-infrared region and forms a straight line, which is generally considered to be the absence of vegetation. The predecessor of NDVI was the Ratio VI index (RVI), which was subsequently refined and became more informative from a practical point of view. To determine the reliability of the practical value of the vegetation index, a number of studies were carried out on agricultural crops, such as wheat, rye, corn, to identify their reflectivity [1, 4, 10].

Precision satellite tracking systems have been actively introduced into livestock farming in recent years, making it possible to optimize production processes and effectively use pastures. This, in turn, can significantly increase the effectiveness of restoring pasture fertility and make it possible to graze a large number of farm animals. The use of digital aerospace technologies and telemetry is becoming an integral part of the modern approach to livestock development [9].

The issue of using remote assessment of the nutritional value of pasture feed and the vegetation index in pasture livestock farming remains poorly studied.

The purpose of this study was to study the relationship between the nutritional value of forage plants of natural pastures and the NDVI vegetation index obtained by remote sensing.

2 Materials and Methods

To achieve the goal, we conducted research on pasture areas of a breeding farm for breeding and raising fine-wool sheep of the Dzhalginsky Merino breed. The farm is located in an arid region in the south of Russia.

2.1 Climatic Conditions

The climate on the farm territory is sharply continental with a range of fluctuations in maximum and minimum air temperatures in summer up to +42 °C, in winter up to 34 °C.

The average annual precipitation is 320–412 mm and increases as you move from the northeastern part of the region to the southwestern.

Geographically, the farm is categorized as arid area. Summer is long, hot, dry with an average monthly temperature of +28 °C in July. Autumn is warm and long, but frosts are very frequent. In the summer, the east wind brings the hot air of the Central Asian deserts. It is associated with droughts and dust storms that begin at wind speeds of 15–20 m/s. Droughts and hot winds of varying intensity are a typical phenomenon for pastures in the South of Russia; in summer there are 85–100 dry days.

2.2 Collection and Processing of Data from Satellite Services

To carry out the work, a unique scientific installation (UNU) "Vega-Science" was used, which is part of the Center for Collective Use "IKI-Monitoring" [14]. Monitoring of the condition of natural pasture lands was carried out using pre-selected coordinates, which were determined as a result of expeditions to the farm.

Satellite data was obtained from the Sentinel-2A/-2B, Terra and Aqua spacecraft. The Sentinel-2A/-2B spacecraft are equipped with MSI (MultiSpectral Instrument), which performs imaging in 13 spectral channels from the visible to the short-wave infrared range of the spectrum within a 290 km wide swath. The spatial resolution of the imaging system varies from 10 to 60 m depending on the spectral range.

The Terra and Aqua spacecraft are equipped with MODIS imaging equipment, which surveys in 36 spectral channels (visible, near, mid and thermal infrared ranges) with a spatial resolution of 250 m to 1 km within a swath width of 2330 km. In this work, the interest was in data with a resolution of 250 m, obtained in two channels - red (620–670 nm) and near-infrared (841–876 nm).

Moreover, in the framework of this work, we used primarily not the original satellite data, but the products obtained from them, represented by NDVI index images (in the case of MSI instrument data, NDVI images obtained from individual scenes were used, and in the case of MODIS instrument data, weekly interpolated NDVI composites were used). The index is calculated using the following formula:

$$NDVI = (NIR - RED)/(NIR + RED) \tag{1}$$

where NIR – reflection in the near infrared region of the spectrum, RED - in the red.

NDVI takes values from -1 to 1. Negative index values are usually typical for water bodies, snow, clouds, and some anthropogenic objects (for example, asphalt roads). The soil and vegetation cover is characterized by positive index values, and the more green phytomass there is within the area under consideration, the higher the index values will be. Vega-Science provides ready-made NDVI images that do not require additional calculations from users.

The study was carried out on pasture areas located in the Ipatovsky district of the Stavropol Territory. For the convenience of processing the information provided by Vega-Science, vector data with the boundaries of the experimental sites were imported into the system (through the system administrator).

The obtained data was selected according to the following criteria:

– survey period – June-August 2023;

- level of data processing – L2A (atmospherically corrected data characterizing reflectivity values at the lower boundary of the atmosphere);
- complete simultaneous coverage of satellite data scenes of the territory of all experimental sites;
- absence of clouds, shadows from clouds and other interfering factors over the territory of the experimental sites at the time of shooting.

2.3 Collection of Pasture Plants for Chemical Research

Pasture forage for research was selected during the main growing season of plants (June-July) and studied using standard generally accepted methods. The chemical composition of feed (crude protein, crude fiber, crude fat, crude ash, calcium, phosphorus, amino acid composition) and moisture were determined using equipment from INGOS (Czech Republic), FIBRETHERM (Germany), VELP SCIENTIFICA (Italy) in the laboratory of the Scientific and Technical Center "Feed and metabolism" (accreditation certificate No. ROSS RU.0001.21PU12 dated October 28, 2014).

3 Results

In their previous studies, the authors described a method for clustering pastures based on the NDVI vegetation index [12].

For the research, there were selected pasture areas with different vegetation index NDVI. Pasture No. 1–0.23, pasture No. 2–0.41, pasture No. 3–0.60, data obtained from satellite services were confirmed by the contact method during on-site research.

To identify the relationship between the NDVI vegetation index and the nutritional value of pasture grass, a chemical analysis of the selected samples was carried out (Fig. 1).

The zoochemical analysis of pasture forage plants showed that the nutritional value of feed is in a functional relationship with the vegetation index NDVI. Of interest is such an indicator as crude protein; grass stand with an NDVI index of 0.60 was superior in crude protein content by 1.3 percentage points and 2.35 percentage points. Grass stand, where NDVI was 0.23 and 0.41, respectively.

The quality of a protein is determined by its amino acid composition; therefore, an in-depth analysis of the selected samples would be carried out (Fig. 2).

An increased content of nonessential and essential amino acids is observed with an NDVI index of 0.60. The exception is methionine; its quantitative indicator was unchanged at all values of the NDVI index (0.06). Among the remaining 15 amino acids, the highest amplitude among the three studied pasture plants with different vegetation index NDVI was aspartic acid (0.22–0.31), glutamic acid (0.34–0.47) and proline (0.13–0.22). These amino acids are associated with energy metabolism and growth energy in sheep, therefore, pasture feeds with a vegetation index NDVI above 0.40 are of practical importance in pasture animal husbandry.

The methodological approaches we have developed for organizing pasture livestock farming using digital aerospace remote monitoring technologies allow us to approach the issue of organizing a system for raising pasture animals in a fundamentally different way in the conditions of modern agro-industrial production, which includes crop and livestock sectors.

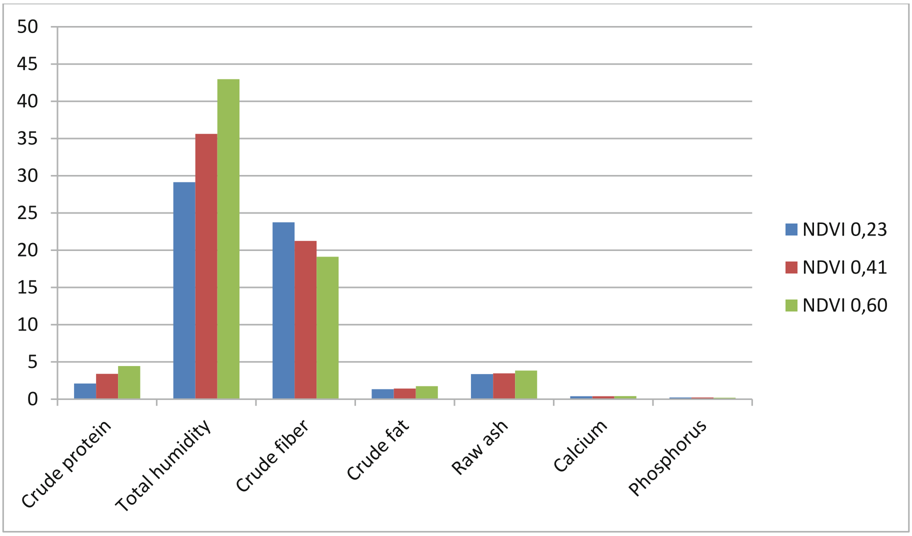

Fig. 1. Nutritional value of pasture grass

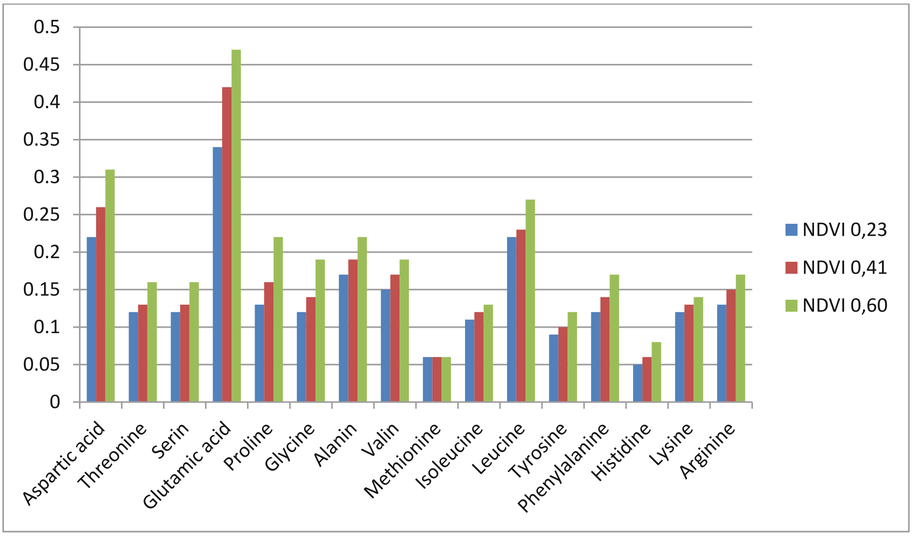

Fig. 2. Amino acid composition of pasture feeds in connection with the NDVI vegetation index

4 Discussion

The results obtained were confirmed in the works of Belarusian scientists, where it was found that the best indicator of erosion among all the considered indices is NDVI. Along the erosion gradient, the average NDVI values decrease by 4 times. In the landscape conditions of Belarus, NDVI can be used to reliably indicate 3 categories of soil erosion

[8]. Also O.V. Mezentsev and V.V. Bevz conducted a study to study the dynamics of the development of erosion processes in the Zerendinsky district of the Akmola region using satellite image data based on the NDVI vegetation index [11].

Thus, the remote method for assessing the risk of pasture degradation using NDVI is an effective tool for monitoring and managing pasture ecosystems, allowing one to make informed decisions on their conservation and development.

5 Conclusion

Organizing a system for the rational use of pasture lands will improve the economic efficiency of pasture livestock farming. Also, the introduction of remote monitoring using aerospace technologies helps to increase the growth energy of animals by 10–13%, and increase the yield of forage plants by 2.5–4 c per 1 ha. Thus, the introduction of new techniques will increase profits from additionally obtained products.

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On the Issue of Energy Efficiency of Dividing Grain Materials into Parts

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Abstract. Cereals have become widely used as affordable food products, and their processing unlocks their nutritional potential. A decrease in the energy efficiency of technological processes for processing grain raw materials occurs due to changes in the design of specialized machines and the use of less energy-intensive grinding methods, for example, by shearing. Grain feed entering the body is transformed in the digestive tract and ensures the implementation of all vital functions of the animal. The fewer nutrients are excreted, the more efficiently the feed is used. The article presents a scientific hypothesis that the energy efficiency of the grain processing process should consist not only of the specific energy intensity of the process (the ratio of energy consumed to productivity), but also equally of the feed bioconversion indicator. Tests on dividing caryopsis into parts were carried out on privately manufactured equipment using strain gauges. An experiment to determine the nutritional value of wheat grain raw materials was ordered from a specialized laboratory. An analysis of the known accumulated experience and available literature shows that when processing grain raw materials, on average, the leaders in energy costs are: grinding, drying, separation and mixing. The proposed methodological approach includes the development of an objective description of the process of processing grain crops using the example of preparing feed mixtures for farm animals.

Keywords: Cereals · Caryopsis · Grain processing · Grinding · Energy efficiency · Development of grinding scheme · Farm animals

1 Introduction

Cereals are widely used all over the world and are an irreplaceable, affordable and highly nutritious food product. Their additional processing and/or treatment allows to greatly increase the beneficial properties, unlock the potential of nutrients, and also opens up many ways to use the finished processed product [22, 23, 26].

Modern trends in improving the designs of machines for grain processing processes do not sufficiently reduce energy costs and cannot change the root problems associated with the low quality of finished products. This, in many respects, was historically due to the lack of quality control of finished products and the availability of cheap power sources for such machines (gasoline and diesel engines, powerful electric motors). However, the growth of the planet's population causes general trends in saving energy resources

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in all areas of production. Thus, a decrease in the energy efficiency of technological processes for processing grain crops should occur through the proposal of new technological schemes. From the point of view of the theory of dividing materials into parts, less energy-intensive methods are cutting, chopping and their derivatives [4–12, 27].

Each object of cultivation, based on its biological characteristics, requires a certain amount and ratio of complete protein, fat, carbohydrates and minerals for its normal existence. After assimilation, one part of the matter and energy is used by organisms to carry out growth processes (plastic metabolism), and the other to carry out their functional activities (functional metabolism). Substance and energy entering the body in the form of food, being transformed in the digestive tract, ensure the implementation of all vital functions of the animal. The less nutrients are excreted in excrement, the more efficiently the feed is used. Therefore, the most important task is to create and use in practice such feed mixtures, the energy of which would ensure plastic exchange to the maximum extent.

Depending on the type of biological objects, their age and fattening period, the most effective are feed mixtures that are balanced not only in energy and basic nutritional elements, but also containing diet ingredients aligned in granulometric composition. Particles of the same size mix better, do not segregate, and the resulting mixtures are homogeneous and more efficiently absorbed by the animal body [1, 4, 5, 9, 10, 13-15, 22–25, 28, 29].

By combining the above theses, we can put forward a scientific hypothesis. The energy efficiency of the grain processing process should consist not only of the specific energy intensity of the process (the ratio of energy consumed to productivity), but also equally of the energy efficiency of the finished grain feed by the end consumer (bioconversion of feed mixtures). For example, milk production in cattle, egg production in poultry, or meat productivity in various farm animals during fattening. Conventionally, this indicator can be called “overall energy efficiency” of the grain processing process.

The implementation of fundamental research into the interaction of the working parts of processing machines with various types of grain raw materials will make it possible to build highly productive and energy-efficient production technologies, taking into account the individual characteristics of the consumer for the effective management of bioconversion of nutrients.

Next, we will consider these processes using the example of processing grain raw materials to prepare feed mixtures for farm animals.

2 Materials and Methods

1. To analyze the results presented in this article, standard techniques for combining known modern scientific data from various sources were used. Including available literature; own research; theoretical foundations of the process of dividing materials into parts, studies of the relationship between energy costs and the characteristics of the crushed product, which were substantiated by F. Kik, P.R. Rittinger, V.A. Kirpichev, P.A. Rebinder, G. Rumpf, A.A. Griffiths and other scientists [1–29].

Grinding of grain crops was carried out on a specially manufactured rotary crusher with a horizontal rotor. The characteristics of the equipment used are presented earlier in the following scientific works of the author [3, 8, 11, 12].

2. Critical stress tests were carried out when cutting grains of forage crops of the following varieties: wheat (Yuka, Tanya, Batko, Yubileynaya 100), corn (Atalis, Diadema, Kristel, Mashuk-480, Mashuk-355), oats (Monarch, Valdin), barley (Dobrynya-3, Kondrat, Gordey). To carry out the experiment, an installation was created that allows one to estimate the force *F* required to dividing grains of various crops into parts by cutting in different planes and with high accuracy, based on strain gauges (Fig. 1).

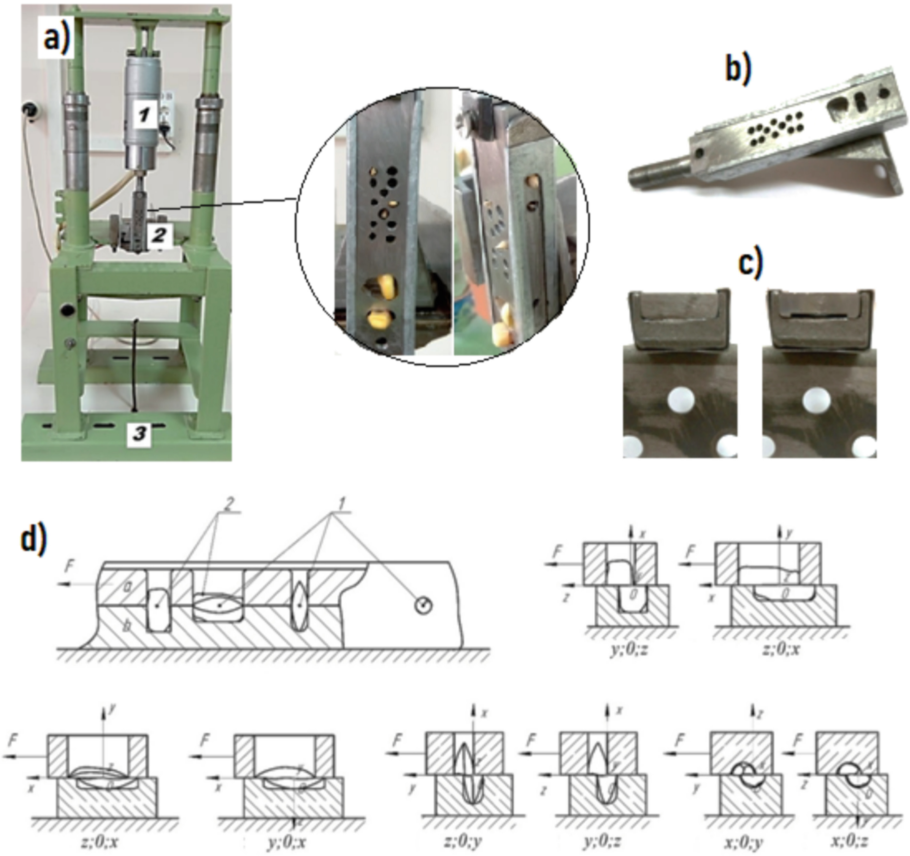


Fig. 1. Installation for testing grains when cutting: a) general view of the installation (1 - electric motor, 2 - cutting element, 3 - frame); b) general view of the cutting element; c) options for cutting clearances; d) diagram of cutting grains along planes.

Installation (Fig. 1, a) contains a moving part *a* and a rigidly fixed guide *b* (Fig. 1, d). In this case, element *a* has several versions for measurements with different sizes of the gap between it and the guide *b* (Fig. 1, c). To fix grains of wheat, barley, oats *1* and corn *2*, appropriate recesses were made in the installation parts (Fig. 1, b).

To determine the critical shear stress τ, the breaking force was determined *F* (Fig. 1, c), which depends on the physical and mechanical properties of grains (strength, moisture, size, etc.), the type of grain materials (corn, barley, wheat and other). After that, in the JMicrovision program, a digital image of area *A* was measured, along which the cutting took place.

3. Tests to determine the nutritional value of wheat grain raw materials with samples of 2 kg in whole and grinded versions were carried out in an independent specialized laboratory "Federal Center for Assessing the Safety and Quality of Grain and Its Processed Products". A mixture of durum fodder wheat varieties (Yuka, Tanya, Batko, Yubileinaya 100) was studied.
4. This article contains an analysis of current works on the topic under study and puts forward a scientific hypothesis. It lies in the fact that the processing process must be considered from the point of view of "overall energy efficiency", which takes into account the specific energy consumption for the implementation of the process itself and the bioconversion of the feed product obtained from the finished raw materials. Based on this hypothesis, a brief theoretical justification for the main stages of the formation of this methodological approach is proposed and given.

3 Results

Analysis of literarature and accumulated experience made it possible to schematically display the main components of the grain processing process (Fig. 2) [1, 12–18, 21, 25–28].

The diagram shows that when processing grain crops, key processes are identified (grinding, drying, mixing, separation and others), which in turn have become characteristic of individual sectors of industry and production. In each individual case, the key and, accordingly, the most energy-intensive type of processing may not be the same.

The most commonly used method is grinding, that is, dividing whole grains into a given number of parts. At the same time, in the scheme, improvement, separation and oil extraction are separated into separate groups, but in their implementation, the process of grinding the feedstock is often used. A comparative analysis of studies and known data on the energy intensity of grain processing processes [6, 7; 15–17; 19, 21] showed that on average the leaders in energy costs are also: grinding - 100…500 kWh/t, which corresponds to the author's data [8, 11]; drying – 20…100 kW•h/t; transportation of raw materials – 10…50 kW•h/t; and its storage – 0.1…1 kW•h/t.

The results of the study of the critical shear contact stress τ, when the grain is divided into 2 or more parts, are presented in Table 1.

The data were obtained at grain moisture content of 13.9…14.5% and correspond to studies conducted at different times by other authors [], the coefficient of variation did not exceed 26%. For all grain crops, the minimum values correspond to the cross section.

Additionally, the critical shear stress τ for wheat was fixed when the gap δ between surfaces *a* and *b* (Fig. 1, c) of the cutting element changed. According to the results of

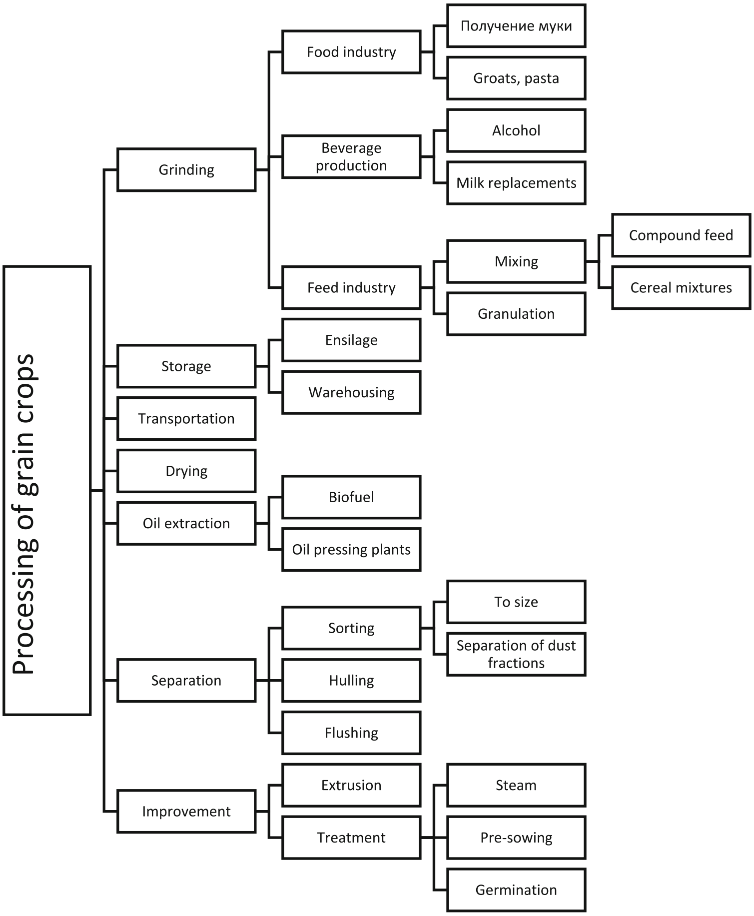


Fig. 2. Scheme of the main types of grain processing

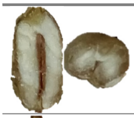
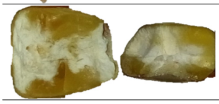
the experiment, a change was noted in the number of grains crushed into 3 or more parts N_3 and the number of whole particles N_0. The critical stress τ of the caryopsis increases on average from 8.7 MPa at the minimum gap and to 11.9 MPa at $\delta = 1.5$ mm (Fig. 3).

If we set the gap above 1.5 mm, then the separation process does not actually take place, which is confirmed when trying to cut wheat with a gap of 2 mm between the working surfaces of the cutting element, when the finished product contained up to 80% of whole grains.

Laboratory tests on the nutrient content of wheat grains are presented in Table 2.

The table shows that grinding can significantly increase the nutritional value of the feed mixture by increasing the percentage of protein, fat and fiber in the total mass. The mass fraction of protein in whole grain is 12.42%, and 14.08% in crushed grain, which is 13.4% more. The amount of fiber in whole grain is 3.44% and 6.17% in ground grain, which is 79.4% higher than the first figure. The fat content in the original product is 2.02%, and in its dust fraction it is 70.3% higher and amounts to 3.44%. The ash

Table 1. Critical stresses of grains when cutting

Shot of the cut surface of the caryopsis	Grain culture	Critical shear/cut stress, MPa		
		along		across
		z;0;x	*x;0;y*	*y;0;z*
	Wheat	10.7	11.5	7.6
	Barley	12.5	14.5	3.8
	Oats	9.9	11.4	3.5
	Corn	4.6		2.9

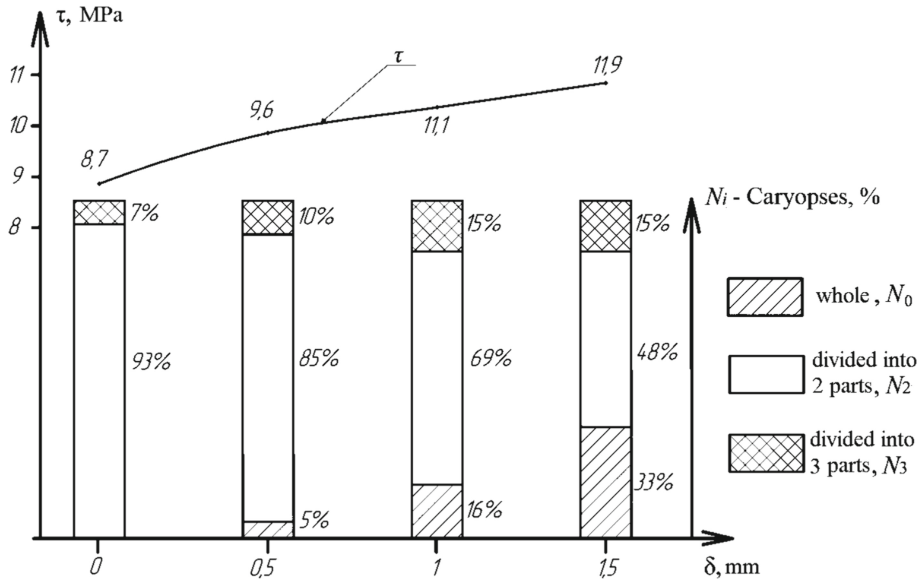


Fig. 3. Change in the nature of dividing of wheat grains into parts with increasing gap δ on the cutting installation

Table 2. Laboratory study of the nutritional value of wheat grains

Indicator	Unit of measurement	Measurement error	Whole grain	Grinded grain
Moisture content	%	±0.2	10.8	10.4
Mass fraction of protein	%	±0.45…0.47	11.08	12.62
Mass fraction of protein (absolutely dry substance)	%	±0.45…0.47	12.42	14.08
Mass fraction of fiber	%	±1.24…1.28	3.06	5.53
Mass fraction of fiber (absolutely dry substance)	%	±1.24…1.28	3.44	6.17
Mass fraction of fat	%	± 0.43…0.48	1.79	3.04
Mass fraction of fat (absolutely dry substance)	%	±0.43…0.48	2.02	3.44
Ash content	%	±0.05	1.54	2.27
Ash content (absolutely dry substance)	%	±0.05	1.73	2.53

content or mineral content in crushed grain is 2.53%, which is 46.2% higher than in whole wheat – 1.73%. Thus, the studies carried out have confirmed that nutritionally balanced feeds should be balanced in granulometric composition.

4 Discussion

The objectivity of the description of the uniformity of the granulometric composition of the crushed product and its compliance with the specified zootechnical requirements is achieved through the use of an indicator of the actual effectiveness of the grinding process. The possibilities of using this technique are presented by the authors [4, 8, 11, 12, 20], where its greater information content is substantiated in comparison with well-known generally accepted assessment methods (grinding modulus and degree of grinding).

Additionally, in this methodology, in accordance with the presented scientific hypothesis, the criterion of "overall energy efficiency" of the grinding process will be introduced, which will allow us to evaluate the bioconversion of the feed mixture based on the actual useful product obtained (milk, egg, meat, etc.) and the total specific energy consumption for its production. At this stage, this principle can be represented as a formula:

$$Koef = {}^{Wei}/_{Cfm}, \tag{1}$$

Koef – criterion of "overall energy efficiency" of the grinding process, kWh/kg;

Wei – specific energy intensity of all operations during the processing of grain crops (crushing, drying, separation and others), kW•h/t;

Cfm – bioconversion of the resulting feed mixture, t/kg.

Thus, it is possible to theoretically formulate what factors determine the reliability of the grain processing process to obtain a given number of particles when dividing grains into parts (Fig. 4).

To experimentally confirm these theoretical calculations and experimentally test the design and technological approach proposed in the works [3, 8, 11, 12] for grinding grain crops, it is planned to manufacture an experimental installation. This will be a feed grain grinder-mixer with the ability to monitor in real time energy costs for processing processes and individually adjust the impact modes during grinding for each individual type of grain.

5 Conclusion

1. Despite the introduction of new technological schemes for processing grain crops and the use of less energy-intensive methods for dividing grains into parts, the technological process of grinding remains the most energy-intensive among all types of influence on grain. Up to 500 kWh/t of finished grain product is spent annually on its implementation. However, this does not guarantee the good quality of such a product and often energy resources are not spent efficiently. A clear indicator of this is the low bioconversion of feed mixtures, which leads to a decrease in livestock productivity in general.
2. The physical and mechanical properties of grain materials at a humidity not higher than 14.5% and a coefficient of variation 8…26%, corresponding to those recorded earlier, have been clarified. The critical shear stress (static impact) was: wheat 7.6…11.5 MPa, barley 3.8…14.5 MPa, oats 3.5…11.4 MPa, corn 2.9…4.6 MPa.

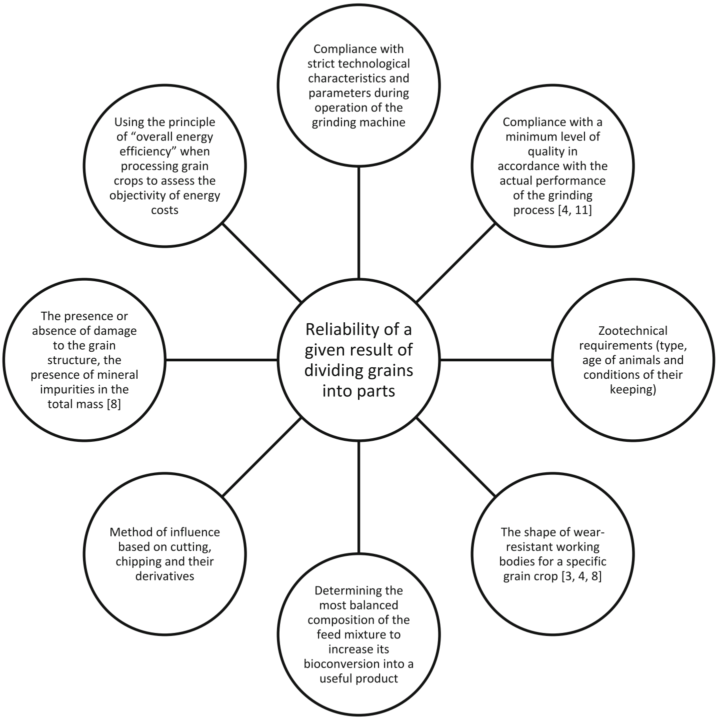


Fig. 4. Scheme for forming the reliability of the process of separating grain into a given number of parts

With an increase in the gap between the cutting surfaces to $\delta = 1.5$ mm or more, the number of whole grains and those divided into 3 or more parts increases. These figures indicate the prospects of creating grain-processing machines based on the cutting principle, which will be more energy efficient than impact shredders widely used in the world [2, 3, 13, 20, 24, 25].

3. Grinding grains can significantly increase the nutritional value of the feed mixture by increasing the percentage of protein, fat, fiber and minerals in the total mass. Laboratory studies have proven an increase in these indicators by 13.4…79.4%. Nutritionally balanced feeds must be 100% balanced in granulometric composition (correspond to the specified grinding), they must not contain whole grains and flour fractions that reduce the efficiency of digestion of such feeds by farm animals [4, 6, 10, 13, 18, 23, 24, 26, 28, 29].
4. As part of testing the proposed scientific hypothesis about the "overall energy efficiency" of grain processing, it is necessary to study the process of grinding grain crops using a design and technological scheme based on cutting, chopping and their derivatives. Describe the overall energy efficiency using a theoretical criterion and experimentally evaluate the effectiveness of reducing energy costs when implementing such a scheme. To determine the feasibility of using high-quality feed, uniform

in granulometric composition, to increase the rate of bioconversion of nutrients into the corresponding livestock products.

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Efficiency of Biopreparation Application in Soya Cultivation on Common Chernozem Soil

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Abstract. Sustainable development of agricultural systems can be ensured by stable and guaranteed yields of agricultural crops. The aim of the research was to select biopreparations influencing the processes of symbiosis in crops for stable production of soybean seeds. The object of the research was medium-ripening soybean variety Duniza. We studied biopreparations containing bacteria of the genus Rhizobium of different preparative forms - dry on the basis of peat: Nitrofix P, Rhizotorfin 634a (dry form), and liquid: Nitrofix Zh, Rhizotorfin 634b (liquid form) and adhesive Adjugrain, which includes polysaccharides of natural origin and the system of their application. On average for three years, the crude mass of active nodules - 25.7 g/m^2, as well as the active symbiotic potential of soybean were the greatest when combining the preparation Rhizotorfin, strain 626a with film-forming Adjugrain, ASP was - 8226 kg × day/ha. Economic efficiency in the form of cash proceeds from the application of this agro-approach was the maximum, with a yield of 2.23 tonnes/ha, cost of production - 12282 rub/t and seed production costs - 24318 rub/ha was 25182 rub/ha.

Keywords: sustainable development · nodule · adhering bacteria · symbiosis · yield · profit · efficiency

1 Introduction

At present, stable production of high-quality grain yields of various agricultural crops is important for the sustainable development of agricultural production to ensure food security of the country [1–3]. Soybean, due to the content in its seeds up to 50% protein, 25% oil and other nutrients can solve the issues related to the deficit of vegetable protein, both in human nutrition and in the livestock industry. S.V. Didorenko et al. (2020), V.T. Sinegovskaya et al. (2021), O.G. Shabaldas et al. (2022) note that to obtain stable high yields of soybean in all regions of the country it is necessary to strictly follow the scientifically based methods of cultivation technology taking into account soil and climatic conditions, as well as the development and improvement of new elements of technology for modern soybean varieties [4–6]. The potential of soybean is quite high, if technological methods are followed, the grain yield can reach up to 3.5–4.5 t/ha, at present the average yield of soybean in the country reaches only 1.6 t/ha [7–9]. Having unique biological features - the ability to fix nitrogen in the process of symbiosis with

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specialised bacteria of the genus Rhizobium, soybean is able to provide plants not only with nitrogen, but also accumulate a high amount of protein in seeds due to biological nitrogen fixation. According to a number of authors, the contribution to nitrogen nutrition of soybean plants due to biological nitrogen fixation is at the level of 50–60%. And this is largely determined by the activity of nodule bacteria and the system of their application [10–12]. The aim of research is to improve the cultivation technology by selecting biopreparations that affect the symbiosis processes in crops for stable production of soybean seeds.

2 Materials and Methods

The study of the influence of biological preparations for seed treatment on the symbiotic potential and yield of soybean was conducted in 2013–2015 in Krasnodar Krai in the conditions of unstable moisture zone on ordinary chernozem. Agrotechnics in the experiments was generally accepted for the cultivation zone, soybean was sown after winter wheat, soil treatment consisted of stubble husking, ploughing and spring pre-sowing cultivation, seed treatment with the studied biopreparations was carried out directly on the day of sowing. Soybean was sown in a wide row (70 cm) [13]. The object of research was a medium-ripening soybean variety Duniza. Biological preparations of different forms containing bacteria of the genus Rizobium: Nitrofix P (2.0 kg/t) Rizotorfin 626a (3 kg/t) (dry form), Nitrofix Zh (2.5 l/t), Rizotorfin 634b (3.0 l/t) (liquid form) and Adjugrein (1.0 l/t) were used as a material for research. In the experiment variants were placed randomly, with 4-fold repetition, the accounting area of the plot was - 28.0 m^2. The studies were conducted in accordance with generally accepted methods [14, 15].

3 Results and Discussion

To determine the effect of seed treatment with bacterial preparations on the activity of symbiotic activity, soil monoliths with root system were sampled and counted: the number and mass of formed nodules. During the period of research weather conditions differed, the most favourable for the growth and development of soybean they were formed in 2013, when for the growing season of soybean fell 297 mm of precipitation, with the sum of active temperatures 2409 °C, critical for moisture availability was 2015, precipitation fell in the amount of 197.8 mm. In this regard, it should be noted that the most active work of the symbiotic apparatus took place in 2013. On average for three years, 1803 pcs/m^2 nodules were formed in the control in the branching phase of soybean. By the phase of bean formation, the number of nodules was 1590 pcs/m2. All studied biopreparations to a greater or lesser extent influenced nodule formation already at the beginning of soybean vegetation, so in the branching phase, depending on the biopreparation, the number of nodules increased compared to the control from 77.0 (Nitrofix Zh) to 277.0 (Rhizotorphin, strain 626a) pcs/m2, which is a significant increase, by the phase of bean formation the number of nodules in the soil monolith with root system significantly increased compared to the variant without seed treatment from 445 (Nitrofix Zh) to 707 (Rizotorfin, strain 626a) pcs/m^2 (Fig. 1).

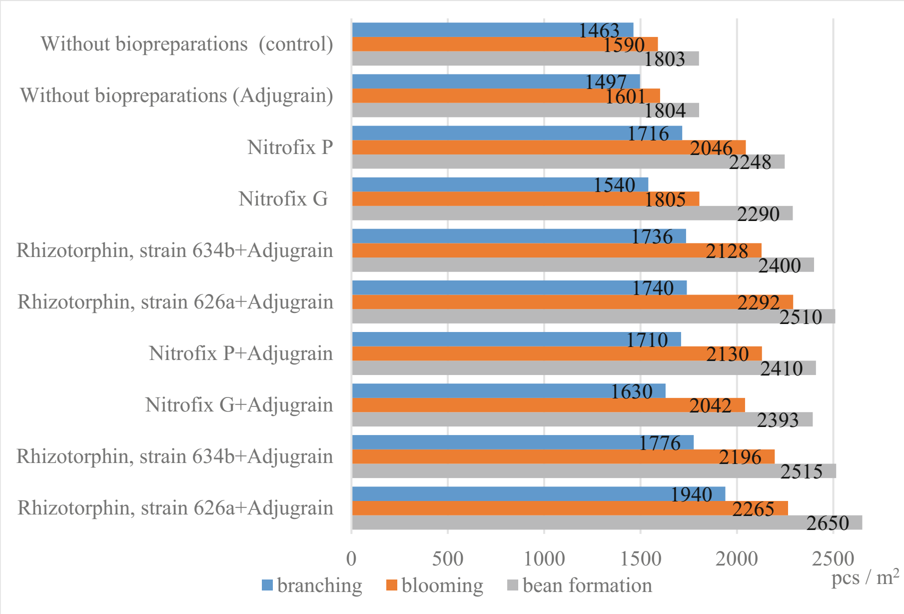

Fig. 1. Number of soybean nodules depending on the application of biopreparations and adhesive, average for 2013–2015, pcs/m^2 (NSR05: branching phase - 58, flowering phase - 125, bean formation phase - 204).

Additional treatment of seeds with adhering agent contributed to an increase in the number of nodules compared to the control from 590 (Nitrofix Zh + Adjugrain) to 847 (Rizotorfin, strain 626a + Adjugrain) pcs/m^2, compared to the variant without seed treatment, but it should be noted that in its complex application with biopreparations reliable increase in the number of nodules compared to the use of biopreparations independently not established. The crude mass of nodules in the control variant in the phase of bean formation was 16.5 g/m^2. The most favourable environment created for nodule bacteria when using preparations based on peat - Nitrofix P and Rhizotorfin, strain 626a, which is a natural environment for microorganisms, promoted the formation of the largest mass of nodules on soybean roots, and, accordingly, per unit area. In variants with bacterial preparations in the process of symbiosis formed the largest mass of raw nodules, compared to the control, so in the phase of bean formation it was more depending on the variant from 2.6 (Nitrofix Zh) to 8.5 (Rizotorfin, strain 626a) g/m^2, or 1.2–1.5 times, which is a significant increase. Additional treatment of seeds with film-forming agent Adjugrain increased the efficiency of symbiosis in soybean crops, in variants with joint application of biopreparations with Adjugrain the mass of nodules was higher than the control by 6.6 - 9.2 g/m^2, i.e. 1.4–1.6 times (Fig. 2).

The maximum mass of nodules in the process of photosynthesis was formed when seeds were treated with biopreparation Rizotorfin, 626a in complex with adhering agent -25.7 g/m^2. It was found that the highest active symbiotic potential in soybean crops was in the most favourable in terms of moisture in 2013. Depending on the variant, it varied

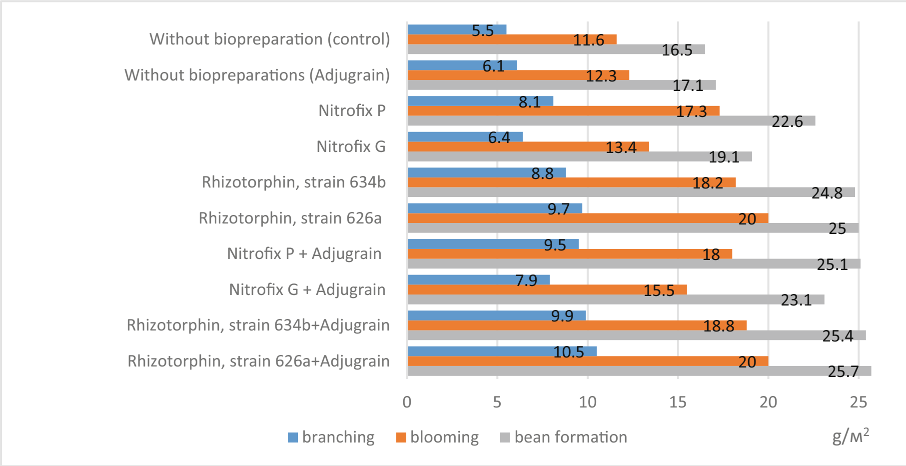

Fig. 2. Crude mass of nodules depending on the application of biopreparations and adhesive, average for 2013–2015, g/m^2 (NSR05: branching phase -2, 5, flowering phase -4.3, bean formation phase - 6.0)

from 4408 (without biopreparation) to 10823 (Rizotorfin, strain 626a + Adjugrain) kg × days/ha (Fig. 3).

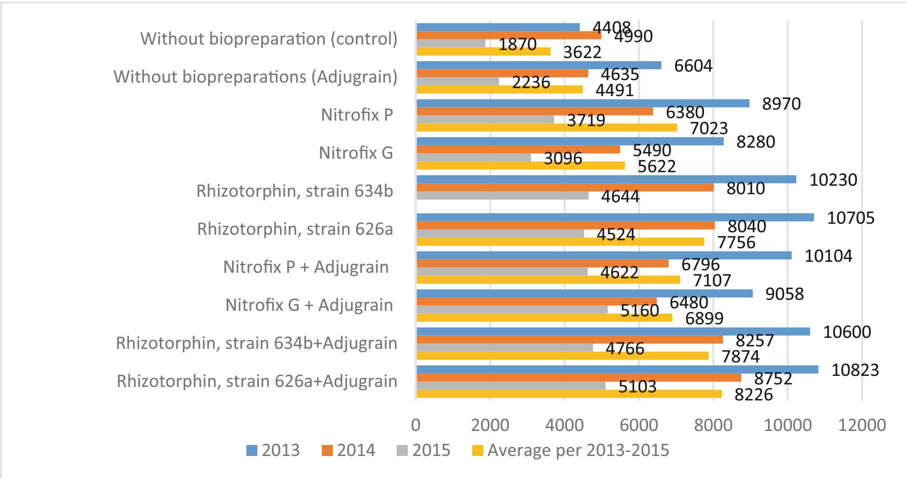

Fig. 3. Effect of biopreparation and adhering agent application on active symbiotic potential of soybean, average for 2013–2015, (branching - bean formation) kg × days / ha

The maximum ASP - 8226 kg × day / ha was established when seeds were treated with Rizotorfin, strain 626a with Adjugrain. Thus, it was found that the use of seed treatment with biopreparations, both alone and in combination with adhering agent has a positive effect in yield increase (Table 1).

Table 1. Soybean yield depending on biopreparation and adhering agent, average for 2013–2014

Variant	Productivity, t / ha	Yield increase, t / ha
Without biopreparation (control)	1.80	-
Adjugrain	1.82	0.02
Nitrofix P	1.92	0.12
Nitrofix G	1.94	0.14
Rhizotorphin, strain 634b	2.06	0.26
Rhizotorphin, strain 626a	2.14	0.34
Nitrofix P2,0 kg/t + Adjugrain	2.03	0.23
Nitrofix G + Adjugrain	1.98	0.18
Rhizotorphin, strain 634b + Adjugrain	2.13	0.33
Rhizotorphin, strain 626a + Adjugrain	2.23	0,43
NSR_{05}	0.11	-

Reliable yield increase on average for three years, compared to the control for the studied biopreparations, both with and without the use of film-former varied from 0.12 to 0.43 t/ha, the highest yield was obtained with seed treatment of Rizotorfin, strain 626a with Adjugrain - 2.23 t/ha. As a result of determining the economic efficiency, it was found that the use of seed inoculation with biopreparations on ordinary chernozem in soybean cultivation is economically beneficial (Table 2).

Table 2. Economic efficiency of application of biological preparations and adhering agent in soybean crops of Duniza variety, on average for 2013–2015

Variant	Indicator			
	cost price, rub/t	labour costs, rub/ha	profit, rub/ha	profitability level, %
Without biopreparation (control)	14748	23596	16404	70
Adjugrain	14588	23633	16867	71
Nitrofix P	14382	24449	18051	74
Nitrofix G	14118	24283	18717	77
Rhizotorphin, strain 634b	13324	24249	21251	88
Rhizotorphin, strain 626a	12776	24275	23225	96
Nitrofix P2,0 kg/t + Adjugrain	13685	24495	20255	83

(*continued*)

Table 2. (*continued*)

Variant	Indicator			
	cost price, rub/t	labour costs, rub/ha	profit, rub/ha	profitability level, %
Nitrofix G + Adjugrain	13969	24306	19194	79
Rhizotorphin, strain 634b + Adjugrain	12851	24289	22961	95
Rhizotorphin, strain 626a + Adjugrain	12282	24318	25182	104

The cost of production at application of biopreparations for soya seed treatment decreased from 366 to 2466 rub/ha, and the profit and profitability level increased from 1647 to 8778 rub/ha, and by 4.3–34.1%, respectively.

4 Conclusions

As a result of research it was established that the active symbiotic potential of soybean was maximum when applying Rhizotorfin, strain 626a with adhesive, ASP was 8226 kg-days/ha. Seed yield increment to the control at treatment of seeds Nitrofix P and Nitrofix Zh was 0.12–0.14 t/ha, at application of Rizotorfin, strains 626a 634b soybean seed yield increased by 0,26–0,36 t/ha. The use of biopreparation in the system with Adjugrain increases the activity of symbiosis in soybean crops by 2.2–6.2%. When using in the technology of soybean cultivation of pre-sowing seed treatment with bacterial preparations with a sticking agent, it is possible to obtain a sufficiently high level of profitability of soybean seed production on ordinary chernozem – 73/8–103.7%.

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Modern System Approaches to Diagnostics of Sturgeon Fish Diseases in Installations of the Closed Water Supply

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Abstract. The article proposes systematic approaches to control and maintain the well-being of aquaculture enterprises that contribute to the sustainable development of industrial fish farming systems. The results of pathologies monitoring that occur in sturgeon fish kept in closed water supply installations are presented. It was found that almost all fish species had clinical signs of various diseases – hyperemia and erosion on the gill covers and fins, ascites and swelling of the mouth. During complex bacteriological studies of the fish with disease, in a number of cases the causative agent of aeromonosis was identified such as *Aeromonas hydrophila, Aeromonas veronii, Aeromonas caviae*, as well as *Pseudomonas anguilleseptica, Citrobacter braakii, Streptococcus parauberis*, parasitological – ciliates of the *Chlamidodontidae* family. The histological studies of parenchymal organs of the fish with disease carried out in this case made it possible to more accurately determine the causes of the disease in the early stages, which makes it possible to systematize the assessment of diseases of sturgeon species and provide a strategy for maintaining the well-being or improvement of fish farms.

Keywords: fish · fish farming · sturgeon · aquaculture · bacterial infections · complex diagnostic tests

1 Introduction

The current stage of the development of aquaculture in the Russian Federation is characterized by intensive technology for growing sturgeon fish on the basis of basin farms. However, in the installations of the closed water supply there is a high probability of the occurrence of diseases of various etiologies, causing great economic damage to the entire fish farming industry [7, 8].

For a long period of time uncontrolled transportation and transplantation of fish, as well as the use of water from natural sources, were accidental sources of parasitic and viral-bacterial infections. At the same time, diseases can be caused by various

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pathogens – both viruses and bacteria, as well as fungi and protozoa, which pose a significant threat to the stability and sustainable development of industrial aquaculture systems [9, 12, 14].

The occurrence of diseases is also provoked by a set of general stereotypical reactions of the body to the action of strong stimuli of different nature, in other words, stress [4, 10]. Under the influence of stress factors, various nonspecific reactions develop in the body, leading to a general adaptation syndrome, the characteristic features of which are hormonal, biochemical and hematological changes in the body of fish. That is, in response to dramatically changing environmental conditions, deep physiological reactions of an adaptive nature occur, which can significantly reduce the body's protective functions to the influence of various fish pathogens [6, 7].

According to the Department of Veterinary Medicine, by the end of 2023 in the Krasnodar region operate 149 fish farms and 374 fishing reservoirs. The share of the Krasnodar region in the total production of marketable fish in Russia is about 9%, in the Southern Federal District – is more than 30% [2].

At the same time, regionalization of the territory of the Russian Federation is carried out only for 16 fish diseases – 8 of which are viral, 2 are bacterial, 3 are parasitic and 3 are fungal. And restrictive diseases (quarantine) are established only for 8 of them. However, there are a number of non-quarantine diseases, including those for which regionalization of the territory of the Russian Federation is not carried out.

The establishment of quarantine entails the mandatory implementation of a number of special measures to eliminate the disease, restriction of the movement of controlled goods, the export of raw materials and products, etc. All costs are borne by the owner of the fish, and therefore the owner incurs very serious losses. And the lack of regulatory documents regulating the implementation of planned preventive treatments entails a number of problems that complicate the process of reproduction and cultivation of expensive gourmet fish.

Therefore, the main task for veterinarians and ichthyopathologists is to develop a plan for systematic monitoring and treatment and preventive measures in this industry based on diagnostic studies and making the correct diagnosis of the disease [1].

In accordance with the plan of diagnostic studies, veterinary-preventive and anti-epizootic measures in fish farms of all forms of ownership, diagnostic studies (bacteriological, virological, parasitological) are carried out for carp aeromonosis, salmon aeromonosis, botryocephalosis, spring carp viremia, viral hemorrhagic septicemia of salmon, gyrodactylosis, dactylogyrosis, myxobacteriosis, opisthorchiasis, pseudomonosis, phylometroidosis.

In the North Caucasus research work has been carried out for a number of years to monitor and analyze the state of fish farms regarding parasitic and bacterial diseases of fish raised in closed water supply conditions [1, 3].

However, a systematic assessment of diseases of sturgeon fish species in the region has not been carried out, on the basis of which the purpose of this study was to analyze their incidence of viral, bacterial, parasitic diseases based on monitoring the condition of fish farms engaged in keeping and growing sturgeon in the installations of the closed water supply.

2 Materials and Methods

During 2023 to monitor and clarify the etiology of the disease in sick fish with various clinical signs, we conducted studies with the following species of sturgeon: Russian sturgeon (n = 10), Russian-Siberian sturgeon (n = 10), Lena (Siberian) sturgeon (n = 10), bastard sturgeon (n = 5), albino beluga (n = 5), sterlet (n = 10). All fish selected for research were kept in the installations of the closed water supply.

Virological studies were carried out using reagent kits designed to detect the DNA of the Siberian sturgeon herpesvirus in biological material using the PCR method with hybridization-fluorescent detection of amplification products in real time (manufacturer: NextBio LLC, trademark "AmpliPrime").

Bacteriological studies were carried out using classical methods, including pathological, microscopic, bacteriological and biological methods with confirmation of isolated cultures on a Maldi-Tof mass spectrometer (manufactured by Microflex LT MALDI Biotyper Bruker Daltonik GmbH, Germany).

Complete parasitological examination was carried out, starting from a general external examination to a complete parasitological dissection, followed by evaluation of preparations and scrapings using light microscopy using a Zeiss AxioImager microscope (manufactured by Carl Zeiss AG, Germany).

Histological examination was carried out using microscopic examination of histological preparations.

3 Results

As a result of the studies carried out on mixed hemorrhagic septicemia of fish in different species of sturgeon, were obtained the following results presented in Tables 1, 2 and 3.

Table1. Pathogens identified in fish during the studies

Types of fish	Diseases/etiology		
	Viral*	Bacterial	Parasitic
Russian sturgeon (n = 10) *(Acipenser gueldenstaedtii)*	–	*Aeromonas hydrophila*	–
Russian-Siberian sturgeon (n = 10) *(Acipenser gueldenstaedtii X Acipenser baeri)*	–	*Aeromonas hydrophila*	–
Lena (Siberian) sturgeon (n = 10) *(Acipenser baeri)*	–	*Aeromonas veronii Pseudomonas anguilleseptica; Citrobacter braakii; Streptococcus parauberis*	Ciliates of the family *Chlamidodontidae*

(*continued*)

Table1. (*continued*)

Types of fish	Diseases/etiology		
	Viral*	Bacterial	Parasitic
Bastard sturgeon (n = 5) *(Acipenser nudiventris)*	–	*Aeromonas caviae*	–
Albino beluga (n = 5) *(Acipenser huso L.)*	-	*Hafnia alvei*	Ciliates of the family *Chlamidodontidae*
Sterlet (n = 10) *(Acipenser ruthenus)*	–	*Aeromonas veronii*	–

* studies were carried out only on the herpesvirus of Siberian sturgeon

Bacteriological studies revealed causative agents of aeromonosis, such as *Aeromonas hydrophila, Aeromonas veronii, Aeromonas caviae*, as well *as Pseudomonas anguille-septica, Citrobacter braakii, Streptococcus parauberis*. During parasitological studies, ciliates of the family *Chlamidodontidae* were identified in Lena (Siberian) sturgeon and albino beluga.

Table 2. Clinical signs of diseases in the studied fish

Types of fish	Clinical signs
Russian sturgeon *(Acipenser gueldenstaedtii) (GUE)*	Hyperemia on the gill covers, erosion on the fins
Russian-Siberian sturgeon *(Acipenser gueldenstaedtii X Acipenser baeri) (GUE X BAE)*	Exhaustion, muscle protrusion (in the form of swelling) in the area of the far end of the axial skeleton (notochord)
Lena (Siberian) sturgeon *(Acipenser baeri) (BAE)*	Erosion on the gill covers and scutes along the spine and on the fins
Bastard sturgeon *(Acipenser nudiventris) (NUD)*	No visible clinical signs
Albino beluga *(Acipenser huso L.) (HUS)*	Inactivity, hyperemia on the top of the skull, in the area of the pectoral fins
Sterlet *(Acipenser ruthenus) (RUT)*	Ascites, swelling and hyperemia of the mouth and anus (protrusion), hyperemia of the pectoral and ventral fins

From the data in the Table 2 follows that almost all fish species had clinical signs of various diseases, with the exception of bastard sturgeon. However, when conducting bacteriological studies in the body of this species, the presence of the causative agent of aeromonosis was determined *(Aeromonas caviae)* (Figs. 1, 2, 3, 4, 5, 6, 7 and 8).

Fig. 1. Hyperemia on the gill covers, erosion on the fins in Russian sturgeon

Fig. 2. Hyperemia in the area of gill covers and ethmoid area in Russian-Lena (Siberian) sturgeon

Fig. 3. Swelling in the area where the body meets the tail in Russian-Siberian sturgeon

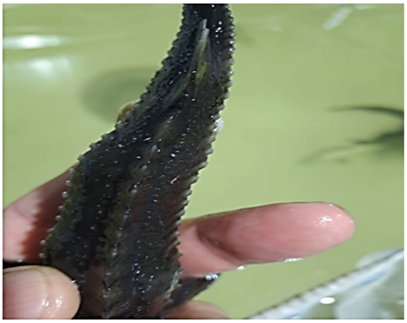

Fig. 4. Swelling in the area where the body meets the tail in Russian-Siberian sturgeon

Fig. 5. Erosion on the gill covers and scutes along the spine of the Lena (Siberian) sturgeon

Fig. 6. Erosion on the gill covers and scutes along the spine of the Lena (Siberian) sturgeon

Fig. 7. Ascites in sterlet

Fig. 8. Ascites in sterlet

Table 3. Results of histological studies of fish

Types of fish	Results of histological studies
Russian sturgeon *(Acipenser gueldenstaedtii) (GUE)*	–
Russian-Siberian sturgeon *(Acipenser gueldenstaedtii X Acipenser baeri) (GUE X BAE)*	– in the spleen tissue: the architectonics of the organ is disturbed, follicular hyperplasia, perivascular zones are infiltrated with lymphoid cells, an inflammatory reaction is observed in the red pulp – proliferation of lymphoid cells. Splenitis. In the liver tissue multiple foci of fatty degeneration of the organ parenchyma are observed (discomplexation of cellular elements, increased levels of lipids, individual droplets of fat, small hemorrhages are detected in the cytoplasm of hepatocytes), foci of necrosis and cell lysis, brown grains of extracellular hemosiderin. Hemosiderosis. Fatty liver degeneration; – in the damaged muscle tissue and skin from the lower part of the body, as well as at the base of the ventral and caudal fins, there is epidermis, the dermis in the affected areas is necrotic, the muscle fibers in the area of the affected areas are destroyed and infiltrated with lymphoid cells and macrophages, with small necrosis. The above pathological changes are characteristic of an alternative type of inflammation

(*continued*)

Table 3. (*continued*)

Types of fish	Results of histological studies
Lena (Siberian) sturgeon *(Acipenser baeri) (BAE)*	– liver: the architectonics of the organ is disturbed, multiple foci of fatty degeneration of the organ parenchyma are observed – hepatocytes are filled with fatty inclusions, single black and brown granules are found in the liver tissue, focal necrosis of the parenchyma, lysis of the liver cells. Fatty degeneration and hemosiderosis of the liver – heart: lymphoid gland hyperplasia; – skin: focal lesion – congestive hyperemia, in the form of vascular injection, pinpoint hemorrhages; – bone scutes: pinpoint hemorrhages, hemorrhages, small foci of necrosis
Bastard sturgeon *(Acipenser nudiventris) (NUD)*	Fatty liver degeneration
Albino beluga *(Acipenser huso L.) (HUS)*	Intravascular proliferation, splenitis, hemosiderosis and fatty liver degeneration
Sterlet *(Acipenser ruthenus) (RUT)*	Necrotic foci of skeletal muscles, bone scutes; Intravascular proliferations. Hyperplasia of the spleen. Fatty degeneration and hemosiderosis of the liver

Histological examination of tissue sections revealed the following changes (Figs. 9, 10, 11, 12, 13, 14, 15, 16 and 17).

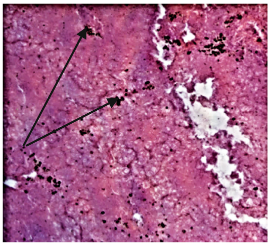

Fig. 9. Liver hemosiderosis in Russian-Siberian sturgeon

Fig. 10. Fatty liver degeneration in Russian-Siberian sturgeon

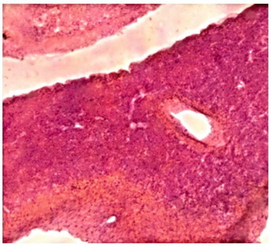

Fig. 11. Splenic hyperplasia in Russian-Siberian sturgeon

Histological studies revealed pathologies in parenchymal organs, such as hemosiderosis in the liver, fatty liver degeneration and spleen hyperplasia.

In addition, disorders in the skeletal muscles have been determined, caused by hemorrhages in the muscles, inflammation and necrotic foci.

In albino beluga, histological studies revealed inflammation of the spleen, hemosiderosis and fatty liver, as well as intravascular proliferation.

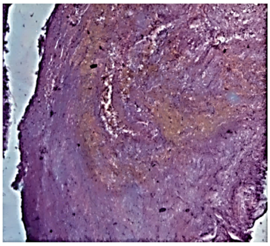

Fig. 12. Skeletal muscle hemorrhage in Russian-Siberian sturgeon

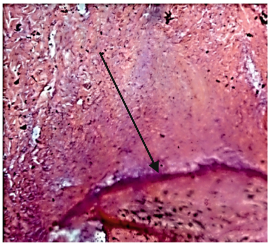

Fig. 13. Necrotic focus of skeletal muscle in Russian-Siberian sturgeon

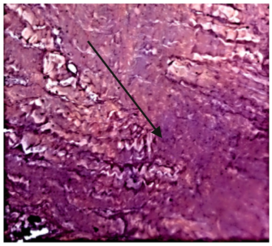

Fig. 14. Inflammation of skeletal muscle in Russian-Siberian sturgeon

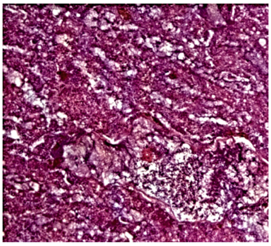

Fig. 15. Intravascular proliferation in albino beluga sturgeon

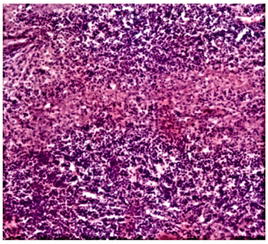

Fig. 16. Splenitis in albino beluga

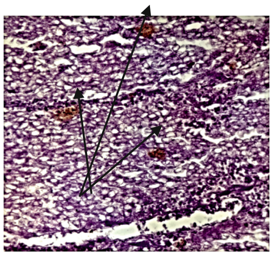

Fig. 17. Hemosiderosis and fatty liver degeneration in albino beluga

4 Discussion

As a result of sequential studies – clinical, virological, bacteriological, parsitological, histological – it was found that in almost every fish farm individuals of sturgeon species with certain pathologies were identified.

Diseases of the circulatory system, immune diseases, intoxication of the body, as well as excess iron salts in water could lead to the occurrence of hemosiderosis. In this case, it would be advisable to conduct additional laboratory tests of water.

Fatty liver degeneration can be caused by feeding excessively high-calorie feeds that contain excessive amounts of saturated fat.

Necrosis of skeletal muscles can develop in the presence of pathogenic microorganisms – bacteria, viruses, fungi, etc., which confirmed the positive results of previously conducted bacteriological studies.

Thus, the results of histological studies make it possible to determine the order of further actions and make a decision on conducting certain diagnostic studies, or determine a strategy for treating diseases.

5 Conclusion

When growing sturgeon species in installations of the closed water supply, despite the closed system, the risks of diseases remain and the prospects for sustainable development of industrial aquaculture systems are jeopardized. This is primarily due to unauthorized transportation of fish, the epizootic status of which has not been confirmed. This may also be due to the use of water from natural sources, since aquaculture enterprises sometimes do not pay due attention to the quality of the water used [6, 11]. Fish diseases are the major problem for aquaculture operations. Losses caused by fish diseases can cause damage in the amount of 10–15% of the cost of production [5, 13, 15].

Analysis of the incidence of sturgeon fish species with viral, bacterial, parasitic diseases in installations of the closed water supply conditions through various studies shows the need to conduct clinical and laboratory studies in a complex. That is, in addition to clinical, virological, bacteriological and parasitological studies, it is recommended to conduct histological studies.

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The Effect of Positive and Negative Aeroionization on Reducing Weight Loss of Agricultural Products

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Abstract. The analysis of scientific articles allowed us to conclude that there is insufficient research on the effect of aeroionization on various crops during storage. To conduct the experiment, an upgraded aeroionizer was used, which creates a concentration of 4900…5000 ions.cm^{-3} separately for positive and negative ions. The processing time was set in the following variants: 15 s, 30 s, 45 s, 60 s, 120 s, 180 s. Potatoes, onions, carrots, and beets were processed in packages of 1 kg each. The storage of processed and unprocessed agriculture lasted 14 days. During this time period, it was found that for potatoes, the minimum losses were 7% for a processing time of 180 s when treated with negatively charged aeroions; for onions, the minimum losses were 4 percent for a processing time of 120 s when treated with negatively charged aeroions; for beetroot, the minimum losses were 15 percent for a processing time of 45 s when treated with negatively charged aeroions; for carrots, the minimum losses were 11% for the untreated version. The weight loss for the unprocessed potato variant was 9%, for the unprocessed onion variant it was 12%, for the unprocessed beet variant it was 25%. The results of the experiment showed that the use of aeroionization of potatoes, onions, beets with negatively charged aeroions makes it possible to reduce mass loss during storage, and therefore save more agricultural products.

Keywords: storage · loss reduction · negative aeroion · positive aeroion

1 Introduction

The problem of preserving the quality of potatoes is of great economic importance. Storage losses are still high: during harvesting, transportation and storage, 30…40 percent of the grown crop is lost, in many cases losses reach 60 percent by the end of storage. Also, during the storage of potatoes, the spread of phytophthora, ring rot, blackleg and other diseases is observed, which seriously worsens the quality and consumer properties of stored products, increases the volume of potatoes that are not suitable for nutrition. Potato storage is the final stage of the entire production cycle. The main goal is to preserve the harvest of the best quality, with the least losses, for as long as possible.

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In science and technology, the effects of various physical methods on the processes taking place in agricultural production are known. The use of electrical, electromagnetic and magnetic effects, as well as their various combinations with sound and optical effects, allows you to correct the functional state of biological objects of plant origin. All known methods of influencing potatoes in order to reduce their losses, prolong shelf life and improve quality can be classified into technological, chemical and physical.

Technological and chemical methods have been studied quite well, but potato losses still remain very high and can reach 50%. The study of physical methods of processing potatoes will reduce potato losses by up to 4…5%.

Physical methods of influencing potatoes include ionizing radiation (gamma and X-rays, accelerated electrons, ozonation), strong electric fields, magnetic fields and aeroionization. Research on the use of physical methods for processing products in order to reduce product losses and prolong shelf life is carried out in 76 countries around the world.

These studies were conducted by scientists of the USSR. For example, studies of gamma radiation. The source of gamma radiation is cobalt Co60, with an energy of 12 meV. During gamma irradiation of potatoes, all tuber tissues are exposed. The Bach Institute of the USSR Academy of Sciences studied the issue of delayed germination of tubers during the long-term storage of potatoes. With gamma irradiation with a dose of 2 krad (20 J·kg^{-1}), the germination of tubers is delayed for 15 days, with irradiation with a dose of 5 krad (50 J·kg^{-1}), the germination delay is 45 days, with treatment of 8 krad, germination is delayed up to 120 days, and with a treatment dose of 10 krad, potato tubers did not germinate at all. Product losses after 10 months of storage amounted to about 10%. Many researchers agree that an effective dose of treatment that prevents potato germination is a dose of 10 krad (100 J·kg^{-1}) at a storage temperature of no more than 13° [1].

Of great interest are the studies conducted at the NIIKH Institute to study the effect of electronic radiation on the safety of potatoes. The source of accelerated electrons is a linear accelerator with an energy of 1.0 meV, with a penetrating power of about 5 mm. Studies on the effectiveness of electron irradiation, in order to ensure long-term storage of potatoes without germination, were conducted on seven varieties of potatoes, differing in ripeness and dormancy period. The irradiation of potatoes was carried out in October before laying the tubers for storage. The dose of potato processing was 20 krad at a radiation power of 500 rad.s^{-1} (5 W.kg^{-1}). The results of product accounting showed that potato losses range from 10% to 14%, during 10 months of storage, depending on the variety [1].

Work was carried out to study the effects of ozone on potatoes, in which it was found that transformations in the carbohydrate complex are among the specific processes that occur in tubers during storage and have a great impact on the nutritional qualities of potatoes. The studied potato varieties differed little in sugar content and the nature of their changes during storage. In ozonated potato tubers, compared with control samples, the starch content by the end of storage is 3–6% higher, and the sugar content is 1.3…1.5 times lower. Under the influence of ozone, there is an increase in the content of ascorbic acid by an average of 1…2 times. The respiration rate of ozonated tubers during storage differed slightly from the control ones. Judging by the biochemical changes occurring under the influence of ozone in potato tubers, the author of the research notes that ozonation does not cause physiological disorders of the fetus. The surface layer of potatoes does not contain easily oxidizable substances, and ozone, as is known, has a purely superficial effect. At the same time, ozone destroys pathogenic surface microflora: the contamination of treated tubers by the end of storage is significantly lower compared to the control ones. Ozonation promotes wound healing on tubers, which increases their resistance to new infections. The percentage of rotting tubers in ozonated batches is significantly lower - 1.5…3.0 times [2].

Gamma radiation studies conducted in India showed that the nature of the effect of gamma radiation doses of 0.04, 0.08, 0.12 and 1 kGy applied in two different periods after harvest (5 and 30 days after harvest) was studied on the behavior of the texture (puncture force, shear force, work done to puncture and shear, cohesiveness and stickiness), microstructure, reducing sugar, total sugar and loss of potato tubers at a storage temperature of 22 °C (relative humidity: 85…90%). The lowest dose (0.04 kGy) was sufficient to suppress the germination of potatoes exposed on day 5, but not for tubers exposed on day 30. Irradiated, non-sprouted potatoes retained their appearance during storage. Potatoes exposed early turned out to be more sensitive to radiation damage, which led to excessive loss of tubers at 1 kGy, but low doses (up to 0.12 kGy) did not increase the susceptibility of tubers to rot. No significant differences between the content of reducing sugar and total sugar in control tubers and tubers irradiated with low doses were observed after 120 days. A high dose (1 kg) caused blackening of kidney tissue, an increase in the percentage of rotting and poor texture quality. An increase in low doses (up to 0.12 kGy) gradually reduced the deterioration of the texture of tubers during storage. Intact cells with rigid cell walls were found on scanning electron micrographs of potatoes irradiated with a dose of 0.08…0.12 kGy, which explains the higher texture values recorded by the samples. The study showed the potential effect of gamma irradiation to increase the shelf life of potatoes in uncooled storages [3, 4].

The use of industrial-type linear accelerators can be an alternative treatment for controlling potato seedlings during long-term storage. The technical aspect of processing has been described and may include large-scale processing of bulk potatoes as they move through a conveyor system to or from a storage location. The aim of the study was to evaluate the use of a linear accelerator for long-term germination control in commercial storage conditions and its effect on the quality of tubers. A linear accelerator with an energy of 18 meV was used to irradiate various batches of "Reddish-brown Burbank" potatoes, suppressing sprouts. Successful germination suppression was achieved at doses from 40 to 50 Gy (0 g of seedling weight after 9 months of storage at 7.2 °C), while higher doses caused an undesirable increase in reducing sugar in tubers. Glucose concentrations in the treated tubers (0.25% by weight of fresh tubers) were higher after treatment than in the untreated controls (0.08%), but returned to control levels after 2–6 months of storage. The glucose concentration in the treated tubers was significantly reduced during storage for recovery by increasing the storage temperature for one month (from 7.2 °C to 14.4 °C), which led to a glucose concentration close to the control. With an increase in the dose rate from the accelerator, the recovery of glucose concentration in tubers as a result of radiation treatment occurred much faster than with a slower dose administration. Potato tubers irradiated with high intensity (100 Gy) high-energy electrons showed an increase in cases of soft and dry rot during storage. The development of diseases of potatoes treated with radiation doses suppressing sprouts (50 Gy) increased in batches with a high rotting potential. Processed batches with a low rotting potential were successfully stored for 8 months or more without increasing the likelihood of rotting or shrinkage. The selection of batches for radiation treatment should include some preliminary assessment of the development of the disease during long-term storage [5, 6].

Healthy potatoes were exposed to low-energy electrons of 400 and 500 keV and stored at 10…12 °C and 99% relative humidity (RH) for 8 months. The aim was to evaluate the effectiveness of surface irradiation of potatoes to inhibit germination of sprouts in lower doses (100, 200, 300, 400 and 500 Gy) when stored at an elevated temperature of 10…12 °C. Untreated potatoes sprouted during 2…3 months of storage. When irradiating potatoes with an electron beam at 400 keV, a dose of 400 Gy and at 500 keV, a dose of 200 Gy suppressed germination. These doses were higher than the recommended doses for gamma radiation (60…150 Gy) for the same purpose. After 8 months, irradiated and non-irradiated potatoes were evaluated for a decrease in sugar content, ascorbic acid, texture, color and quality of chips. The results indicate the effectiveness of irradiation of the potato surface with low-energy electrons to inhibit germination, prolong shelf life and improve the quality of tuber processing due to the possibility of storage at an elevated temperature of 10…12 °C. [7, 8].

Accordingly, according to information presented in open scientific sources, potatoes treated with gamma radiation can be stored at higher temperatures of 8, 12 and even 20 degrees, potato weight loss does not exceed 20%, and in some cases 8% over 10 months of storage; the processes of germination, drying and rotting completely stop, the appearance of potatoes remains practically unchanged, the nutrient content does not decrease.

The significant disadvantages of this method include: the high cost of devices for radiation treatment of products, the bulkiness and complexity of equipment for radiation treatment of products, as well as the insufficiently studied nature of the effect of gamma radiation on food [9].

The effects of magnetic, electric fields and ozone do not pose a danger to humans, does not leave radiation in products, has a lower cost, and equipment made on the basis of magnetic and electrical technologies is more technologically advanced and easy to operate than radiation treatment plants for products [10].

The analysis of scientific research has established that currently there is an interest in the use of electrophysical methods for processing potatoes before and during storage, such as exposure to electric and magnetic fields, ozonation, ionization. Preliminary studies have shown that the treatment of potato tubers with magnetic fields has a bactericidal effect and causes a change in the biomagnetic potential and permeability of the cell surface, which in turn ensures penetration into the cytoplasm of starch grains with subsequent disruption of cell metabolism. It is this circumstance that can explain the improvement in the shelf life of potatoes, which allows you to extend its shelf life. Thus, magnetic and other methods of exposure make it possible to improve the safety of potatoes. The study of these methods is an urgent task.

2 Materials and Methods

Currently, there are no scientific studies to determine the effect of aeroionization on the storage of potatoes, carrots, beets, onions. Therefore, the authors of the article had a goal to scientifically study the effect of aeroionization on agricultural crops during storage.

It was necessary to solve the following tasks:

- to manufacture a device for generating positively charged and negatively charged aeroions;
- measure the mass of tubers of potatoes, carrots, beets, onions at the beginning of the experiment;
- to carry out the treatment of tubers of potatoes, carrots, beets, onions with positively charged aeroions;
- to carry out treatment of tubers of potatoes, carrots, beets, onions with negatively charged aeroions;
- place the processed tubers of potatoes, carrots, beets, onions for storage in a room with constant temperature and humidity;
- place untreated tubers of potatoes, carrots, beets, onions with positively charged and negatively charged aeroions in the same room;
- within 14 days, measure the mass of all tubers, determine their appearance, identify damage and rotting zones on the tubers;
- at the end of storage of tubers, to establish the nature of the effect of negative and positive aeroions on tubers of potatoes, carrots, beets, onions;
- to determine the optimal parameters of the effect of aeroions on changes in the mass of tubers of potatoes, carrots, beets, onions;
- to determine the dynamics of changes in the mass of processed tubers of potatoes, carrots, beets, onions compared with unprocessed ones.

During the experimental research, high-precision devices certified in Russia were used: high-precision electronic scales, ammeter, voltmeter, air temperature measuring device, hygrometer for measuring air humidity.

During the experiment, the following research methods were used: the method of multifactorial experiment, statistical analysis, determination of adequacy, method of observing the object of study and fixing any important changes in shape, reactions, properties.

The experiment and mathematical processing of experimental data were carried out according to the following plan:

- determination of equipment, number of experiments, cost of funds;
- measurement accuracy analysis—checking and calibration of instruments, checking of manufactured samples (gaps, tolerances, etc.);
- measurement quality control—determination of the largest measurement error and rejection of repeated measurements;
- conversion of measured parameters from absolute values to relative values;
- determining the deviation of the original parameters from the model parameters;
- finding the variance and the mean square deviation;
- smoothing tabular data and graphs;

- interpolation and extrapolation of functional dependencies.

The analysis of the factors influencing the effectiveness of magnetic water treatment made it possible to identify fixed and variable factors.

The recorded factors were: the same variety of agriculture for all experiments, the same temperature and humidity during storage, the concentration of positively charged aeroions and negatively charged aeroions. For the experiments, the most common varieties in the Stavropol Territory of the Russian Federation were selected, namely, potatoes of the Aurora variety, onions of the Classic variety, beetroot of the Bordeaux variety, carrots of the Laguna variety.

The variable factors of the experiment were the processing time and the polarity of the aeroions.

Generators of positively and negatively charged ions were used during the experiment. Potatoes, onions, carrots and beets were treated with negative and positive aeroions. The concentration of aeroions in the range of 4900…5000 ions.cm^{-3} was created in a special closed chamber. The processing time was set in the following variants: 15 s, 30 s, 45 s, 60 s, 120 s, 180 s. Also, to compare the data in the experiment, an option that had not been processed was used. The processed culture weighing 1 kg was placed in the chamber and maintained for a set time. Then the processed material was stored in insulated plastic bags at room temperature (22…25 °C) and humidity of 70…75%. Mass measurements were carried out daily for all variants, and the external condition of the crops was recorded. The experiment was conducted for 14 days. At the end of the experiment, the residual mass and appearance of the processed materials were recorded and the mass loss for each culture was determined.

Tuber mass losses for all agricultural crops were determined by the formula (1):

$$\Delta M = 100 - (\frac{M2}{M1} \cdot 100)\%, \quad (1)$$

where *M1* is the mass of tubers at the beginning of the experiment, kg; *M2* is the mass of tubers at the end of the experiment, kg.

To manufacture a device for generating positively charged and negatively charged aeroions, an ion ionizer was used (Fig. 1), sold by manufacturers in the Russian Federation. The ionizer ION is equipped with pointed electrodes, which, by means of corona discharge and electrostatic emission, form negatively or positively charged aeroions, depending on the polarity of the current source.

The current source of the air ionizer has been redesigned and modernized by the authors. The upgrade was necessary to use the ION air ionizer to create a separate concentration of positively charged aeroions and a separate concentration of negatively charged aeroions.

The concentration of aeroions was monitored using the concentration meter of positive and negative aeroions "Sapphire – 3M" (Fig. 2).

Fig. 1. Generator of positively and negatively charged aeroions ION

Fig. 2. The appearance of the concentration meter of positive and negative aeroions "Sapphire – 3M"

3 Results

According to the results of the experiment, it was found that the treatment of root crops with negatively and positively charged aeroions with the same concentration of 4900…5000 ions·cm^{-3} has different effects on storage losses of different crops of root crops.

The main results on weight loss at the end of the experiment are presented in Table 1.

For potatoes, the minimum losses during processing with negatively charged aeroions of 7.6% are observed for a processing time of 180 s, but for this processing time, maximum losses of 11.9% are observed when processing with positively charged ions. Also, minimal losses of 7.2% are observed when treated with positively charged aeroions and a processing time of 15 s.

For onions in all processing modes, the mass loss is less than for the untreated control, for which the loss is 11.5 percent. A minimum loss of 3.6% is observed when treated with positively charged aeroions and a processing time of 120 s. When treated with negatively charged ions, a minimum loss of 3.8 percent is observed for a processing time of 180 s. However, there is a processing mode in which the losses are greater than the untreated control, and this mode corresponds to a processing time of 45 s for negatively charged ions, and the losses are 12.1%.

Table 1. Tuber mass loss at the end of the experiment, percentage

Agro culture	Treatment mode with a concentration of 4900…5000 ions.cm^{-3}	Processing time, seconds						Raw control
		15	30	45	60	120	180	
Potato	positively charged aeroions	7.2	8.2	8.9	10.2	9.4	11.9	9.7
	negatively charged aeroions	8.2	8.7	8.8	10.1	9.1	7.6	
Onion	positively charged aeroions	8.4	4.9	5.9	9.7	3.6	8.5	11.5
	negatively charged aeroions	7.1	7.4	12.1	9.4	9.3	3.8	
Beet	positively charged aeroions	22.5	22.1	18.8	17.6	22.7	27.9	25.6
	negatively charged aeroions	16.7	22.3	15.2	20.9	23.8	17.1	
Carrots	positively charged aeroions	18.4	11.4	15.8	16.6	15.2	13.4	11.6
	negatively charged aeroions	16.8	11.8	16.6	19.7	14.1	14.3	

For beetroot, the weight loss in most processing options is less than the loss of the untreated control. For the treatment mode with positively charged aeroions, the minimum beet mass loss is 17.6% for a processing time of 60 s. The maximum beet mass loss of 27.9% is observed when treated with positively charged aeroions for 180 s, which is not much higher than the loss of 25.6% for untreated control.

For carrots, losses above 11.6% are observed in all variants, which is higher than the losses of the untreated control, except for variants with a processing time of 30 s for positively and negatively charged aeroions, in which losses are equal to the untreated control.

4 Discussion

An experiment to observe the effect of negatively and positively charged aeroions on tubers of various agricultural crops allowed us to obtain results that can later be implemented for large storage facilities of agricultural crops. In the experiment, several agricultural crops were studied, namely potatoes, onions, beets, carrots, which were stored at elevated temperatures and humidity. As a result of the experiment, it was found that the most favorable conditions for reducing losses of potatoes, onions and beets are the use of negatively charged aeroions and a fixed processing time from 15 to 180 s. For potatoes, this time is 180 s, for onions, this time is 180 s, for beets, this time is 45 s. The use of aeroionization of carrots did not yield positive results, since the losses in all experiments of this crop are greater than the losses of the untreated control, and when treated with positive or negative aeroions with a processing time of 30 s, the losses are equal to the losses of the untreated control. Therefore, the use of aeroionization for storing carrots is ineffective.

The authors of other scientific studies on the processing of agricultural crops in various ways studied only one crop, did not investigate the effect of aeroionization processes with positive or negative aeroions on the storage of agricultural products [11–14]. Ozonation devices, gamma radiation, linear accelerators for processing agricultural products have a high cost, are designed to process large volumes of products and can have a negative impact on the human body. Aeroionization devices are much cheaper than other ionizing devices, can be used to process small volumes of agricultural products (up to 100 kg), and do not harm the human body. Aeroionization devices are also universal. As the experiment showed, one aeroionization device generating negative aeroions can be used to reduce storage losses for potatoes, onions, and beets. This device can be used in a small farm with low productivity, in which the shelf life of agricultural products does not exceed 1…3 months.

5 Conclusion

1. For experimental studies, an air ionization device was manufactured that allows the production of positive or negative aeroions, depending on the experimental conditions.
2. As a result of experimental studies, the effect of negatively charged aeroions on the mass change during storage of potatoes, onions, beets, and carrots was obtained.
3. Also, as a result of experimental studies, the effect of positively charged aeroions on the mass change during storage of potatoes, onions, beets, and carrots was obtained.
4. To reduce mass losses during storage of potatoes, onions, carrots, it is recommended to use negatively charged aeroions with an ion concentration of 4900…5000 ion.cm^{-3}.
5. The obtained treatment modes with negative aeroions for the storage of agricultural crops are recommended for use by farms with a short shelf life of manufactured agricultural products (1–3 months).
6. In the future, it is necessary to conduct studies for the concentration of negative aeroions above 5000 ion.cm^{-3}, and the volume of stored products over 1 kg.
7. Experimental studies have shown that the use of negatively and positively charged aeroions makes it possible, depending on the type of tubers and root crops, to significantly reduce storage losses, increase storage temperature, and reduce energy consumption.

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Description of the Chemical Content and Properties of Convective Drying to Apple Fruit Snacks

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Abstract. Apple is a natural product rich in biological compounds, dietary fibers, macro elements and microelements. Convective drying is effective way to make such valuable raw materials to preserve and improve sensory properties for future consumers. Convective drying is an advanced means of preserving food products. The best possible results of the drying stage are achieved by performing numerous experiments. As a result, it is necessary to select the preferred characteristics of dehydration regimes on a scientific basis. Then it showed high-quality finished products with long shelf life property. Important to note that sensory and physical-chemical properties of the dried product were proved and noted at a heating temperature of 55 °C.

Keywords: Convective drying · fruit snacks · microelements · sensory analysis

1 Introduction

The development and production of new generation food products for healthy, functional and therapeutic nutrition is an innovative direction in food chemistry, which is of extremely important practical importance and social effectiveness. There is an increased attention to Kazakhstani products of natural origin: berries and fruits, as the main raw materials for the production of products for healthy and functional nutrition. This is due to their accessibility and consumer preferences of all population groups [1]. In the system of rational and balanced nutrition, a person needs two to three snacks during the day between main meals. Each meal should have an individual combination of proteins, fats, carbohydrates, fiber and with the specified parameters of caloric content and antioxidant activity. Fruit snacks are promising food products for these purposes. Fruit and berry snacks are a new direction in healthy eating. Fruit and berry snacks are thinly sliced, dried slices of fruits and berries without adding other ingredients.

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It is a truth that crunchy and healthy natural product that does not require additional preparation and is ready to eat. Due to the careful vacuum drying technology, snacks retain almost all the necessary nutrients - vitamins and nutrients that are in the fresh product.

In the food industry, such products as sulfur dioxide, caustic soda, alkali and fats are used in the processing of fruit snacks [2]. During storage, fresh fruits deteriorate quickly due to enzymatic, biochemical and microbiological changes. Artificial or natural drying inhibits the growth of microorganisms. Fruits are characterized by a high water content and a low amount of dry matter. About 5% of moisture is associated with cellular structures, and most of it is in free form and can be removed using drying plants.

Fruits and berries are dried to increase storage stability, deteriorate packaging requirements and decries weight shelf life of finished product [2]. New measurements in drying methods have been introduced to reduce energy consumption and operating costs. Specific values of mass transfer characteristics are required for effective design of both a new convective drying modes and equipment or modernization of existing systems [5].

The existing convective drying plants are made in the form of specialized structures using the laws of thermodynamics for drying raw materials, while creating an environment with the properties of a heat carrier in order to remove heat and dry fruits [3]. Moreover, it is vitally important to note that high temperatures and direct sunlight negatively affect the preservation of biologically active compounds such as vitamins and polyphenols. Increased nutritional value is provided against the background of analog canning. Compared with traditional technologies, freeze drying has a number of important advantages: after sublimation, products lose moisture and retain useful components; sublimation retains the shape, smell, taste and color of berries and fruits. Freeze–dried berries and fruits - melon, watermelon, apricot, plum, raspberry, strawberry, cherry, cherry and others, an ideal product for those who do not want to spoil dishes with artificially grown analogues, cares about the health of the consumer [4, 5].

The choice of fractions is thin slices with different sizes with gradation by fractions, gris or granules, powder, pieces of regular shape. After freezing, harmful microorganisms and fungi will not appear in the sublimates. 100% preservation of the structure, shape, color and beneficial properties of canned fruit. Freeze-dried fruits and berries in any period of the year after the restoration of their shape delight with their aromas and the quality of their natural texture.

2 Materials and Methods

Experimental studies were carried out in research laboratory of acting plant processing industry InnovTechProduct LLP, Kazakhstan. The experiments were conducted in the spring and summer months 2023 year.

There were used different methods of current research: Sensory analysis, quantitively and qualitive methods of identification chemical contents of macro and microelements. Common accepted, standard methods of raw materials research were used to implement the tasks. Local apples growing in the South of Kazakhstan were used as raw materials.

The range of analyzed convective drying modes was selected in such a way as to ensure the preservation of useful elements in fruits [3]. The experiments were carried out on a laboratory convective drying unit at heating temperatures from 40 to 80 °C in increments of 5 degrees. The fruits were dried on pallets in one layer. The drying control parameters were the drying heating temperature (°C), the mass fraction of fruit moisture (%) [4].

3 Results

As a result of practical research, the duration of convective drying of objects at a temperature from 40 to 80 °C in increments of 5° was established.

To determine the sensory analysis, a technique was used that provides an assessment based on such indicators as color, taste, smell and consistency, each of which was evaluated on a 5-point scale [9.10]. Thus, the total maximum score was 20 points. Table 6 shows the results of the sensory evaluation of dry fruits (Table 1).

Table 1. The results of the sensory analysis of dry fruits when selecting the temperature of convective drying

Indicators	Temperature of convective drying, °C								
	40	45	50	55	60	65	70	75	80
Taste	4	4	5	5	4	3	2	2	1
Color	4	4	5	5	3	3	1	1	1
Smell	4	4	5	5	3	2	2	2	0
Texture	4	4	5	5	3	2	4	2	2
Total	16	16	20	20	15	10	9	7	4

The best results of sensory properties for apple fruit snacks were observed when the heating temperature was in the range of 55–65 °C. it was evaluated from 16 to 20 points. But further increasing of temperature of convective drying to 80 °C showed a deterioration of the sensory analysis to 2 points. The maximum scores of sensory characteristics according to the table were obtained at a heating temperature of drying apples of 50–55 °C.

Next table showed qualitive and quantitively chemical composition of apple fruit snacks: Moisture (Methods for determining moisture according to all-Union State Standard 28561–90), free acids (Methods for determining titratable acidity according to all-Union State Standard 25555.0–82), total and invert sugar, pectin substances, tannins and cellulose (Table 2).

Table 2. Chemical composition of apple fruit snacks

Indicators	Apple fruit snacks, %
Moisture, %	89
Free acids, %	2,19
Total sugar, %	12,35
Invert sugar, %	2,38
Pectin substances, %	0,92
Tannins, %	0,23
Cellulose, %	0,58
Nitrogenous substances, %	0,20
Ash, %	0,44

Table 3. Analysis of the mineral composition of ash residues of apples, growing in the Turkestan region [7, 9, 10]

	Name of indicators, mg/kg	Fruit apple snacks (in ash residues)
		Mass fraction of ash, in %- 0,6
1	Fe, mg/kg	508,208
2	Li, mg/kg	390,351
3	Mg, mg/kg	6996,66
4	P, mg/kg	20633,1
5	K, mg/kg	32898,7
6	Ca, mg/kg	8849,24
7	Ti, mg/kg	58,2545
8	Mn, mg/kg	64,3344
9	Cu mg/kg	52,9941
10	Zn, mg/kg	253,027
11	As, mg/kg	35,8967
12	Se, mg/kg	2,87834
13	Rb, mg/kg	212,386
14	Sr, mg/kg	97,8233
15	Zr, mg/kg	9,83151
16	Mo, mg/kg	5,84383
17	Ba, mg/kg	822,369
18	Pb, mg/kg	9,15406

From Table 3, Among analyzed characteristics apple fruit snacks contains sufficient amount of biological compounds. After that samples after convective drying and mineral composition of ash residues were subjected to the determination of the quantitative content of chemical elements by inductively coupled plasma mass spectrometry on the basis of the regional engineering laboratory "Structural and Biochemical Materials". This method allows the determination of a number of metals and several non-metals in concentrations up to $10^{-10}\%$, i.e. one particle out of 10^{12}. The method is based on the use of inductively coupled plasma as an ion source and a mass spectrometer for their separation and detection.

4 Discussion

The optimal technological characteristics of sensory properties in apricots (from 16 to 20 points) were noted in the following situation. The heating temperature was in the range of 40–85 °C. When the temperature rises to 80 °C the scores of sensory properties are reduced to 2 points.

Current studies have been conducted on the effect of heating temperature on the efficiency of the convective drying process of apples. For reasons of the most rational ratio of dehydration time and the degree of preservation of valuable components of fruit raw materials, the following heating temperature values for convective drying can be recommended: for apples –50–55 °C. The obtained experimental results can be used in engineering practice in the technology of fruit and vegetable processing.

As it is shown on the Tables, apple fruit snacks contain a high content of useful microelements: Fe, Ca, K, P, Mg, Zn, Cr, Ag and fibers and valuable biological compounds.

Convective drying is an advanced means of preserving food products [1]. The best possible results of the drying stage are achieved by performing numerous experiments. As a result, it is necessary to select the preferred characteristics of dehydration regimes on a scientific basis. Definitely it will show high-quality finished products. Important to note that sensory and physical-chemical properties of the dried product will be proved.

5 Conclusion

The perspective directions of convective drying of local apples of Turkestan region for fruit snacks are described. To conclude important to summaries results of chemical content of apple fruit snacks after convective drying. The optimal technological characteristics of sensory properties in apples fruit snacks (from 16 to 20 points) were noted in the current research. Proposed method of convective drying was used to confirm the effect of heating temperature on the sensory properties of finished products on the modern market. Taking into account the optimal chemical content of fibers, iron, and microelements should be recommended for the production of fruit processing in Turkestan region with idea to preserve biological compounds and prolong shelf life.

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Agrochemical and Chemical Properties of Soils on the Dried Bottom of the Aral Sea

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Abstract. The article provides data on the chemical and agrochemical properties of soils on the dried bottom of the Aral Sea. The purpose of the study is to study the agrochemical and chemical properties, as well as the reclamation state of the soils of the dried bottom of the Aral Sea. The object of the study was the soils of the southern and eastern parts of the Aral Sea. The southern part of the dry bottom of the Aral Sea was close to the city of Muynak, the eastern part was in the Kuktash area. The agrochemical properties and reclamation state of the soils of the dried bottom of the Aral Sea were studied using generally accepted classical methods. The chemical elemental composition was studied using inductively coupled plasma (ICP) optical emission spectrometry. The data obtained show that in the soils of the dried bottom of the Aral Sea the content of nutrients and organic carbon is very low, and the content of elements that are involved in soil salinization is very high. The soils of the dried up bottom of the Aral Sea, in most cases, have been turned into saline marshes. Of the elements studied, the most abundant (as their quantity decreases) are calcium, aluminum, sodium, potassium, iron, magnesium, strontium, titanium, barium, manganese, and phosphorus. The content of other elements is significantly low. Thus, the agrochemical properties and reclamation state of the soils of the dried bottom of the Aral Sea in the southern and eastern directions are poor and require appropriate measures. In the gross elemental composition, the content of sodium, chlorine, and mineral carbon is high, the content of organic carbon, nitrogen, and phosphorus is low, which negatively affects the reclamation state, humus and nutrient regimes of the soil.

Keywords: Aral Sea · eastern part of the Aral · south part · soil of the dry bottom of Sea · agrochemical property · chemical composition · elemental composition · gross forms · reclamation state · humus · macronutrients · microelements

1 Introduction

As a result of the drying of the Aral Sea, a large area of land was formed, which amounts to several million hectares. The total area of the dried bottom of the Aral Sea is 6 million hectares, of which 3.2 million hectares are located on the territory of Uzbekistan, 2.8 million hectares in Kazakhstan [1]. Currently, the development of these lands is underway by sowing various salt-tolerant desert crops to cover the surface of the land of the dried-up Aral Sea bed with vegetation. For these purposes, saxaul, Cherkez, tamarix, salt grate

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and other plants of desert saline zones are used [1–3]. Currently, seed germination and survival rates of these plants are very low. One of the reasons is the salinity of these soils and their unsatisfactory chemical and agrochemical properties [4–7]. Before carrying out any agronomic, reclamation and environmental measures, it will be necessary to study the properties and regimes of the soil and assess their condition. For example, soil properties and regimes play an important role in the germination, growth, development, accumulation of crops, the formation of the chemical composition and quality of plant products. On the dry bottom of the Aral Sea, a complex of sandy-desert, hydromorphic, semi-hydromorphic sandy-desert soils, as well as sandy-desert and sandy solonchaks has formed [5]. In the Kazakhstan part of the Aral Sea, solonchaks occupy 56.1%, sands 24.39%, the rest 29.31% belong to burozems [7]. The soils of the dried bottom of the Aral Sea contain a high content of heavy metals and persistent organic compounds, pesticide residues, which negatively affects biodiversity and human health [9–11]. From the dried bottom of the Aral Sea, saline soil was formed, which is the Aralkum desert; the dust of this Aralkum contains large quantities of bicarbonate, sulfate and calcium ions [12, 13]. Therefore, the study of agrochemical and chemical properties, reclamation state of soils, and the dried bottom of the Aral Sea is relevant.

2 Materials and Methods of Research

For these purposes, soil samples were taken from the dried bottom of the Aral Sea and laboratory studies were carried out. Soil samples were taken from various places on the dry bottom of the Aral Sea in the southern part of the Aral Sea near the city of Muynak and in the eastern part in the Kuktash area (coordinates $43040^{I}52^{II}$ and $60002^{I}54^{II}$). In the selected samples, the content of ammonium nitrogen ($N\text{-}NH_4$) was determined using the Nessler reagent on a spectrophotometer, nitrate nitrogen using the Grandval-Lajous method, mobile phosphorus and exchangeable potassium in one sample using the Machigin-Protasov method on a spectrophotometer and flame photometer, respectively, the reaction of the medium (pH) on a pH meter potentiometrically. Total salt content based on solid residue and electrical conductivity in aqueous soil extract prepared in a ratio of 1:5. In water extracts, the amount of carbonates, bicarbonates (total alkalinity), chlorides, sodium, potassium, and calcium ions was determined. At the same time, the elemental composition of the soils of the dried bottom of the Aral Sea was determined using optical emission spectrometry with inductively coupled plasma - ICPE.

3 The Results Obtained and their Discussion

The results of the analysis show that in the soils of the dried bottom of the Aral Sea the content of mineral nitrogen is very low. At the same time, the content of ammonium nitrogen is higher than nitrate nitrogen. For example, in soil samples taken at the 0-headquarters in the top layer of soil, the content of ammonium nitrogen was 11 mg/kg of soil, in the soil sample taken around the helipad - 10 mg/kg, at 22 km - 7 mg/kg soil, and the content of nitrate nitrogen in these samples is 13; 12; 11 mg/kg soil. And in the soils of the eastern part of the Aral Sea in the Kuktash area (coordinates 43040I52II and 60002I54II), the content of ammonium nitrogen in the 0–10 cm soil horizon was

7.41 mg/kg, in the 10–30 cm layer −8.14 mg/kg, in 30–50 cm layer - 6.55 mg/kg, while in these samples the content of nitrate nitrogen was lower, amounting to 5.26; 5.26; 4.31, respectively (Table 1). The content of available phosphorus in the soils of the dried bottom of the Aral Sea was very low. In soil samples taken at headquarters, the content of available phosphorus was 7.0 mg/kg of soil, in the soils around the helipad -−5.0 mg/kg, at 22 km −5.0 mg/kg. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, the amount of mobile phosphorus in the 0–10 cm layer was 3.21 mg/kg, in the 10–30 cm layer −4.14 mg/kg, in the 30–50 cm layer −3.26 mg/kg soil. In plant nutrition with potassium, the content of exchangeable potassium is of great importance. In many cases, the content of exchangeable potassium was high. For example, the content of exchangeable potassium in soil samples taken at the 0-headquarters near the Aral Sea was 346 mg/kg, in the soils around the helipad −326 mg/kg, at 22 km - 346 mg/kg. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, the content of exchangeable potassium was 346 mg/kg in the 0–10 cm layer, 128 mg/kg in the 10–30 cm layer, 187 mg in the 30–50 cm layer /kg (Table 1). The content of water-soluble potassium, determined from the aqueous extract, is of great importance. The content of water-soluble potassium in all soil samples from the dried bottom of the Aral Sea at the 0-headquarters and around the helipad was 50 mg/kg of soil, only in the soil sample taken at 22 km was 100.5 mg/kg. At the same time, in the eastern part of the Aral Sea in the Kuktash area, the content of water-soluble potassium in the 0–10 cm layer was 180 mg/kg, in the 10–30 cm layer −100 mg/kg, in the 30–50 cm layer −100 mg/kg of soil. Consequently, the content of water-soluble potassium is higher in the eastern part of the dry bottom of the Aral Sea than in the southern part.

Thus, the content of mobile nutrients in the soils of the dried bottom of the Aral Sea in terms of nitrogen and phosphorus is very low, which complicates the nitrogen and phosphorus nutrition of plants. The content of exchangeable and water-soluble potassium is high in most cases.

The humus content in the soils of the dried bottom of the Aral Sea is very low, which shows the low fertility of these soils. For example, in soil samples taken at headquarters 0, the humus content was 0.27%, in the soils around the helipad −0.27%, at 22 km - 0.35%. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, the humus content in the 0–10 cm layer was 0.67%, in the 10–30 cm layer - 0.67%, in the 30–50 cm layer −0.55% (Table 1). Consequently, in the soils of the dried bottom of the Aral Sea, along the soil profile from top to bottom, the humus content decreases. In the eastern part of the Aral Sea, the content of humus and organic carbon is higher than in the southern part. In general, the content of humus and organic carbon is significantly low, which requires agricultural technologies that increase the content of organic matter.

The reaction of the environment (pH) of the soils of the dried bottom of the Aral Sea was in the range of 7.42–8.54. For example, in soils taken at the 0-headquarters, the pH was 8.54, around the helipad −8.49, at 22 km −8.51. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, the reaction of the environment in the 0–10 cm layer was 7.42, in the 10–30 cm layer −7.68, in the 30–50 cm layer - 7.54 (Table 1). In the eastern part of the Aral Sea, the reaction of the environment (pH) of the soil is less than 8, which indicates that the reaction of the environment of these soils is typical of many soils in Uzbekistan. In the southern part of the Aral Sea in the 0-headquarters, around the helipad and 22 km, the pH of the environment is much higher and represents alkaline soils. Therefore, these soils require chemical reclamation aimed at increasing the proportion of calcium and reducing sodium. For these purposes, plaster (gypsum) must be used what gives a good effect.

The content of calcium and magnesium carbonates in the soils of the dried bottom of the Aral Sea was relatively high, which determines the alkalinity of the reaction of these soils. In addition, carbonates strongly influence the mobility of many macro- and microelements. With a high content of carbonates, the mobility of phosphates, iron, and many trace elements, especially manganese, decreases. The content of insoluble carbonates in the 0–10 cm layer of soil taken from the dried bottom of the eastern part of the Aral Sea in the Kuktash area was 13%, in the 10–30 cm layer −20.1%, 30–50 cm layer −17.4% (Table 1). Consequently, the content of calcium and magnesium carbonates is higher in the lower horizons than in the upper layer. Such data on the content of carbonates in the soils of the dried bottom of the Aral Sea are available in the works of other authors [14] .

The soils of the dried bottom of the Aral Sea are highly saline. The total content of water-soluble salts is very high; according to this indicator, they are salt marshes. The content of water-soluble salts in soils taken at the 0-headquarters was 15.55%, at the helipad −16.52%, at 22 km - 46.95% (Table 2). Consequently, in soil samples taken at 22 km, the total content of water-soluble salts is very high, which greatly impedes the growth and development of plants. In the southern part of the Aral Sea, the total content of water-soluble salts was much higher than in the eastern part. But, in general, the gross content of water-soluble salts in the eastern part of the Aral Sea in the Kuktash area was very high. So, for example, in the 0–10 cm layer of soil the total content of water-soluble salts was 3.063%, in the 10–30 cm layer - 1.567%, in the 30–50 cm layer - 2.260% (Table 2). Consequently, more salts accumulate in the upper layer of soil, which is associated with high evaporation of water from the soil and low precipitation. Under such conditions, the upward flow of water in the capillaries of the soil increases, which contributes to the accumulation of salts in the upper layer of the soil. Consequently, these soils are real saline soils that is salt marshes and contain different types of water-soluble salts, which in most cases have a negative effect on soil fertility and the growth and development of plants. Among them there are very few that act as nutrients for plants or improve the properties and fertility of the soil.

The total alkalinity of the soil of the dried bottom of the Aral Sea ranged from 0.1520–0.3360%, which is a very high indicator for total soil alkalinity. The total alkalinity in soil samples taken at the 0-headquarters was 0.1520%, at the helipad −0.2130%, at 22 km–0.3050%. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, total alkalinity in the 0–10 cm layer was 0.3355%, in the 10–30 cm layer −0.3360%, in the 30–50 cm layer −0. 3360% (Table 2).

Salinization with chloride ions was observed in the soils of the dried bottom of the Aral Sea. Chloride ion has a negative effect on living organisms in the soil, incl. Microorganisms and plants. The content of chloride ion in soils taken at the 0-headquarters was 2.467%, at the helipad - 3.010%, at 22 km - 6.825%. In soil samples taken in the eastern part of the Aral Sea, the amount of chloride ion in the 0–10 cm layer was 2.450%, in the 10–30 cm layer - 1.050%, in the 30–50 cm layer −1.750%. The content of chloride ion was higher in the top layer of soil of the dried bottom of the Aral Sea and in the southern and eastern parts. Chloride ions are very mobile and, depending on the flow of water in the capillaries, change their positions in the soil.

The content of water-soluble sodium in the salt regime of the soil is of great importance. Sodium leads to alkalinization of the soil, promotes the formation of soda salinity, which has a strong negative effect on the reclamation state of the soil, since soda salinization is considered the most dangerous salinization of the soil. In the analyzed soil samples, the content of water-soluble sodium ranged from 0.1586–0.1604%, which is much higher than their MPC. For example, the content of water-soluble sodium in soil samples taken at the 0-headquarters was 0.1604%, at the helipad −0.1596%, at 22 km–0.1596%. In soil samples taken in the eastern part of the Aral Sea in the Kuktash area, the content of water-soluble sodium in the 0–10 cm layer was 0.1588%, in the 10–30 cm layer −0.1586%, in the 30–50 cm layer −0. 1588% (Table 2). Consequently, the soils of the dried Aral Sea bottom have a high content of water-soluble sodium, which shifts and increases the pH of the soil towards alkalinity and contributes to a high pH. At the same time, soil aggregates forming soil structures are highly dispersed.

The content of water-soluble calcium in soil samples taken in the eastern part of the Aral Sea in the Kuktash area in the 0–10 cm layer was 0.096%, in the 10–30 cm layer - 0.026%, in the 30–50 cm layer - 0.041%. The highest content of water-soluble calcium was observed in the upper 0–10 cm layer of soil. In the soils of the southern part of the dried bottom of the Aral Sea, the amount of water-soluble calcium in the 0-headquarters was 0.0020%, around the helipad −0.0020%, at 22 km - 0.0029% (Table 2). Consequently, the content of water-soluble calcium is higher in the soils of the eastern part of the dried bottom of the Aral Sea, which has a positive effect on the salt regime of these soils. In the soils of the southern part of the dry bottom of the Aral Sea, the amount of water-soluble calcium was significantly less than in its eastern part. This contributes to a decrease in the reclamation state and fertility of these soils.

Thus, the reclamation state of the soils of the dried bottom of the Aral Sea is very poor, due to the high content of water-soluble salts, incl. Sodium and chlorides. These soils are solonchaks and require improvement of ameliorative conditions and chemical and agrochemical composition.

The elemental composition of soils on the dried bottom of the Aral Sea changed depending on the location of soil sampling and the soil horizon. The gross content of elemental calcium in the soils taken around the helipad was 5.9769%, and in the soils taken in the eastern part of the Aral Sea in the Kuktash area, the amount of gross calcium was greater and in the 0–10 cm layer it was 6.9586%, in the 10–30 cm layer −6.6885%, in the 30–50 cm layer - 6.6784%. The gross content of elemental magnesium in the soils taken at the 0-headquarters was 0.7976%, at the helipad - 0.6419%, at 22 km - 1.9590%. In the eastern part of the Aral Sea in the Kuktash area, the gross content of elemental magnesium in the 0–10 cm layer was 1.3719%, in the 10–30 cm layer −0.8388%, in the 30–50 cm layer - 1.0380% (Table 3). The gross content of elemental potassium was higher in soils taken at the 0-headquarters, around the helipad and at 22 km than in the eastern part of the Aral Sea in the Kuktash area. For example, the content of gross forms of elemental potassium in soil samples taken at the 0-headquarters was 1.5755%, around the helipad −1.4132%, at 22 km - 1.3438%. In soils taken in the eastern part of the dried bottom of the Aral Sea in the Kuktash area, the amount of gross forms of elemental potassium in the 0–10 cm layer was 0.8091%, in the 10–30 cm layer - 0.8689%, in the 30–50 cm layer - 0.9336% (Table 3). The content of gross sodium was higher, the amount of potassium and magnesium was less compared to calcium. An increase in the proportion of sodium compared to calcium and potassium is dangerous for the reclamation state and salt regime of the soil. For example, the gross content of elemental sodium in soil samples taken at the 0-headquarters was 1.6721%, at the helipad −1.9864%, at 22 km - 4.7696%. The content of gross sodium in soils taken in the eastern part of the Aral Sea in the Kuktash area was high. The highest total sodium content was observed in the top layer. For example, the gross amount of elemental sodium in the 0–10 cm layer of soil of the dried bottom of the eastern part of the Aral Sea in the Kuktash area was 2.5924%, then in the 10–30 cm layer −1.4850%, in the 30–50 cm layer − 1 .7077%. The content of gross elemental sodium is very high, which is a potentially dangerous content for increasing salinization and alkalinization of the soil.

The gross content of elemental phosphorus is much less than the amount of the above elements. The content of gross forms of elemental phosphorus in soil samples taken at the 0-headquarters was 247 ppm (0.0247%), around the helipad −181 ppm (0.0181%), at 22 km - 306 ppm (0.0306%). The content of elemental phosphorus in soils taken from the dried bottom of the eastern part of the Aral Sea in the Kuktash area was slightly higher and amounted to 391 ppm (0.0391%) in the 0–10 cm layer, 275 ppm (0.0391%) in the 10–30 cm layer. 0275%), in the 30–50 cm layer −419 ppm (0.0419%) (Table 3). Consequently, the gross content of elemental phosphorus is very low, which cannot provide the plant with adequate phosphorus. With such a low amount of gross phosphorus, the formation of phosphorus available for plants occurs in small quantities.

In soils taken from the dry bottom of the Aral Sea, a high content of bulk forms of elemental aluminum was observed. The gross content of elemental aluminum ranged from 2.3875–3.3166% in the soils around the headquarters, helipad and 22 km, 4.4584–5.4231% in the soils of the dried bottom of the eastern part of the Aral Sea in the Kuktash area. In carbonate and alkaline soils, such as the soils of the dry bottom of the Aral Sea, the mobility of aluminum is low, which prevents the negative impact of aluminum ions on the soil and plants. A relatively high content of bulk forms of elemental iron was found in the soils of the dried bottom of the Aral Sea. The content of gross forms of elemental iron in the soils taken at the 0-headquarters was 0.8577%, around the helipad - 0.7557%, at 22 km - 1.5999%. The content of elemental iron was higher in soil samples taken from the dried bottom of the eastern Aral Sea in the Kuktash area than in the 0-headquarters and helipad. The gross content of elemental iron in the 0–10 cm layer of soil, taken from the dried bottom of the eastern part of the Aral Sea in the Kuktash area, was 1.3089%, in the 10–30 cm layer −1.2490%, in the 30–50 cm layer - 1 .7471% (Table 3). The gross content of iron is relatively higher, but under such conditions of the soils of the dried bottom of the Aral Sea, the mobility and availability of iron to plants should be low. Thus, high alkalinity and carbonate content of the soil contribute to a decrease in the mobility and availability of iron.

Table 1. Agrochemical properties of soils, the dried bottom of the Aral Sea

number	Soil sampling location	Soil horizons, sm	Humus, %	$N\text{-}NH_4$, mg/kg	$N\text{-}NO_3$, mg/kg	Mobile phosphorus, mg/kg	Exchangeable potassium, mg/kg	Reaction of the environment, pH	Insoluble carbonates, %
1	0-headquarters	0–25	0,27	11	13	7	346	8,54	not determined
2	Helipad	0–25	0,27	10	12	5	326	8,49	not determined
3	At 22 km	0–25	0,35	7	11	5	346	8,51	not determined
4	Eastern part of the Aral	0–10	0,67	7,41	5,26	3,21	346	7,42	13
5	Eastern part of the Aral	10–30	0,67	8,45	5,26	4,14	128	7,68	20,1
6	Eastern part of the Aral	30–50	0,55	6,55	4,31	3,26	187	7,54	17,4

Relatively high contents of gross forms of titanium and manganese were observed. In soil samples taken from the dried bottom of the eastern part of the Aral Sea in the Kuktash area, the content of bulk forms of elemental titanium and manganese was higher than in soils taken at the 0-headquarters, around the helipad and at 22 km. For example, in the soil taken at the 0-headquarters, the gross content of elemental titanium was 0.1293% (1293 ppm), around the helipad - 0.1612% (1612 ppm), at 22 km - 0.1328% (1328 ppm), and in a 0–10 cm layer of soil taken from the eastern part of the dried bottom of the Aral Sea in the Kuktash area, the amount of gross titanium was 0.1966% (1966 ppm), in a 10–30 cm layer - 0.1509% (1509 ppm), in the 30–50 cm layer - 0.1911% (1911 ppm). The gross content of elemental manganese in soils taken at the 0-headquarters was 194ppm (0.0194%), around the helipad - 228ppm (0.0228%), at 22 km - 296ppm (0.0296%). In soils taken from the dried bottom of the eastern part of the Aral Sea, the amount of manganese in the 0–10 cm layer was 412 ppm (0.0412%), in the 10–30 cm layer - 357 ppm (0.0357%), in the 30–50 cm layer - 468ppm (0.0468%). The gross content of elemental manganese is high, which can potentially improve manganese nutrition of plants under certain conditions.

The gross content of strontium in soil samples taken at the 0-headquarters was 1400ppm (0.14%), around the helipad - 823ppm (0.0823%), at 22 km - 3100ppm (0.31%), at 0–10 cm layer of soil of the dried bottom of the eastern part of the Aral Sea in the Kuktash area - 594ppm (0.0594%), in a 10–30 cm layer -—472ppm (0.0472%), in a 30–50 cm layer —353ppm (0.0353%). The gross content of elemental barium was 365; 405; 247; 414; 554; 475ppm respectively (Table 3). Consequently, the gross content of elemental barium was higher in soils taken from the dried bottom of the eastern part of the Aral Sea.

Table 2. Salt composition of soils, dried bottom of the Aral Sea

number	Soil sampling location	Soil horizons, sm	Electrical conductivity of soil water extract (EC)	Dense residue, %	Total alkalinity (HCO_3), %	Chloride ions (Cl), %	Ca^{2+}, %	Na^{+}, %	K_2O, %
1	0-headquarters	0–25	12280	15,55	0,152	2,467	0,0020	0,1604	0,0050
2	Helipad	0–25	13620	16,52	0,213	3,010	0,002	0,1596	0,0050
3	At 22 km	0–25	29640	46,95	0,305	6,825	0,0029	0,1596	0,01105
4	Eastern part of the Aral	0–10	12730	3,063	0,3355	2,45	0,096	0,1588	0,018
5	Eastern part of the Aral	10–30	3523	1,567	0,3360	1,05	0,026	0,1586	0,010
6	Eastern part of the Aral	30–50	7090	2,260	0,3360	1,75	0,041	0,1588	0,010

Table 3. Gross elemental composition of soils, dried bottom of the Aral Sea

number	Soil sampling location	Soil horizons, sm	Contents of gross forms of elements, %										
			Ca	Mg	K	Na	P	Al	Fe	Ti	Mn	Sr	Ba
1	0-headquarters	0–25	не опр	7976	15755	16721	247	23875	8577	1293	194	1400	365
2	Helipad	0–25	59769	6419	14132	19864	181	33166	7557	1612	228	823	405
3	At 22 km	0–25	не опр	19590	13438	47696	306	25427	15999	1328	296	3100	247
4	Eastern part of the Aral	0–10	69586	13719	8091	25924	391	44584	13089	1966	412	594	414
5	Eastern part of the Aral	10–30	66885	8388	8689	14850	275	50017	12490	1509	357	472	554
6	Eastern part of the Aral	30–50	66784	10380	9336	17077	419	54231	17471	1911	468	353	475

4 Conclusion

Thus, the elemental composition of the soils of the dried bottom of the Aral Sea is dominated by elements such as calcium, aluminum, sodium, magnesium, potassium, iron, titanium, phosphorus, carbon, manganese, strontium and barium. Their quantity is relatively high compared to other elements. The exception should be elements such as silicon and sulfur. Carbon is found in the form of minerals and organic substances. It is found more in the form of soluble and insoluble carbonates, and less in organic substances. Along with high salinity, these soils have low humus content, which makes their fertility low. The low humus content in these soils indicates a low activity of humification processes. The soils of the dried bottom of the Aral Sea have a poor nutritional regime, which is due to the low content of mobile nutrients, such as ammonium and nitrate nitrogen, mobile phosphorus, water-soluble and exchangeable potassium. This may be due to the low microbiological activity of these soils due to the high content of water-soluble salts.

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The Efficacy of Biologically Active Substances in Garden Strawberry Propagation Technology in Vitro

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Abstract. The garden strawberry is currently considered to be the most widespread berry crop. Despite the existence of a well-developed in vitro culture propagation methodology, ongoing technological advancements are required to keep pace with the evolving variety and composition of nutrient media. In the cultivation of crops and biotechnology, the regulation of plant growth and development with biologically active substances is crucial due to their economic viability and cost-effectiveness. The expanding range of biologically active substances, both in their pure form and as components of growth regulators, necessitates a thorough investigation of their beneficial physiological effects on plants. This research was conducted from 2022 to 2023 at the scientific and production center for the nursery cultivation of fruit and berry crops in Southern Russia. We examined the impact of biologically active substances within the Modified nutrient medium and Murashige and Skoog medium on the propagation efficiency of garden strawberry in vitro. Using the Modified medium led to an increase in morphometric parameters and enhanced regenerative capabilities of plants compared to the Murashige and Skoog medium. The biologically active substances investigated (tryptophan, aspartic acid, indole-3-acetic acid) stimulated the growth and development of microplants, with morphometric parameters exceeding those of the control. During the rhizogenesis phase, the inclusion of indole-3-acetic acid in the nutrient yielded the highest rooting rates for garden strawberry microplants – an average of 73.8% across the experiment. This rate was comparable to the use of tryptophan, where the difference of 0.5% was found to be statistically insignificant.

Keywords: garden strawberry · clonal micropropagation · in vitro · biologically active substance · variety · nutrient medium · rooting capability

1 Introduction

The in vitro cultivation technology for berry crops represents a reliable and forward-looking approach for generating healthy planting materials. This method boasts several advantages over traditional techniques, including a higher multiplication factor, genetic uniformity of the produced planting material, enhanced viability of regenerants, and the capability for year-round operation [1].

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Garden strawberry is currently the most prevalent berry crop. Despite the existence of a well-established in vitro propagation methodology, there is a necessity for technological refinement to accommodate the changing variety and nutrient medium composition. In vitro cultivated strawberry varieties demonstrate diverse regenerative capacities, necessitating tailored nutrient medium selection for various genotypes. An optimal nutrient medium is a crucial factor for plant bioproductivity [2, 3]. Incorporating highly accessible forms of elements into nutrient media facilitates the self-regulation of the hormonal balance in plants and stimulates their growth.

Essential nutrients in the nutrient medium are critical for normal plant development and facilitating biochemical reactions. However, there is a wide range of substances of natural and synthetic origin with growth-stimulating properties, whose utilization can significantly enhance the efficiency of the in vitro propagation method.

Biologically active substances influence physiological processes and the operation of the hormonal system in plants, both of which are closely interrelated. The hormonal system serves as a vital regulatory mechanism, influencing key physiological processes such as growth, new organ formation, transition to flowering, flower sex determination, leaf senescence, dormancy, and bud break.

In the context of intensive agricultural crop production technologies, the regulation of plant growth and development through biologically active substances is highly valued for its economic efficiency and minimal application costs. The expanding range of biologically active substances, both in pure form and as components of growth regulators, requires detailed examination of their beneficial physiological impacts on plants. Employing biologically active substances in plant microclonal propagation technologies helps overcome critical challenges and stress factors. This approach ensures the production of high-quality planting materials with high survivability rates.

2 Materials and Methods

The research was conducted in 2022–2023 at the Scientific and Production Center for the Nursery Cultivation of Fruit and Berry Crops at Stavropol State Agrarian University, located in southern Russia.

The experiment was designed with three factors: Factor A - strawberry variety, Factor B - nutrient medium, and Factor C - growth regulator. The subjects of the research were the strawberry varieties Albion and Brighton.

The initiation culture used apices from strawberry leaves planted in plastic containers. The sterilization process for the plant material comprised two stages: first, a 10–20 s treatment with 96% ethyl alcohol, followed by a 20-min immersion in a 0.01–0.1% potassium permanganate solution. After sterilization, the material was rinsed three times for 5 min each in sterile distilled water.

Subsequently, the plant tissue was placed into tubes on agar-based nutrient media as per the experimental design (Factor B). The study utilized two nutrient media: the Murashige and Skoog medium [4] as the control, and a Modified medium as the experimental nutrient medium. This Modified medium was enhanced with mineral salts and carboxyl-containing chelate complexes of micronutrients with ethylenediaminetetraacetic acid (EDTA) chelate compounds [5]. Both control and experimental nutrient media contained sucrose (30,000 mg/L) and agar-agar (7,000 mg/L), with the pH adjusted to 5.7 before autoclaving. The nutrient media at all in vitro stages were enriched with biologically active substances (Factor C): aspartic acid, tryptophan, and indole-3-acetic acid, each at 0.3 mg/L.

Cultivation conditions included a light intensity of 2000–2500 l× for a 16-h day at an air temperature of +22 to +24 °C. Over three months, the survivability of explants was routinely monitored, followed by three sequential passages at the multiplication stage. Microplant cuttings were transferred to glass culture vessels, five per vessel, with each passage lasting 60 days. The cultivation conditions for regenerant plants during the multiplication and rhizogenesis stages were identical to those during the introduction of explants into in vitro culture.

Morphometric assessments of explants were conducted 30 days post introduction into in vitro culture, evaluating microshoot length, and the number of microshoots, leaves, and roots. Intensity of axillary bud formation in microplants was tracked weekly, with vegetative part growth lengths measured at the study's conclusion. The nutrient medium's effect on microcutting rooting was examined by assessing rooting rates, the number of roots formed, and their average length according to the government standard - GOST 54051–2010 [6].

The experiment was replicated three times at each stage, with 50 propagated plants per replication. Results were statistically analyzed following B.A. Dospekhov [7] and A.V. Isachkin [8] using Microsoft Office Excel 2007 and STATISTICA_10.0.1011 to ensure robust data interpretation.

3 Results

Upon introduction of the meristem into the nutrient medium, active growth of primary garden strawberry explants was observed. Thirty days after cultivating garden strawberry microplants on nutrient media, morphometric measurements were recorded. The morphogenetic potential of garden strawberry explants was realized under direct organogenesis in vitro conditions.

Morphometric indicators varied among the studied garden strawberry varieties. The Brighton variety exhibited a greater leaf-forming ability than Albion: the average shoot length was greater by 0.74 cm, and the number of microshoots and leaves was higher by 0.47 and 0.71 respectively. In comparison, the Albion variety produced an average of 0.61 more roots per explant than Brighton.

The incorporation of the Modified medium and biologically active substances resulted in the formation of additional shoots at varying frequencies relative to the control variants of the experiment. A comparison of the two nutrient media (Factor B) revealed that the Modified medium had an advantage in the growth analysis of microplants. The average shoot length was greater by 0.2 cm, the number of microshoots per explant higher by 0.19, and the counts of leaves and roots increased by 1.21 and 0.91, respectively, as shown in Table 1.

Overall, the text effectively communicates the findings of the research, with only minor adjustments needed for optimal clarity and conciseness.

Biologically active substances stimulated the growth by garden strawberry microplants. The shoot length was greatest when tryptophan was used, significantly

Table 1. Impact of Biologically Active Substances and Nutrient Media on Morphometric Indicators of Garden Strawberry Microplants 30 Days Post In Vitro Culture Introduction, 2022–2023

Variety (Factor A))	Nutrient Medium (Factor B)	Growth Regulator (Factor C)	Length of Microshoot, cm	Number of Microshoots per 1 Explant, pcs.	Number of Leaves per 1 Explant, pcs	Number of Roots per Explant, pcs
Albion	Murashige and Skoog	Control	0.66	1.60	6.15	3.90
		Tryptophan	0.88	2.22	7.25	6.15
		Aspartic acid	0.76	1.90	6.85	4.94
		Indole-3-acetic acid	0.81	2.20	7.05	7.21
	Modified nutrient medium	Control	0.75	1.67	7.55	4.95
		Tryptophan	1.15	2.35	8.25	7.15
		Aspartic acid	0.86	1.95	8.02	5.47
		Indole-3-acetic acid	0.94	2.28	8.09	7.40
Brighton	Murashige and Skoog	Control	1.15	1.92	7.04	2.85
		Tryptophan	1.75	2.52	7.78	5.62
		Aspartic acid	1.42	2.30	7.46	4.65
		Indole-3-acetic acid	1.54	2.64	7.63	5.80
	Modified nutrient medium	Control	1.35	2.15	8.21	4.58
		Tryptophan	2.05	2.89	9.16	6.47
		Aspartic acid	1.64	2.45	8.70	5.65
		Indole-3-acetic acid	1.85	3.02	8.93	6.69
LSD_{05} (A)			0.62	0.32	0.58	0.50
LSD_{05} (B)			0.16	0.12	0.84	0.74
LSD_{05} (C)			0.09	0.07	0.12	0.45

exceeding control values, with the use of aspartic and indole-3-acetic acids resulting in an average increase of 0.17 to 0.48 cm. The application of indole-3-acetic acid in the nutrient media led to an increase in microshoot length compared to the control by 0.15 to 0.5 cm, and compared to aspartic acid by 0.05 to 0.21 cm.

Although tryptophan led to the highest number of microshoots per Albion explant, the increase was not significant compared to indole-3-acetic acid, with differences of only 0.02 units in the Murashige and Skoog medium and 0.07 units in the Modified medium. The highest number of shoots per microplant of the Brighton variety was obtained with the use of indole-3-acetic acid, marking a significant difference from tryptophan. Given the varying responses of the microplants of the studied garden strawberry varieties to microshoot formation, the average number of shoots with tryptophan application was not significantly greater than with indole-3-acetic acid by 0.04 units.

The maximum number of leaves per garden strawberry microplant was achieved with tryptophan, showing a similar trend as observed in shoot length. The average number of leaves with tryptophan in the nutrient media was notably higher compared to the control, aspartic acid, and indole-3-acetic acid by 0.18 to 0.87 units.

The application of indole-3-acetic acid in nutrient media resulted in the highest average number of roots per garden strawberry microplant in the experiment, exceeding the control by an average of 2.71 roots. Tryptophan was also found to be effective for root formation, with the average number of roots per microplant significantly surpassing the control by 2.28 roots.

Sequential subculturing of garden strawberries across three passages revealed that the Albion variety exhibited the highest regenerative capacity at the proliferation stage, with its multiplication coefficient averaging 0.2–0.37 units higher than Brighton. Notably, regenerative capacity peaked at the second passage, compared to the first and third passages (Table 2).

Table 2. Impact of Biologically Active Substances and Nutrient Media on the Intensity of Branching and Rooting in Garden Strawberry Varieties, 2022–2023

Variety (Factor A))	Nutrient Medium (Factor B)	Growth Regulator (Factor C)	Multiplication Coefficient, units.			Rooting on the 28th day (average over 3 passages), %
			1st Passage	1st Passage	3rd Passage	
Albion	Murashige and Skoog	Control	2.0	4.8	4.6	67.5
		Tryptophan	3.0	6.3	5.9	72.6
		Aspartic acid	2.8	5.9	5.6	70.8
		Indole-3-acetic acid	3.5	6.8	6.4	73.0
	Modified nutrient medium	Control	2.2	5.1	4.8	70.2
		Tryptophan	3.3	6.5	6.3	75.8
		Aspartic acid	3.2	6.2	6.0	72.3
		Indole-3-acetic acid	3.5	6.8	6.7	76.1
Brighton	Murashige and Skoog	Control	1.8	4.5	4.2	65.7
		Tryptophan	2.9	5.8	5.5	71.5
		Aspartic acid	2.5	5.5	5.3	69.9
		Indole-3-acetic acid	3.2	6.0	5.8	72.1
	Modified nutrient medium	Control	2.1	4.6	4.5	68.5
		Tryptophan	3.1	6.3	6.0	73.2
		Aspartic acid	2.8	5.9	5.6	70.6
		Indole-3-acetic acid	3.5	6.8	6.5	74.0
LSD_{05} (A)			0.1	0.2	0.2	1.0
LSD_{05} (B)			0.2	0.2	0.2	1.5
LSD_{05} (C)			0.2	0.2	0.2	0.6

The average multiplication coefficient over three passages was 2.7 to 5.7 units, across the Murashige and Skoog nutrient medium, which was 0.3 to 0.4 units lower than the average for the Modified medium. This is a significant difference.

Utilizing biologically active substances in the nutrient medium was proven to be quite effective. One month into cultivation, it was observed that the multiplication coefficient for all studied garden strawberry varieties exceeded the control upon the application of biologically active substances. The inclusion of indole-3-acetic acid in the nutrient medium resulted in the highest regenerative capacity observed in microplants – the average multiplication coefficient was greater than the control by 1.4 in the first passage, 1.8 in the second, and 1.9 in the third. Tryptophan application exceeded the control's average by 1.1 to 1.4 units over three passages, while aspartic acid outperformed the control by 0.3 units.

Rooting analysis of garden strawberry microplants was performed on the 28th day of each passage and on average over three passages. The rooting ability of the Albion variety was higher than Brighton by an average of 1.6%. All examined factors—namely the Modified medium and the use of biologically active substances—had a positive impact on rooting. On the 28th day, microplants rooted in the Modified nutrient medium showed an average 2.2% higher rooting ability over three passages than those in the Murashige and Skoog medium The addition of indole-3-acetic acid to the nutrient media resulted in the highest average rooting rate for garden strawberry microplants, at 73.8%. This rate was significantly higher than the control by 5.8% and was comparable to the rate with tryptophan use, differing by an insignificant 0.5%. The incorporation of aspartic acid in nutrient media increased the rooting rates by an average of 2.9% compared to the control.

4 Discussion

Clonal micropropagation in artificial nutrient media under sterile conditions—in vitro - is crucial for producing healthy planting material for berry crops. However, technological improvements are necessary to enhance the rooting of microplants, particularly for new varieties.

Many scientific studies have explored optimal conditions for the microclonal propagation of fruit and berry crops of different varieties, which vary in growth and development intensity depending on biotechnological techniques [9–11]. The varied response among varieties is due to the endogenous content of growth substances within the plants. This characteristic is genetically determined, influenced not only by species but also by individual varieties [12].

A comparative assessment of the studied garden strawberry varieties showed that the Albion variety, while enhancing root system formation, exhibited less leafiness compared to the Brighton variety. Enhanced development of the root system in microplants increases their adaptability and rooting degree, as confirmed by the data obtained (Table 2).

For the successful propagation of berry crop microplants in vitro culture, selecting an optimal nutrient medium composition is crucial. This selection accounts for nutrient availability and their interaction [13–16]. In the Modified nutrient medium used for the experiment, the nutritional elements have a high degree of water solubility and availability for plants, especially micronutrients in chelated forms. Using the Modified nutrient medium increases the availability of elements for plant tissue absorption. This enhancement is evident when compared to the Murashige and Skoog medium, as shown by comparative analyses of morphometric indicators, branching point formation, and rooting in garden strawberry microplants.

In the clonal micropropagation of plants in vitro, the presence of exogenous biologically active substances in the nutrient medium, which exert a growth-stimulating effect on the plants, is an important factor regulating morphometric processes. Analysis of scientific data has shown that optimal morphogenic responses in microplants in vitro culture vary depending on the application of substances with rooting properties [17, 18].

The experiment investigated the effectiveness of using biologically active substances within nutrient media for propagating garden strawberry in in vitro culture. The substances studied (tryptophan, aspartic acid, indole-3-acetic acid) activated the growth and development of microplants. Aspartic acid, as a precursor to all other amino acids and a component of nitrogen metabolism in the plant organism, contributed to the growth of the root system and leaf surface, although the data obtained for the studied indicators were lower than those for tryptophan and indole-3-acetic acid.

Tryptophan, by nature, is a key intermediate of auxins, which activate root growth and stimulate the growth of meristematic tissues [19]. The effect of tryptophan in different dosages has a variable impact on plants and depends on the optical isomeric form. Some studies indicate that D-tryptophan inhibits plant growth, especially at high concentrations [20]. According to research by other authors, the use of L-tryptophan in nutrient media stimulates growth processes [21, 22].

Our experiments found that tryptophan, used in its L-form, actively contributed to the increase in morphometric indicators of the aerial part of microplants, achieving the highest values in the experiment. Tryptophan's effect on the rooting of microplants was on par with the influence of indole-3-acetic acid, which yielded the maximum regenerative capability and rooting.

Indole-3-acetic acid belongs to the group of auxins, intensifying cell division, and confirming its impact on root formation processes. Auxin hormones are used in rooting woody, medicinal, fruit, and berry crops [23, 24].

The action of exogenous auxins in activating root formation may be linked to the function of specific genes and transport proteins that respond to these hormones. Specific genes encode transcription factors involved in the auxin response, and their activation leads to root formation [25].

A major drawback of indole-3-acetic acid is its poor solubility in solutions, which sometimes complicates its use. Hence, growth stimulators containing this substance include chemical additives to improve its solubility. The use of tryptophan, which belongs to the group of auxins and has a similar effect on plants as indole-3-acetic acid, with good water solubility, is recommended in in vitro technologies to enhance root formation in microplants.

5 Conclusion

The research established that incorporating biologically active substances into nutrient media and using a Modified nutrient medium, containing mineral salts of micronutrients in chelated forms with EDTA, enhances the efficiency of microclonal propagation of garden strawberry.

The use of the Modified medium led to an increase in morphometric indicators compared to the Murashige and Skoog medium: on average, the length of microshoots was significantly greater by 0.2 cm, the number of microshoots per explant increased by 0.19, and the number of leaves and roots by 1.21 and 0.91, respectively, compared to the control one. The regenerative capacity of strawberry plants was improved with the Modified medium compared to Murashige and Skoog.

Comparative evaluation showed that the Brighton variety exhibited more foliar development and had a superior root count and rooting ability in microplants than the Albion variety.

Based on the analysis of the impact of biologically active substances on plants in vitro, it was established that the greatest results in terms of microshoot length, the number of microshoots, and leaves per explant were achieved when using tryptophan in the nutrient medium—measurements were significantly larger than the control by 0.48 cm, 0.66, and 0.87 units, respectively. The highest number of roots per individual garden strawberry microplant was obtained with the use of indole-3-acetic acid—averaging 6.78 per microplant, a substantial difference of 2.71 more than the control, and a non-significant increase of 0.43 when compared to tryptophan.

The most active proliferation of the strawberry shoots was observed with the use of indole-3-acetic acid—the replication coefficient on average through three passages was 3.4 to 6.6 units. Rooting of the microshoots on the nutrient media with the incorporation of biologically active substances held an advantage over the control. The rooting efficiency of microplants with the use of indole-3-acetic acid was the highest on the 28th day of the subculturing, reaching 73.8% on average in the experiment, a rate comparable to that achieved with tryptophan, differing by an insignificant 0.5%.

Therefore, the findings recommend utilizing auxins such as tryptophan and indole-3-acetic acid to increase the effectiveness of garden strawberry propagation in vitro.

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Intelligent Agricultural Techniques, Tools and Systems

Selection of Diagnostic Parameters When Assessing the Technical Condition of Spark Plugs

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Abstract. The study considers the problems of diagnosing the elements of the ignition system. It is necessary to choose diagnostic parameters providing small errors in the indirect measurement of the structural parameter during the evaluation process of technical state. It predetermines a small error in the method of measurement and an instrumental measurement error. The obtained diagnostic information on the availability of malfunctions is not always reliably and accurately. The study presents the results of testing of modern iridium spark plugs. The hypothesis is confirmed that the breakdown pressure of spark plugs affects the composition of exhaust gases. The relation between the breakdown pressure of spark plugs and the indicators of exhaust gases toxicity is established. It is determined that in the process of diagnosing the parameters of exhaust gases toxicity and breakdown pressure of spark plugs is possible to make a more accurate diagnosis about the condition of spark plugs. Based on the above statement, it is proved that timely replacement of spark plugs will increase their efficiency by 17%, will reduce the amount of exhaust gases emissions by up to 8%, and will also lead to engine fuel economy by 10–12%, which will lead to an increase of oil resource in the engine and, accordingly, the entire engine.

Keywords: Diagnostics · Machines · Repair · Diagnostic parameters · Maintenance · Malfunctions · Spark plugs · Operation · Resource

1 Introduction

It is known that diagnostics is an integral element and a constituent part of the machine maintenance process. The principle purpose of diagnostics is to minimize the costs of maintenance and repair of vehicles with a higher quality of operation [1, 2]. The given purpose is achieved by timely detection and prevention of vehicle failures, maintaining optimal adjustments, by minimizing vehicle downtime due to technical malfunctions, by a qualified knock-down-free evaluation of the technical condition of mechanisms, on the basis of which reasonable recommendations are given on the implementation of preventive operations, repair, further maintenance-free operation, replacement of a component part of the vehicle, etc.

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The widespread introduction of electronics elements and electronic systems in modern engines [3] and their operation under conditions of a complex of destabilizing destabilizing factors complicated the diagnostic process. It is connected with a choice of diagnostic parameters and their response to the actions of an operator-diagnostician [4]. But the experience of diagnosing modern cars and many above factors demonstrate that obtained diagnostic information about the presence of a malfunction is not always reliable and accurate. Very often, there is a requirement to use additional diagnostic indicators or parameters that will affect other important criteria.

It is well known that one of the most important components determining the qualitative operation of the engine of mobile power means is the ignition system, and the greatest number of failures is fallen at it. [1, 5].

2 Materials and Methods

During the operation of the ignition system, gradual failures of spark plugs are observed, emerging from carbonization which occurs due to deposit of combustion products and oil on the heat insulator housing, as well as a result of the influence of gas and electrical erosion. [3, 6].

Thus, the appearance of malfunctions in the ignition system in the form of a sparking failure can be caused not only by a malfunction of serviceability of the spark plugs. The state of the ignition coil, high-voltage wires, spark plug caps, etc. influenced on it. [3]. Therefore, the diagnosis of the state of the ignition system may not be accurate and reliable. In this case as a rule, many service companies or car service stations offer alternate replacement of all elements of the ignition system to eliminate these malfunctions. Consequently, spark plugs, high -voltage wires, etc. are changed. Although, in fact, the spark plugs did not have a large resource and could serve for more than ten thousand kilometers of a run.

This is especially true for iridium and platinum spark plugs. The cost of these spark plugs is rather high, and it is not always advisable and profitable to change them having a small run. We offer to use two parameters together to evaluate the ignition system – breakdown pressure of spark plugs and exhaust gas toxicity indicators. The concept of "measurement accuracy" and the reliability of the obtained information is very important when choosing and evaluating diagnostic parameters, it characterizes the quality of measurements, demonstrating the proximity of their results to the true value of the measured quality [6, 7].

By analogy with this concept, it may be said that the accuracy of diagnostics will be estimated by the proximity of the structural parameter magnitude to its true value. Obviously, the smaller is an overall error in determining the technical condition of the object, the higher is the accuracy and reliability of the diagnostics. And the accuracy of diagnostics, in turn, depends on a number of factors:

- accuracy of measurement instruments;
- selected diagnostics method;
- distribution law of measurement error;
- accepted reliability of measurements;
- human operator or automaton errors.

The following indicators are used for quantitative characteristics of the reliability of engine systems (ignition systems): the probability of failure-free operation, the mean time to failure, the failure flow parameter and mean time between failure [3, 8, 9].

The probability of failure-free operation $\hat{P}(L)$ is statistically determined by the experimental data using the formula

$$\widehat{P}(L) = \frac{n_p}{N} \quad (1)$$

where n_p - a number of systems that worked reliably up to a given operating time (run), L, N is a total number of experimental cars in a batch.

The content of this indicator lies in the fact that it quantitatively characterizes that the probability of the ignition system failure will not happen within a given operating time. At the same time, the established warranty run or the accepted frequency of maintenance is usually taken as specified operating time.

Mean time to failure $\hat{L}_1$ represents the average value of the first failure time, and is statistically determined by the formula:

$$\hat{L}_1 = \frac{1}{N}\sum_{i=1}^{N} L_i \quad (2)$$

where $\hat{L}_1$ - the first failure time of an i engine, thousand km.

If, according to experimental data, the distribution function of the first failure time is determined, the probability of failure-free operation and the mean failure time can be determined by the exact formulas:

$$P(L) = \int_{l}^{\infty} f(l)dL \quad (3)$$

$$L_1 = \int_{0}^{\infty} lf(L)dL \quad (4)$$

where f (L) - the density distribution function of the first failure time. For a repaired product, such as a car, the moments of failures during operation form a flow, which is commonly called a failure flow. As a differential characteristic of this flow, the parameter of the failure flow is used, the statistical evaluation can be found by the approximate formula:

$$\omega(L) = \frac{\sum_{i=1}^{N} r_i(L + \Delta L) - \sum_{i=1}^{N} r_i(L)}{N\Delta L} \quad (5)$$

where r_i - a number of failures of an i engine for the considered operating time; ΔL- the run interval at which the failure flow parameter is determined as a mean value. Mean time between failures indicates the mean value of operating time between failures and is statistically determined by the ratio of the full operating time of cars to the general number of failures.

Thus, indirect measures of the operating conditions can be selected as diagnostic variables, namely exhaust gas toxicity, engine vibration, etc. In some cases, it is possible to carry out direct measurement of a structural parameter, for example, a gap in the spark plug, an advance angle of ignition, etc.

The list of structure parameters that are reasonably to check when diagnosing a vehicle is the initial information on which all subsequent developments are based:

- sequence of studies aimed at identifying the nomenclature of diagnostic variables;
- sequence of the development of control and diagnostic tools, etc.;
- evaluation of the technical and economic efficiency of diagnostics.

3 Results

The obtained collection of structure parameters was subjected to comparative cost estimates by determining the probable costs connected with the elimination and prevention of failures for every individual parameter. The criterion of maximum costs was used for engines of mobile power facilities being in service.

The procedure of their determination is as follows: [10].

- all failures were collected and analyzed. A list of limiting structure parameters was identified and then the probability of failure Q_i was determined according to an i parameter for the inter-control period.

In case of the non-repeated selection

$$Q_i = \frac{n_i}{N} \tag{6}$$

In case of the repeated selection

$$Q_i = \frac{n_i}{N + \sum_{j=1}^{N} (m_j - 1)} m_j \geq 1 \tag{7}$$

where n_i, m_j -a number of i failures for the inter-control period: total and for every j machine, respectively;

N – a number of engines being under observation;

- the costs A_i, associated with failure elimination by parameter, taking into account the vehicle deadlock, are determined
- the probable losses for the inter-control period associated with failure elimination by parameter are calculated (in rubles);

$$S_i^{/} = Q_i A_i \tag{8}$$

- the costs associated with routine scheduled maintenance to prevent an element failure by parameter for the period $t_{\underline{M}}$ are established (in rubles);

where C_{Oi} - cost of one service;

$$S_i^{/} = Q_i A_i \tag{9}$$

The costs associated with restoring the parameter during repair are calculated (in rubles)

$$S_i^{///} = K_{pi} C_{pi} (1 - Q_i) \tag{10}$$

$$\text{where} \quad K_{pi} = \frac{t_M}{t_p} \tag{11}$$

C_{pi} - the cost of restoring of i parameter during repair;
t_M, t_p - the inter-checking and inter-repair operating time accordingly;

- the total specific costs associated with the elimination and prevention of failure by t_M structure parameter,

$$S_i = \frac{S_i^{/} + S_i^{//} + S_i^{///}}{t_M} \tag{12}$$

- the total specific costs by the parameters are ranged in a decreasing sequence

$$S_1 \geq S_2 \ldots \geq S_i \geq \ldots S_m \tag{13}$$

where $S_m > 0{,}01 S_1$.

The obtained series (13) served as a basis for the subsequent refinement of the parameters proposed by the authors of the study.

Next, the total specific costs per an element are determined by the i structure parameter with the established frequency of diagnosis t_M, permissible parameter variation, the mean life of the element t_{fi} depending on t_M and D, as well as the costs A_i, C_{pi}, C_{oi}, B_i:

$$S_i^D = \frac{Q_i^D A_i}{t_{fi}} + \frac{(1 - Q_i^D) C_{pi}}{t_{fi}} + \frac{\kappa_{Di} B_i}{t_{fi}} + \frac{K_{oi} C_{oi}}{t_{fi}} a \tag{14}$$

(in rubles/operating time unit),

where Q_i^D - the probability of the element failure according to the i structure parameter when diagnosing the element;

K_{Di}, K_{oi} - a number of examinations (diagnostics) and routine maintenance by i structure parameter during the period of te element operation. The value K_{oi} is calculated taking into account the probability of the element servicing as a result of its diagnosis.

The possible specific saving obtaining as a result of diagnosing elements for every parameter can be determined by the following expression:

$$W_i^U = S_i - S_i^D \text{(in rubles /operating time unit)} \tag{15}$$

where S_i - specific costs determined by the formula (14), when D is equal to the limiting change of the parameter, that is, when the element is not diagnosed. A similar value S_i is found by the formula (12).

The significance of the parameters is estimated by the formula

$$W_i^o = \frac{W_i^U}{W_{\max}^U}(W_i^U \succ 0) \tag{16}$$

The parameters are mapped out when costs reduction is insignificant at the expense of diagnosis.

The remaining parameters are ranged in the order of saving decrease (absolute values W_i^U or relative W_1^o):

$$W_1^o \geq W_2^0 \geq \ldots \geq W_n^0 \tag{17}$$

Consequently, the condition (17) characterizes both the list of structure parameters that it is advisable to diagnose and their management efficiency.

Thus, the obtained series (17) serves as a basis to decide the issue of choosing control-diagnostic tools for every structure parameter and timely detection and prevention of vehicle failures, maintaining optimal adjustments and minimizing vehicle dead time due to technical malfunctions.

By analogy, the diagnostics efficiency of individual mechanisms, systems, components and unites of the vehicle is evaluated. For example, fuel systems. Where the value $\sum\limits_{i=1}^{n} W_i^U$ represents costs reduction for a machine as a whole due to diagnosing it by all parameters.

In modern cars, the operation of the ignition system and the fuel system are closely connected. Electronic sensors and devices are responsible for all processes. The obtained experimental studies [11, 12] conducted in this direction cannot be fully used for modern electronic control systems of the engine.

The study indicates [13] that the operation of spark plugs significantly affects the combustion process of the fuel-air mixture and, accordingly, the composition of exhaust gases. The share of failures of this element accounts for up to 6% during operation [14]. Therefore, in order to reduce the number of failures and to increase the efficiency of diagnosis, the authors of this study propose to use an additional diagnostic parameter - exhaust gas toxicity and the breakdown pressure of the spark plug when evaluating the technical condition of the ignition system, in particular, spark plugs.

4 Discussion

The breakdown pressure parameter of the spark has been considered more than once in the studies [3, 5]. They indicate that plugs affect the technical and economic operation of the engine, but only on classical fuel and ignition systems. As of today, there is no established interconnection between the breakdown pressure of spark plugs and the toxicity indicators of exhaust gases of modern engines.

However, it is possible to determine the usefulness of a plug for further operation when used special diagnostic devices such as Э203П with a high degree of reliability. Such devices enable to observe visually the process of spark formation. At the same time, the plug is under pressure corresponding to the working pressure in the cylinder.

The plug is considered to be of high quality if stable spark formation occurs at a gap of 1.0 mm and under a pressure of 5 atm. However, it does not take into account the fact that modern engines run on lean mixtures, have a higher operating temperature, compression ratio and power- per- liter than engines manufactured 20–30 years ago. Therefore, it is not quite correct to specify the following criterion that a plug is of high quality if stable spark formation occurs at a running clearance installed by a manufacturer and a pressure in the measuring chamber equal to 10…11 atm.

It is also necessary to take into account the fact that the humidity in the chamber of the device differs from the humidity in the combustion chamber of the cylinder, so the spark formation process will be different. However, according to the studies [5], 5% of misfire in the combustion chamber increases the content of hydrocarbons (CH) in exhaust gases of the engine by about 3 times. Therefore, the noted nature of the action of electric spark parameters on the ignition process of the gas-air mixture cannot be completely transferred to the ignition process in the combustion chamber of the internal combustion engine. In actual operating conditions, there are wide fluctuations in the composition of the fuel-air mixture in the engine cylinders. These phenomena are further aggravated in some modes of operation of the engine (partial loads, unsteady modes). To establish the interconnection between the indicators of exhaust gas toxicity and the breakdown pressure of spark plugs, the authors of the study conducted experimental investigations.

A certain number of spark plugs (DENSO) were selected with different breakdown pressure from 1 to 12 atm., which was measured by the above device. During the experiments, the pressure in the device chamber was gradually built up by using a hand pump.

The plugs were alternately installed on the engine, and after that, according to the identical method, toxicity indicators of exhaust gases CO and CH were measured in two modes of operation: at minimum rotational speed of the engine crankshaft and at average rotational speed of the engine crankshaft (n = 0,6 nmax) (Figs. 1, 2).

Thus, the measurement of the carbon monoxide content in the exhaust gases (CO) of the engine showed that the toxicity content is the lowest on new spark plugs under a pressure of (12 atm. It changes at an idle and average operating mode not significantly from 0.25 to 0.4% at decreasing in the breakdown pressure. The exhaust gases composition changes in a large-scale side and reaches 2–4% at the average operating mode when decreasing breakdown pressure. It was determined in the studies that the breakdown pressure decreases by increasing a run of spark plugs [5, 14]. Therefore, it is possible to judge the plugs condition and their residual life according to the indicators of exhaust gas toxicity in the absence of malfunctions in other systems and mechanisms of the engine.

The measuring results of the indicators of the amount of hydrocarbons (CH) and carbon monoxide demonstrate an increase in the amount of hydrocarbons in the exhaust gases, it can be explained by incomplete combustion of the fuel-air mixture, and the carbon monoxide content increases. The results of the exhaust gas toxicity test showed that the toxicity indicators of CO and CH increase but the CO_2 content decreases with reduce of the breakdown pressure on the spark plugs.

Further tests of the exhaust gases toxicity demonstrate its increase as a result of the combustion process deterioration of the fuel-air mixture. This is due to the fact

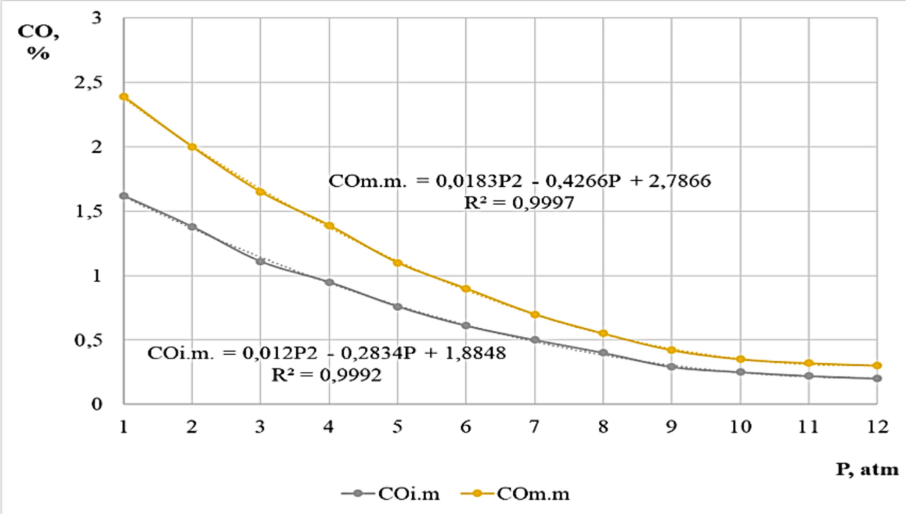

Fig. 1. Change of the toxicity indicators of the exhaust gases (CO) at two operating modes

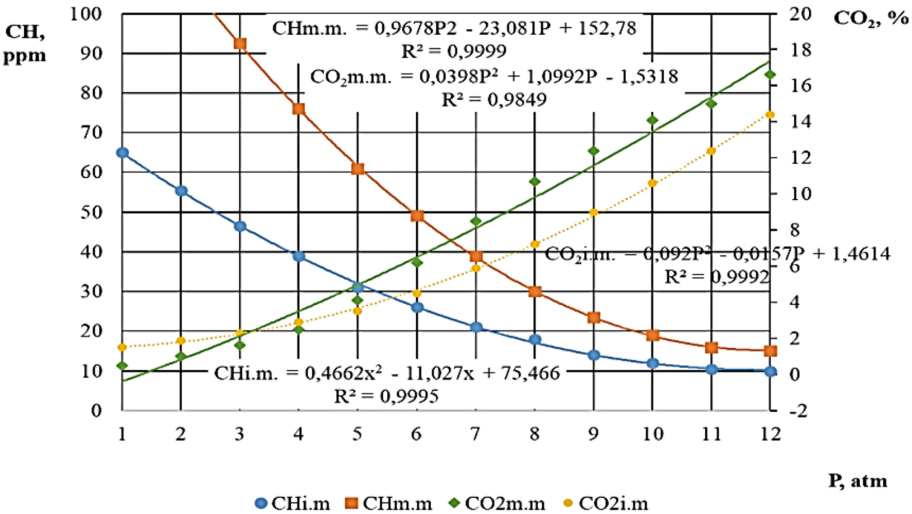

Fig. 2. Change of indicators of toxicity of exhaust gases (CH and CO_2) on two operating modes

that conducting bridges are formed on an insulator, which shunt the spark gap forming resistance Rш during the long-term operation of iridium or platinum spark plugs (under a breakdown pressure of 3–4 atm. And a run over 85…100 thousand km.)

This resistance leads to an increase of the ignition coefficient η_3 which, in turn, reduces the secondary voltage on the ignition coil and the breakdown voltage of the spark plug $U_{пр}$.

It follows from the study [5] that a decrease in the breakdown voltage reduces the spark discharge energy $W_{\text{пр}}$:

$$W_{np} = \int_{0}^{t_{ip}} U_{np} * i_2(t)dt,$$

where W_{np} - the spark discharge energy, J; t_{ip} - the spark discharge time, s; i_2 - the current in secondary coil, A; U_{np} -the breakdown voltage, V.

A decrease of the spark discharge energy W_{np} leads to a "weak" spark on the spark plug, resulting in incomplete combustion of the mixture, forming an increased content of toxic components in the exhaust gases at the same time.

No adjustments of engine systems and mechanisms were carried out during all experimental studies in order to obtain an accurate and reliable diagnosis of the state of exhaust gases. The toxicity of the exhaust gases was measured in the exhaust system up to an exhaust gas neutralizer. It made possible to exclude its operation and influence on the afterburning process of exhaust gases.

5 Conclusions

It is possible to give a more accurate diagnosis about the state of the fuel system and ignition system during the process of diagnosing the parameters of exhaust gas toxicity and the breakdown pressure of spark plugs. The breakdown pressure and, consequently, the spark plugs resource affect the composition of the exhaust gases and, accordingly, the neutralizer resource and the car dynamics due to the influence on the combustion process. As mentioned before, one may come to the conclusion that timely replacement of spark plugs can increase their efficiency use by 17%, reduce the amount of exhaust gas emissions up to 8%, and also will lead to fuel economy by 10–12%, to an increase in the oil resource in the engine and, accordingly, the entire engine.

The above results of the study will allow during the process of diagnosing the fuel system and ignition system by modern diagnostic testers and stands together with indicators of exhaust gas toxicity:

1. To accept the breakdown pressure parameters of spark plugs and exhaust gas toxicity indicators as diagnostic, since they are accurate and reliable being evaluated together.
2. To evaluate the effect of spark plug service life on exhaust gas toxicity;
3. To increase the life of the neutralizer and maximize the use of spark plugs;
4. To exclude the influence of spark plugs on the engine operation by the toxicity parameter and their run;
5. To save financial resources of auto- enterprises, car owners and service center employees at unjustified purchase of spark plugs.

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The Justification of the Design and Operating Parameters of the Diaphragm Pump

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Abstract. The sustainability of ensuring food security depends on the efficiency of its agriculture and food industry. The only point where food security is not currently ensured is milk and high-protein dairy products. In the milk processing chain, milk is indeed moved through pipelines, pumped from one container to another, and processed through various devices. The most important distinctive feature of the diaphragm-type pump is a minimal mechanical effect on a pumped product due to the exclusion of the influence of the centrifugal forces on it. Therefore, they are mostly used for light pumping of the products, in particular milk. The net volume of the working chamber, durability and efficiency of the pump application largely depend on the diaphragm design. The pump flow was studied depending on the stroke frequency of the diaphragm, the height (resistance) of the liquid injection line into a receiving tank and a number of pump geometry and its parts, in particular, the design of the diaphragm and valves. The flow was determined as a quotient of dividing of liquid volume getting into the receiving tank during the pump action period. Theoretical dependencies were obtained to calculate the diaphragm pump efficiency, the capacity of its working chamber and the required working diameter of the diaphragm. The obtained research results formed the basis for the developed design of the diaphragm pump with an electromagnetic drive. Based on the performed research, the prototype of the electrically driven diaphragm pump was developed and tested under the production conditions.

Keywords: Diaphragm pump · diaphragm · milk · vacuum · net volume · pump chamber · milking unit

1 Introduction

The growth of the world's population is the main factor leading to a constant increase in demand for food in the global market. The food security of a country is the basis for preserving its statehood and sovereignty. The only point of the doctrine where food security is not currently ensured is in milk and high-protein dairy products obtained from it. Milk belong to a special category of transportable medium. Thus, in the processing chain from a cow's udder to a processor, milk is repeatedly moved through pipelines (hoses), pumped from a container to a container, and pressed through various devices (cleaners, coolers, etc.). Numerous studies by domestic and foreign scientists confirm

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the particularly negative impact of such mechanical effects on milk, leading to a change in its phase state, and, consequently, to decreasing in quality indicators and technological properties [1–3].

Hydraulic machines called pumps are used as pressure devices [4]. Of all the variety of requirements for milk pumps, it is necessary to highlight the main one: to take minimal mechanical effect on a pumped product and prevent its foaming during pumping [5]. Diaphragm (membrane) milk pumps meet this requirement most fully. They are classified as devices constructed for light pumping of products [6].

A diaphragm (membrane) pump is a volumetric pump, a work member of which is a flexible plate (diaphragm, membrane) fixed at the edges and bending under the action of a lever mechanism (mechanical drive) or as a result of changes in air pressure (pneumatic drive) or liquid (hydraulic drive), performing a function equivalent to the function of a piston in a piston pump. The undeniable advantages of diaphragm pumps are the absence of a motor, a gearbox, rotating parts, seals and bearings, as well as compact dimensions, low materials consumption and versatility of use [7, 8].

Diaphragm pumps are equipped with a mechanical, pneumatic, hydraulic or electric drive. The experience of application of electrically driven diaphragm pumps in processing lines of the enterprises at the agro-industrial complex has shown their high efficiency in comparison with other designs, primarily due to the reduction of specific power inputs and increased operational reliability [9, 10].

Depending on the number of chambers, diaphragm pumps are divided into single-acting (single-chamber) and dual operation (double-chamber) pumps. The most important operational parameter of the diaphragm pump is its flow rate (efficiency), one of the ways to increase it is to increase the net volume of the working chamber, as well as to optimize the parameters of the suction and discharge lines. The net volume of the working chamber, durability and efficiency of the pump application largely depend on the diaphragm design. There are three main types of diaphragms used in different models of diaphragm pumps.

The simplest design of the flat-type diaphragms allows achieving a high degree of compression. The connection of such diaphragm with a rod is carried out through an opening specially made in its central part. The presence of such opening often causes deterioration in the tightness of the diaphragm, which can begin to leak the pumped medium into the second chamber of the pump. In addition, the elements of the threaded connection, with the help of which the diaphragm is connected to the rod, are in constant contact with the working environment, which is undesirable when pumping foodstuffs.

Molded diaphragms are connected to the pump rod using a screw pressed into a disk of a convex form installed on the opposite side of the working chamber. Thus, when using such membranes for the pumps, a contact of the pumped medium with metal fasteners is excluded. However, the pumps, on which diaphragms of this type are installed, are characterized by lower efficiency since convex diaphragms are less elastic.

The pumps with structured diaphragms are distinguished by the highest efficiency, maximum service life, and the least costs. When using these diaphragms, leaks of the pumped medium are practically eliminated; in addition, the latter does not come into contact with metal fasteners.

Except for the diaphragms, the important elements of the pump that determine its operating characteristics are the working chamber, check valves at the inlet and outlet, the rod connecting the drive shaft to the membrane, inlet and outlet pipes.

One of the options to use diaphragm pumps is to apply them as devices to create vacuum in individual milking units. This pump is compact in size which allows placing it on the carts when the operators of milking units transport this pump with cans around a farm. It is also important that when operating vacuum diaphragm pumps, a minimum of noise and vibration is generated. Other advantages of diaphragm pump application are resistance to high humidity and ensuring high rate of pumped medium.

However, in milking units and milk lines, diaphragm pumps have not received proper use due to thier poor effeciency and a very limited resource (service life) because of failure of the diaphragm and valve mechanism disorder. In addition, as technical devices, such pumps have a lower coefficient of efficiency compared to centrifugal pumps [11, 12]. Therefore, to find the way to eliminate these shortcomings seems to be an urgent direction in the field of improving their design and operational parameters of the devices intented for milk pumping [13].

2 Materials and Methods

In the process of doing work, the materials of theoretical and experimental research in the field of diaphragm pumps, improving their design towards the most fully meeting the requirements of the technology, increasing production safety and coefficient of effeciency were used [14]. The materials of our own work of many years in the field of milking unit operation UDS-3B, UDM-200, UDA-8 on dairy farms and complexes of the Stavropol Territory (Russian Federation) with an analysis of the reasons for the premature failure of their functional parts including milk pump were used [15–17]. The experimental studies were carried out at the stand for operation of the diaphragm pump (Fig. 1) of the Research Laboratory at the Department of Machinery and Technologies of the Agro-Industrial Complex of the Stavropol State Agrarian University [18].

The pump flow was studied depending on the stroke frequency of the diaphragm, the height (resistance) of the liquid discharge line into the receiving tank and a number of geometric dimensions of the pump and its parts, in particular, the design of the diaphragm and valves. The flow was determined as the quotient of dividing the liquid volume getting to the receiving tank by the pump operating time. The pump operating time was set by using a timer.

The number of diaphragm strokes was set by adjusting the pump drive. It was changed from 10 to 60 per minute every 10 cycles. The pressure on the discharge line was changed by using a filter-resistance regulator. Among other pump parameters, the stroke of the diaphragm and the diameters of the suction and discharge pipes were changed. The stroke of the diaphragm was regulated by installing a screw stop at the end of one of the pump covers, and the pipe diameters were replaced by others. For this purpose, replaceable pipes (with corresponding valves) with diameters of 15, 20, 25 and 30 mm were manufactured.

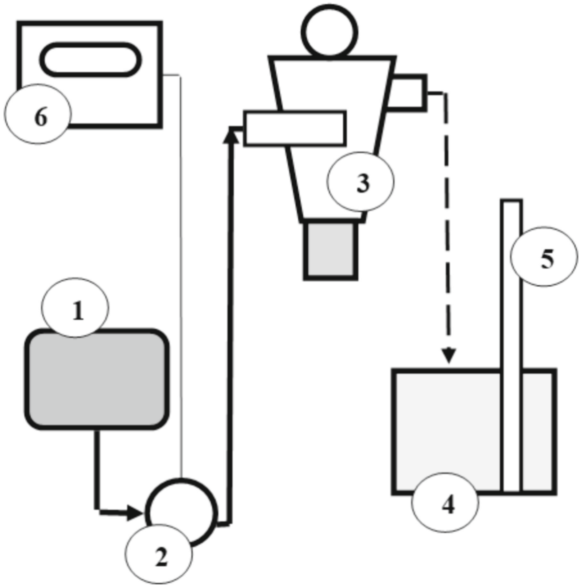

Fig. 1. General view (a) and diagram (b) of the stand to study the operation of the diaphragm milk pump: 1 – milk collector; 2 – diaphragm pump; 3 – filter-resistance regulator; 4 – receiving tank; 5 – measuring bar; 6 – timer

3 Results

When replacing the diaphragms of the pumps in question, a change (chamber) is determined due to the displacement of the diaphragm (membrane) during the working cycle, after which the volume change is multiplied by the number of working cycles per unit of time.

When substituting a diaphragm with a solid center for a structured diaphragm, the increase of the net volume of the working chamber pump, and therefore, the increase in the volume of displaced liquid (*Wn*) is determined as the difference between the volumes *Wc* and *Wj*, i.e.:

$$Wn = Wc - Wj \tag{1}$$

It is graphically presented in Fig. 2.

To determine the dependence of the capacity of working chambe pump, and therefore, the volume of the displaced fluid per stroke of the rod, six intermediate values of the diameter of the structured diaphragm were taken, as shown in Fig. 3.

A functional dependence of the working chamber capacity of the diaphragm pump on the parameters influencing it was obtained after appropriate transformations:

$$W = \frac{\pi L}{12}((D_P + 0,5D_C)^2 + \frac{3}{4}D_C^2) \tag{2}$$

where L – stroke of the diaphragm rod, dm;

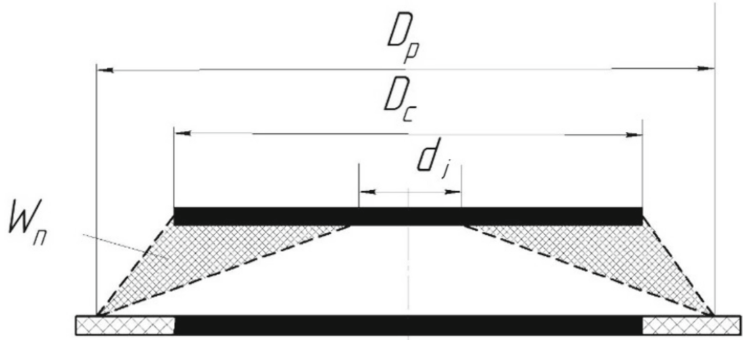

Fig. 2. Increase of the volume of displaced liquid Wп when using a structured diaphragm

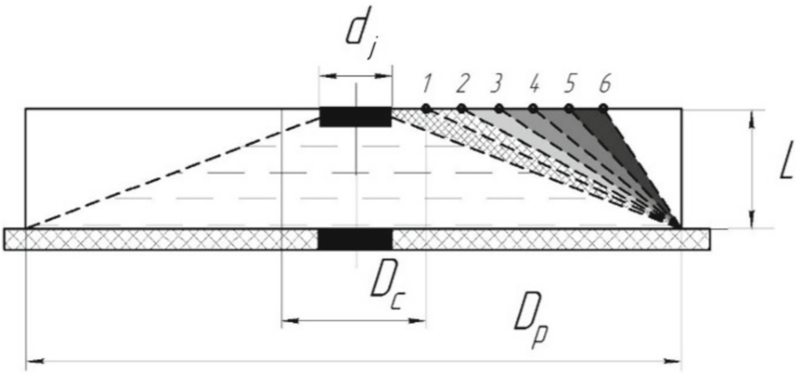

Fig. 3. Intermediate values of the diameter of the structured diaphragm

D_c – diameter of the structured diaphragm;

D_p –working diameter of the diaphragm, dm (in further calculations, D_p is taken equal to 1.8 dm).

Figure 4 shows a graph of the relationship between the volume of the working chamber pump and the diameter of the structured diaphragm. The required pump flow with a working chamber volume of 0.38 dm^3 will be provided with a structured diaphragm diameter of 1.3 dm. Which corresponds to the maximum intensity of milk flow into a milk collector of domestic milking units (ADM-8A, UDM-200, UDA-8, etc.),

The dependence to determine the required working diameter of the diaphragm is obtained from the formula (2):

$$D = \sqrt{W\frac{12}{\pi L} - \frac{3}{4}D_C^2} - \frac{D_C}{2} \tag{3}$$

The working diameter of the diaphragm directly determines the size of the pump casing, and, consequently, its dimensions, weight and cost. As a rule, *Dp* is taken within 0.8…0.85 of the diameter *D* of the pump casing.

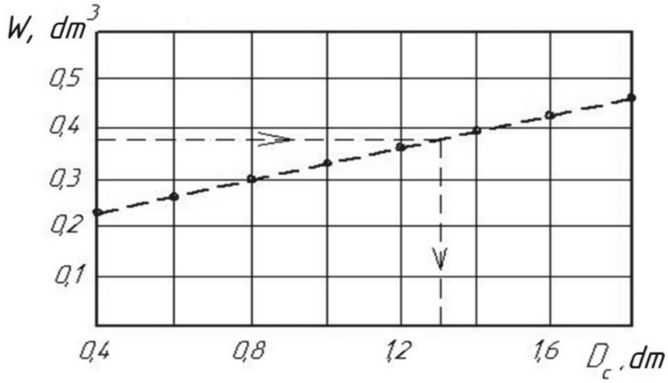

Fig. 4. Dependence of the volume of the working chamber on the diameter of the structured diaphragm

In addition to the diaphragm, the embodiment of the valve mechanism has a significant effect on the operating indices of the pump. The ball valves are widely used in the valve mechanisms of the milk pumps. The advantage of these valves is the provision of the valve "self-adjustment", which lowers the standards for accuracy of manufacturing of its guides. A ball valve can be made of either a metal or rubber element [19, 20].

The effect of the height of fluid delivery into the collection tank and the pressure in the suction line on the delivery of a diaphragm milk pump is presented in Fig. 5. A change in the fluid pressure in the delivery line by the diaphragm milk pump into the collection tank does not have a significant effect on the pump flow [21, 22]. Thus, an increase in the height of delivery N within 0… 1.5 m reduces the pump flow by 12% for every 0.5 m of height.

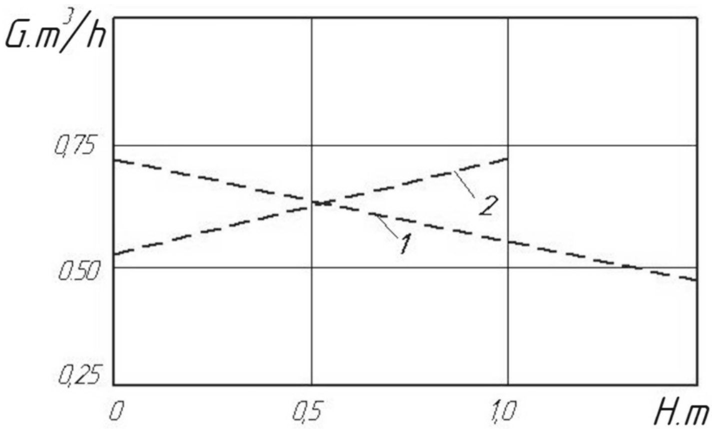

Fig. 5. Dependence of pump flow on the height of fluid delivery into the collection tank (1) and pressure in the suction line (2)

An increase of pressure in the liquid suction line into the pump leads to an increase in its flow.

Based on the obtained studies of the design parameters of vacuum pumps for pumping milk in milking machines providing delicate pumping of dairy products, a design with an electromagnetic drive has been developed (Fig. 6).

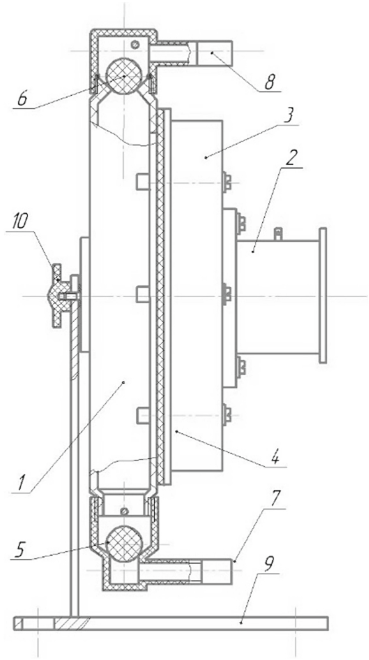

Fig. 6. Diaphragm pump with the electromagnetic drive: 1 – body; 2 – electromagnet; 3 – cover; 4 – diaphragm; 5 – suction valve; 6 – discharge valve; 7 – suction pipe; 8 – discharge pipe; 9 – fastening; 10 – clamp

The diaphragm pump is driven by a control solenoid that allows you to change the frequency and length of the road.

The proposed design of the diaphragm pump will allow pumping milk from 500 to 1500 l/h without negative impact on the pumped product.

4 Conclusion

The competitive advantages of any device, including a diaphragm pump, are largely determined by its material consumption being an indirect indicator of cost. One of the ways to reduce this indicator is to substitute diaphragms with a solid center for the structured diaphragms.

Analysis of literary sources, as well as the results of our own theoretical and experimental studies of the working process of the diaphragm pump show that the effectiency of its application in pipe-line milking is due to [23, 24]:

– the most complete preservation of the technological properties of milk and reduction of its losses;
– reducting of material consumption and cost of the pump at the same time increasing its operational reliability;
– increasing pump efficiency.

Thus, when the diameter of the structured membrane is increased from 0.4 to 1.4 dm due to increasing the volume of the working chamber pump, its productivity is increased by 1.8 times.

As a result of reducing the milk residues in the pump chambers per 100 cows in milk during the year, an additional 100…150 L will be obtained depending on the milking frequency. In relation to the option of a modular dairy farm for 100 cows in milk or pipeline milking a milking line with a daily productivity of 3 tons/day, only by reducing milk losses, the annual savings will approximately be 110…120 thousand rubles.

Among the studied options of stepped changes in the flow of the diaphragm milk pump, the options to regulate the membrane stroke and stroking rate (work cycles) are of great interest.

It is advisable to increase the technical and operational parameters of the diaphragm pump due to:

– ensuring its operating mode by means of the electric drive of the working body;
– increasing the diameter of the ball valves from 20 to 25…30 mm;
– using structured diaphragms.

On the basis the performed research, the test model of the electrically driven diahpragm pump has been developed and tested under the production conditions. The given pump design provides milk flow within the range of 500…1500 l/h. The payback was 1.7 year.

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The Use of a Magnetic Liquid Seal in the Design of an Electric Pulsator for a Milking Machine Manufactured Based on a Linear Electric Motor

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Abstract. Sustainable agricultural systems are a prospect for the development of the agricultural sector as a whole, including dairy farming. One of the main tasks of sustainable agriculture in this area is the creation of milking machines with intelligent modes of operation. Such longitudinal devices can be created on the basis of linear motors with a magnetofluidic seal. One example of their use is as a seal in an innovative design of an electro-pulse machine used in milking operations. By using a magnetic fluid in a sealing unit, it is possible to keep the shaft of a linear motor in place, preventing unwanted movement and vibration. This helps to ensure a more consistent and higher quality milking process. The researchers looked at different samples of magnetic fluid, each with a different concentration of solid particles, in order to better understand their magnetic and heat properties. The developed sealing unit can withstand significant pressure, as confirmed by theoretical calculations. The research into magnetic fluids has led to the determination of their key characteristics for use in magnetofluidic sealing units of an electropulsator, thus paving the way for their use in modern technical systems with a linear actuator.

Keywords: electropulsator · electropulsator · magnetofluidic seal unit · valve mechanism · milking machine

1 Introduction

In sustainable agriculture, one of the key tasks is the development of milking machines with intelligent control. These devices can be based on linear motors with magnetofluidic seals. One of the innovative methods for solving this problem is the use of magnetofluidic seals (MFS) [1]. These seals are based on the unique properties of magnetic fluids, which can be magnetized while maintaining their fluidity. These fluids are composed of minute magnetic particles dispersed in a liquid carrier and stabilized using surfactants, which prevents their agglomeration. MFS are characterized by high tightness, minimal wear and low maintenance requirements, making them an ideal choice for a wide range of industrial applications. MFS have found application in a wide variety of equipment in various industries, including food and chemical industries, oil refining, mining, metallurgy, energy, agriculture, and in the manufacture of pharmaceutical products.

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The characteristic size of the colloidal particles is about 10… 20 nm. Thanks to the unique properties of magnetic fluids, MFS have a number of significant advantages over seals of traditional designs: practically complete absence of leaks of the sealed medium under specified working conditions, low power loss, low torque, minimal wear due to purely fluid friction in the gap between moving and stationary elements, high maintainability and ease of maintenance [2].

The mentioned MFS units were used in the design of a new electropulsator for pairwise milking based on a linear electric motor with MFS units (Fig. 1) [3]. The aim of the study was to determine the parameters of the magnetic fluids of the seal unit for the developed electropulsator. The innovative electropulsator for pairwise milking, based on a linear electric motor with a MFS, contains a single body 1 with a constant vacuum pipe 2, connected to the vacuum line, the upper 3 and lower 4 pulsators of identical design, each of which has a variable vacuum pipe 5, connected through a manifold to the inter-wall chambers of the milking cups, as well as an atmospheric channel 6 with filter 7 and cover 8. Inside the upper 3 and lower 4 pulsator are partitions 9 with an opening 10 separating the chamber 11 of constant vacuum and the chamber 12 of variable vacuum. Through the opening 10 passes the shaft 13, which is the basis for the assembly of the armature 14 of the linear electric motor consisting of two magnetic-conducting disks 15 and a non-magnetic layer 16. The assembly armature 14 is located between two magnetic conductors 17 and 18 of the U-shaped form with two magnetizing coils 19 and 20. At the opposite ends of the shaft 13 are fixed cone valves 21 and on a sliding fit are disk-shaped valves 22 made in the form of a disk, under which there are stops 23. The chambers of constant vacuum 11 of the upper 3 and lower 4 pulsating are connected by channel 24, the shaft 13 is fixed in the axially symmetric direction using two units 25 of the MFS.

The electropulsator for paired milking based on the linear electric motor with the MFS operates as follows. When a control signal is applied to the magnetizing coil 20, the armature 14 and shaft 13 attract to the magnetic conductor 18, opening the cone valve 21 channel 6 of the upper pulsator 3, through which air passes through the filter 7 creates atmospheric pressure in the variable vacuum chamber 12, which is supplied to the interstitial space of two front milking cups. As a result, the rubber intensively affects the nipples, causing the onset of the compression phase. At the same time, the disk-shaped valve 22 closes the opening 10, limiting the access of vacuum to the chamber 1. The cone valve 21 of the lower pulsator 4 closes the channel 10 limiting the occurrence of atmospheric pressure in the chamber of variable vacuum 12 while the stop 23 smoothly raises the disk-shaped valve 22 and allows the vacuum to fill the variable vacuum chamber and the sub-nipple and interstitial spaces.

The linear electric motor provides control over the amplitude of movement of the assembly armature 14, and therefore the position of the cone valves 21. If the current in the magnetizing coil 19 increases and the current in the coil 20 decreases, the armature 14 and the shaft 13 being attracted to the magnetic conduit 17, smoothly open the cone valves 21 opening 10 of the lower 4 pulses and close the similar opening of the upper 3 pulses, transferring the operation of the pairwise milking electropulsator to the counterphase, while in the milking glasses of the front quarters there is a compression phase, and in the rear ones - a suction phase.

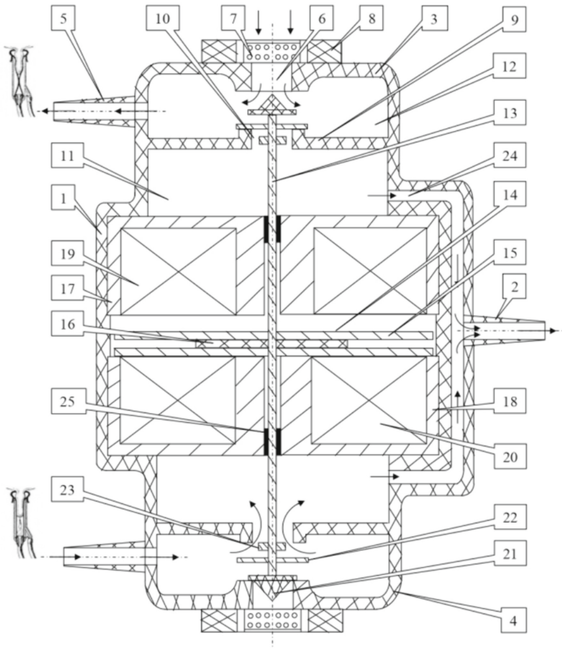

Fig. 1. The design of an electropulsator for pairwise milking based on a linear electric motor with nodes of a magnetofluids seal

The linear electric motor allows you to smoothly move the cone valves 21 of the upper 3 and lower 4 pulse in the extreme lower position, simultaneously adjusting the dynamics of the transition process in two cycles: suction and compression. Units 25 magnetofluids are a kind of sliding bearings, but they are made on the basis of a magnetic fluid (MF) and allow fixing the position of the shaft 13 in the axisymmetric position for a tight overlap of the atmospheric channel 6, which ensures a stable alternation of vacuum in the interwall chambers of milking cups and to reduce friction during the movement of the shaft 13, which increases the energy efficiency of the linear motor. The proposed mode of operation is necessary to bring machine milking into compliance with the physiological features of the milk yield process in cows, as well as to reduce the negative impact of the milking machine on animal health.

In order to eliminate the coaxiality of the cone valve 21 relative to the atmospheric channel 6 and minimize the magnitude of friction of the rod 13 about the internal surfaces of the magnetic conductors 17, 18, there are two elements 25 in the external part of the magnetic fluids. Each of the elements 25 is located in a groove filled with magnetic fluid. The leakage of the magnetic fluid in the groove is excluded by the toroidal permanent magnet, limited by the clamp. In the process of moving the rod 13 elements 25 magnetic fluid retain it in a strictly axial position, eliminating distortions, locking and vibration. When the cone valve 21 occupies the extreme upper position, it abuts against the seat, thereby ensuring a dense overlap of the atmospheric channel 6. While the hole 10 in partition 9 is open, as the disk-type valve 22 rises by stop 23. Vacuum pressure through branch pipe 2 constant vacuum fills chamber 11 constant vacuum and via the hole 10 chamber 12 variable pressure, after that expands through branch pipe 5 to inter-wall chamber of milk glasses, providing standard process of machinery milking. As such, the nipple gum doesn't experience deformation, and milk by action of pressure difference in the udder and below the nipple flow to sub-nipple camera, and from there through the milk tube is diverted to milk receiver. This is the stage of sucking (picture 2). Device has symmetric design and functions in counter-phase. Lower cone valve 21 starts to shift to lower position, stop 23 to rod 13 linear electric motor descends down, lower disk type valve 22 by action of vacuum drawn and covers hole 10 avoiding consumption of vacuum. Through the lid 8, filter 7, atmospheric channel 6, atmospheric air enters, filling chamber 12 with variable pressure and through pipe 5 inter-wall chamber milk glasses, the pressure in which increases to atmospheric. Due to the pressure difference in inter-wall and sub-nipple chambers nipple rubber starts to compress, enveloping the nipple of the udder. This is transitional process from sucking stage to compression stage (Fig. 2).

By adjusting the smoothness of movement of the conical valve 21 down using a linear motor, it becomes possible to control the dynamics of the transition process from the suction stage to the compression stage. When the conical valve 21 occupies an extreme lower position, the hole 10 in partition 9 is also blocked by the disk valve 21, and the atmospheric channel 6 is fully open. Chamber 12, variable pressure, pipe 5 and inter-wall cameras milk glasses are filled with atmospheric air. Pressure in inter-wall camera equal atmospheric and nipple rubber closes nipples udder from action vacuum in sub-nipple cameras milk glasses. This is stage of compression.

Suction and compression form a working cycle. The number of cycles is set by the number of pulsations, the duration of the cycles is regulated by the ratio of the stages. The control system allows you to set the required modes of milking and pre-milking massage of the udder. Pre-milking massage occurs due to an increased number of pulsations. In this mode, there is incomplete deformation of the nipple rubber, which contributes to increasing the intensity of milk yield [5].

2 Materials and Methods

Figure 3 schematically shows one of the developed elements of MFS, used in the design of the described electropulsator. These elements are located in the grooves of the magnetic conductors, filled with magnetic fluid 2. The leakage of magnetic fluid 2 in the groove is excluded by the toroidal permanent magnet 3, limited by the retainer 4, the inner cylindrical surface of which forms the pole of the MFS. The elements of the magnetic fluid seal hold the rod of the linear motor in a strictly axial position, excluding its distortions, locking and vibration during movement.

Before assembling the MFS unit, a magnetic fluid is applied to the working surface of the pole and the surface of the shaft with a brush. The assembly is installed in the groove in the magnetic conductor of the electropulsator in the following sequence: first - the toroidal magnet 3, then - the retainer 4. After assembly, the minimum distance from the pole to the surface of the shaft is 0.15 … 0.18 mm.

Consider a theoretical model of the MFS, which allows for the analytical calculation of its static characteristics [6]. Let the volume of MF with a length L and width h

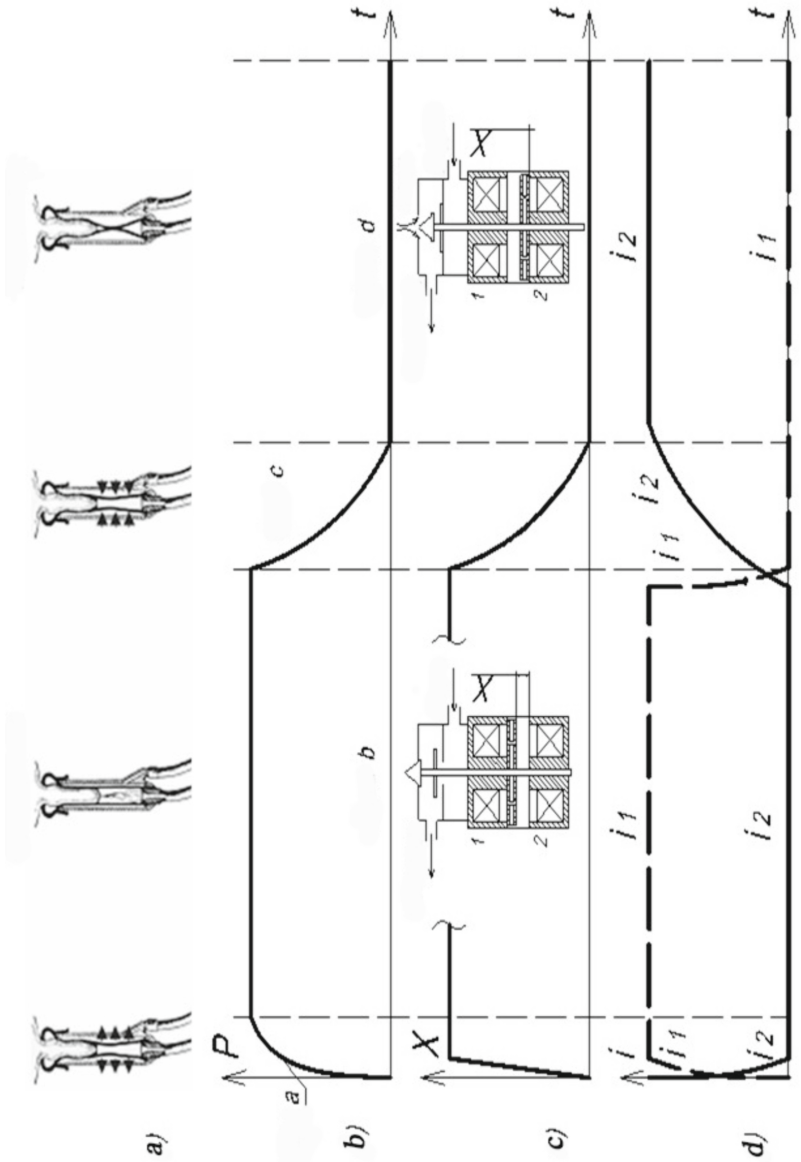

Fig. 2. The relationship of parameters by phases of milking: a) changing the shape of the nipple rubber; b) cyclogram of pressure changes in the inter-wall chambers of milking cups; c) moving the armature of a linear motor with a pulsator valve mechanism; d) the shape of the current on the magnetizing coils of the linear motor; phase of milk excretion; compression phase; phase a; phase b; phase c; phase d; to the glasses of the milking machine; atmospheric air; vacuumb) cyclogram of pressure changes in the inter-wall chambers of milking cups; c) moving the armature of a linear motor with a pulsator valve mechanism; d) the shape of the current on the magnetizing coils of the linear motor; phase of milk excretion; compression phase; phase a; phase b; phase c; phase d; to the glasses of the milking machine; atmospheric air; vacuum

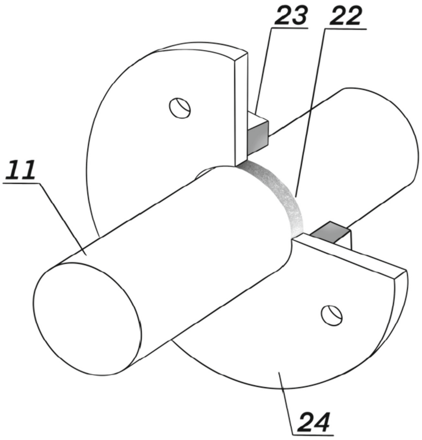

Fig. 3. The element of the magnetofluidic seal of the rod of the developed electric pulsator of the milking machine

fill the gap between the plane of the electrical pulse rod and the magnet. MF is held in the gap by an inhomogeneous magnetic field created by a magnetic pole with a microinhomogeneous surface with a pointed end part. The field inhomogeneity provides high magnetic field concentration. The shape of the free surface does not significantly affect the results, so the surface of MF volume is assumed to be flat [7]. In the MFS gap, the volume of the magnetic fluid, in the absence of pressure drops, takes an equilibrium position $b = L/2$, corresponding to a zero value of the resulting magnetic force. When the volume is displaced from the equilibrium position, for example, under the influence of a resulting pressure drop $\Delta p = p_2 - p_1$, a magnetic force equal to zero begins to act on it F_y, directed along the axis of the rod and tending to return it to the equilibrium position. The force F, acting on the volume V magnetic fluid with magnetization M from the side of the magnetic field with the modulus of strength H and gradient ∇H is calculated as an integral over this volume:

$$F = \mu_0 \int_V M \nabla H dV, \tag{1}$$

Where μ_0 – is the magnetic permeability of vacuum.

Assuming that the MF is magnetized to saturation $M = M_s$ and taking into account the flat geometry, for the magnetic force we can write:

$$F_y = \mu_0 M_s W \int_{-b}^{L-b} \int_0^h \frac{\partial H}{\partial y} dxdy = \mu_0 M_s W \int_0^h \left[H(y = L - b, x) - H(y = -b, x)\right] dx, \tag{2}$$

where W – length of the liquid drop in the third dimension.

This force determines the sustained pressure drop of the MFS $\Delta p = p_2 - p_1 = F_y/Wh$.

A fairly good approximation to reality, which allows analytical consideration, is the assumption that the microinhomogeneity of the magnet pole surface is determined by the equation of the hyperbola $y^2 = (x^2 - h^2)tg^2\beta$, where h –coordinate x of the hyperbole vertex (the size of the gap between the rod and the pole of the magnet). The angle 2β is the angle between the asymptotes of the hyperbola. In this case, the magnetic field lines are described by the function $\sigma = const$:

$$\sigma = \frac{1}{2}\left[\sqrt{(x/c+1)^2 + (y/c)^2} + \sqrt{(x/c-1)^2 + (y/c)^2}\right], \tag{3}$$

where $c = h/\cos\beta$.

Thus, the modulus of the strength of the magnetic field in the gap is determined by the expression

$$H = H_a \frac{h\sin\beta}{\left[\left[(x^2+y^2)\cos^2\beta + h^2\right]^2 - 4h^2x^2\cos^2\beta\right]^{1/4}}, \tag{4}$$

Here $H_a = H(x = h, y = 0)$ – value of the magnetic field strength at the vertex of the microinhomogeneity having a hyperbolic form. One of the main characteristics of the magnetic system under consideration, which will be preserved, we will consider the magnetic flux Φ in the magnetic core. We will assume that almost the entire magnetic flux in the gap is concentrated between two extreme magnetic lines, emerging from the points where the microinhomogeneity is conjugated with the rectilinear part of the magnetic core. Taking into account the symmetry of the problem:

$$\Phi = 2\int_0^s H_x(x=0)dy = 2H_a h(tg\beta)\ln\left(\frac{s\cos\beta + \sqrt{s^2\cos^2\beta + h^2}}{h}\right). \tag{5}$$

The coordinate s is found from the equation for the extreme magnetic line σ_s, which has a value of:

$$\sigma_s = \sqrt{1 + s^2\cos^2\beta/h^2}. \tag{6}$$

Taking into account (6), the expression for the magnetic flux can be written as:

$$\Phi = 2H_a h(tg\beta)\ln(\sqrt{\sigma_s^2 - 1} + \sigma_s). \tag{7}$$

The value σ_s of is determined by (3) from the value of this magnetic line at the point of its exit from the surface. The coordinate y of this point is equal to δ, and the coordinate is found from the hyperbola equation.

Determine the critical pressure drop value Δp held by the MFS as the maximum possible for a given liquid volume size L. It corresponds to a position of the liquid volume in which one of its vertical borders coincides with the pole symmetry axis of the magnet ($b = L$). The greatest limit $\Delta p_{\max}$ value of this pressure drop will be reached when the volume length of the liquid tends to infinity, i.e., when the second vertical border of the drop is practically out of the magnetic field action zone.

Taking into account the obtained relations, for the maximum pressure drop sustained by the MFS we can obtain the expression:

$$\Delta p_{\max} = \frac{\gamma}{2\ln\left(\sqrt{\sigma_s^2 - 1} + \sigma_2\right)}\left(\frac{\pi}{2} - \beta\right), \tag{8}$$

where $\gamma = \delta/h$.

Calculation according to (7) shows that the critical pressure drop increases with decreasing gap and already at the length of the fluid volume, approximately equal to half the width of the magnetic circuit ($L/\gamma = 1$), reaches the maximum possible value.

The described design used a magnetic fluid (MF), which is a suspension of highly dispersed magnetite particles in kerosene, stabilized using oleic acid. Such fluids are referred to as "oxide magnetic fluids", since magnetite is an oxide magnetic material. The use of MF of this type is due to its high thermal stability and the ability to retain its properties for a long time [8].

Table 1. Physical characteristics of magnetic fluid samples used in experiments

Sample	**Density ρ, kg/m^3**	**Volume concentration** φ, %	**Saturation magnetization Ms, kA/m**	**Surface tension ,** 10^{-3} **N/m**	**Viscosity, ,** 10^{-3} **Pa·s**	**Thermal conductivity** λ, **W/m·K**
MF № 1	1315	12	31,4	18,1	24,3	0,160
MF № 2	1155	8	21,5	20,7	13,8	0,096
MF № 3	1198	9	24,1	19,5	15,4	0,111

3 Results

During the development and calculation of MFS for linear motor of electric pulsator the following physical properties of MF samples are defined [9–11]: saturation magnetization MS, density ρ, volume concentration of magnetic phase φ, surface tension σ, dynamic viscosity η, and heat conductivity λ. The values of these physical properties are given in Table 1.

During the study, the physical characteristics of three samples of magnetic fluid were determined. The initial sample has a density of 1315 kg/m^3 and a saturation magnetization of 31.4 kA/m (MF No. 1). The other two samples, MF No. 2 and MF No. 3, were obtained from the initial magnetic fluid by diluting it twice with kerosene. The difference between the MF No. 2 and MF No. 3 samples is that MF No. 3 was subjected to significant thermal exposure, which consisted in its long, about 10 min, boiling. The study of the MF No.3 sample is of interest from the point of view of the "strength" of the unit during prolonged operation under extreme temperature conditions, which, however, in practice, should not be observed when the electric pulsator operates normally.

The saturation magnetization MS and magnetization curve were obtained using a VSM 7400 Series vibrating magnetometer (LakeShore Cryotronics). The thermal conductivity of the MF was determined using a DTC-300 thermal conductivity analyzer (TA Instruments).

The density of the samples of the magnetic fluid was determined by the method of hydrostatic weighing of a reference cylinder of known volume in them and was calculated using the formula:

$$\rho = \frac{P_a - P_l}{gV}, \tag{9}$$

where P_a and P_l - the weight of the cylinder in air and in liquid, respectively.

One of the important parameters determining the magnetic properties is the content of a solid magnetic phase (can reach 25%) in magnetic fluids. The volume concentration of a magnetic phase φ in the liquid was found from the ratio:

$$\phi = \frac{\rho_{mf} - \rho_l}{\rho_m - \rho_l}. \tag{10}$$

where ρ_m – magnetite density;

ρ_l – the density of the dispersion medium (kerosene);

ρ_{mf} – magnetic fluid density.

Figure 4 shows the magnetization curves for the MF No.1, MF No.2, and MF No.3 samples of magnetic fluid.

As can be seen from the graph, the magnetization of all MF samples increases linearly in the initial sections of the curves. The linear nature of the dependence remains up to the values of the external magnetic field strength of about 30 kA/m. With a further increase in the magnetic field strength, the MF magnetization increases non-linearly and monotonically until it reaches saturation at 600…700 kA/m. For the MF No.1 sample with a volume concentration of particles of 12%, the saturation magnetization MS = 31,4 kA/m, while for the twice diluted MF No.2 sample with a volume concentration of 8%, the saturation magnetization is expectedly one-third less: 21,5 kA/m.

For the MF No.3 sample, obtained from the MF No.2 sample by thermal exposure during its boiling, an increase in the volume concentration by 12% is noted, which is explained by the evaporation of the liquid carrier medium of the particles during boiling [12]. The value of saturation magnetization for MF No.3 was 24,1 kA/m. Thus, it can be noted that the considered MF samples show good resistance to prolonged thermal exposures and do not require replacement during normal use of the MFS with a short-term increase in the node temperature to 90 °C.

When studying the thermal conductivity of samples of magnetic fluid, an increase in the thermal conductivity coefficient with increasing temperature was discovered. The thermal conductivity increased by 1.6 times.

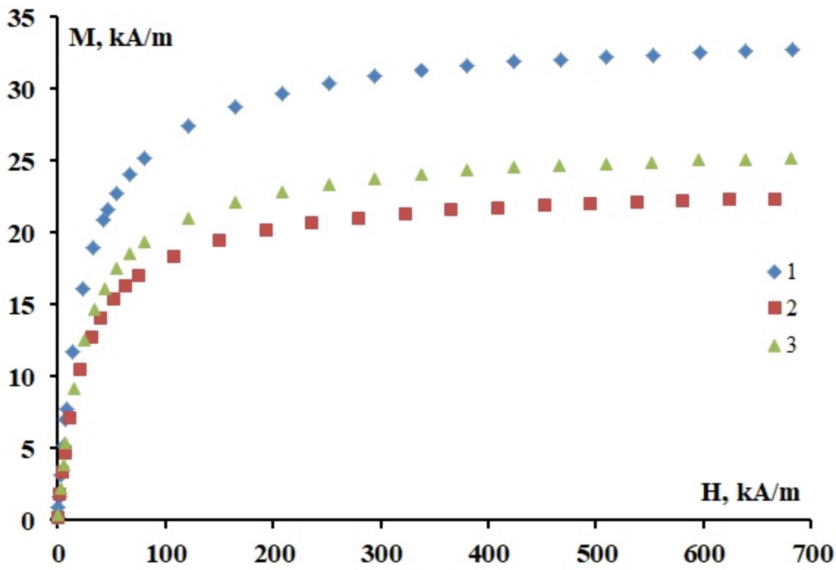

Fig. 3. Magnetization curves of magnetic fluid samples: 1 – MF № 1, 2 – MF № 2, 3 – MF № 3 M, kA/m; H, kA/m

4 Discussion

According to our estimates, the pressure drop Δp that the proposed MFS design with the considered magnetic fluid samples is able to withstand is $10^4 \ldots 10^6$ Pa. MF, being drawn into the gap between the pole inserts and the shaft, where the field has maximum strength, forms a tight plug with an increased internal pressure. Such a plug can withstand a pressure drop, which is determined by the formula:

$$\Delta p = \mu_0 \int_{H_{\min}}^{H_{\max}} MdH, \tag{11}$$

where μ_0 – magnetic constant;

M – magnetization of magnetic fluid;

H – magnetic field strength in the gap;

H_{max} and H_{min} – maximum and minimum magnetic field strengths at the boundaries of the magneto-fluid plug at the time when it retains the maximum pressure drop.

5 Conclusion

During the work, the physical parameters of the magnetic fluid for the seal in the electropulsator assembly were studied. The characteristics of the seal based on magnetizable nanodisperse fluids are justified, which satisfies the developed design of the linear motor and the calculated value of the pressure drop that the MFS can maintain during operation.

The use of the developed pair milking electropulsator based on a linear motor with magnetic fluid seal units operating in counterphase allows achieving a more uniform milk outflow with stable pulsations, protects the manifold from overflow during peak milk yield and creates a stable air vacuum in the sub-nipple and inter-wall chambers of the milking glasses while simultaneously reducing the mechanical load on the udder of the animal. In addition, it increases the energy efficiency of using milking machines and brings the operation principle of the installation closer to the physiological features of the milk yield process in cows and minimizes the negative impact on animal health.

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Sustainability in Veterinary Practice

Morphological Markers of Changes in Sows' Placenta with Different Tissue Receptivity

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Abstract. The intrauterine period of farm animals plays an important role in ensuring the sustainable development of agricultural systems. During this period, it is important to provide optimal conditions for the development of the fetus so that it can be healthy and strong after birth. The article presents studies of morpho-functional changes in the receptive profile of placental tissue of sows. Physiology study of the pregnant body indicates the functional load of all interrelated reactions in the "mother-placenta-fetus" system. This problem includes a number of measures to provide farms with livestock without undesirable perinatal complications. According to the methodology developed for assessing the enzymatic activity of the placenta, animals with high enzymatic activity of the placenta (with a placental carboxypeptidase level above 4.0 ± 0.18 units) were identified in the experimental group. The control group were animals with low enzymatic activity of the placenta (with the level of placental carboxypeptidase below 4.0 ± 0.18 units). Determination of the placenta thickness revealed significant changes. Thus, in the control group, the total thickness of the placenta was 2.95 ± 0.11 cm, the thickness of the fetal part was 0.72 ± 0.09 cm, the maternal part was 2.03 ± 0.04 cm. However, these indicators in the experimental group were significantly lower: the main one – 2.07 ± 0.14, the fetal one – 0.48 ± 0.09 cm, the maternal one – 1.54 ± 0.06 cm, respectively. A decrease in the thickness of the main regional elements of placental tissue indicates a thinning of the fetoplacental barrier complex.

Keywords: placenta · morphogenesis · sow · receptive profile of placental tissue · enzymatic activity · fetoplacental complex

1 Introduction

To achieve sustainable development of agricultural systems, it is necessary to take into account the ecological, economic, and social aspects of production. Sustainable development of farm animals begins before they are born, so it is important to ensure optimal conditions in utero to ensure animal health and productivity in the future. This includes proper nutrition of the animal mother, providing comfortable living conditions, and regular veterinary observation. The intrauterine period has its own individual characteristics and is the defining period of the laying, formation and development of the organ-tissue

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complex of the future living organism. Pregnancy as one of the components of a complex chain in a single mammalian reproduction process has common patterns determined by the specific features of fetal development and its placental connections [1, 2]. Therefore, research on the assessment of morpho-functional changes in the receptive profile of placental tissue in sows is relevant and promising, since new data will allow predicting the productive longevity of multiple animals, preventing and treating the identified complications of the next upcoming pregnancies.

According to the literature review, insufficient disclosure of the issue of structural changes in the placenta at different levels of its enzymatic activity was determined [3–5]. Therefore, studies to assess morpho-functional changes in the receptive profile of placental tissue in sows is relevant and promising, since the new data obtained will allow predicting the productive longevity of multiple-fetus animals, to carry out prevention and therapy of the identified complications of the upcoming pregnancies. Research on the mechanisms in the receptive profile of placental tissue in animals should be a systematic assessment of the entire morphogenesis while it's formation during the pregnancy [6, 7]. At the same time, the pathological condition of the placenta leads to an incomplete placental barrier, violation of placentation conditions and further destructive changes in the entire fetoplacental complex [8–10].

Before the study, it was assumed that the different level in enzymatic activity of placental tissue would be manifested by structural pathomorphological changes in the tissue elements of the maternal and fetal parts of the placenta.

The aim of the study was to evaluate morphofunctional changes in the receptive profile of placental tissue in sows with different farrowing multiplicity and the litter number.

2 Materials and Methods

The experimental part of the research was carried out on the basis of the cooperative pig breeding farm in Krasnodar Territory, Russian Federation. The object of the study was sows of the Large White breed. The subject of the study was the receptive profile of placental tissue in sows with various multiplicities of farrowing and the litter number. Animals with high enzymatic activity of the placenta (with a placental carboxypeptidase level above 4.0 ± 0.18 units) were identified as experimental group. Animals with low enzymatic activity of the placenta (with the level of placental carboxypeptidase below 4.0 ± 0.18 units) were identified as control group. The methods for evaluating the enzymatic activity of the placenta were developed by us and described in previous studies.

The placentas of 20 sows after childbirth were the material for the experimental part. Sampling was carried out by fixation in a 10% solution of neutral formalin. The fixed material served as the basis for the formation of sections for coloring (the manual of V.V. Semenchenko and co-authors, 2006). Micrometric analysis was carried out on the presence of morphofunctional changes in the receptive profile of placental tissue of sows various multiplicities of farrowing and the litter number, using an Olympus BX45 microscope with lenses $\times 4$, $\times 10$, $\times 20$, $\times 40$, $\times 100$. Histological preparations were stained with hematoxylin and eosin, while the Mallory method was used for comparative evaluation.

Statistical analysis of the obtained results was carried out by using the professional program "Biostatistics 4.03". The data obtained were verified according to the Normal Distribution law at $P \leq 0{,}05$.

3 Results

Significant differences were observed at the visual examination of the external and internal parts of the placentas in sows. In animals from the control group, the fetal part of the placenta looked smooth and without significant changes, what was not observed in the experimental group (Fig. 1).

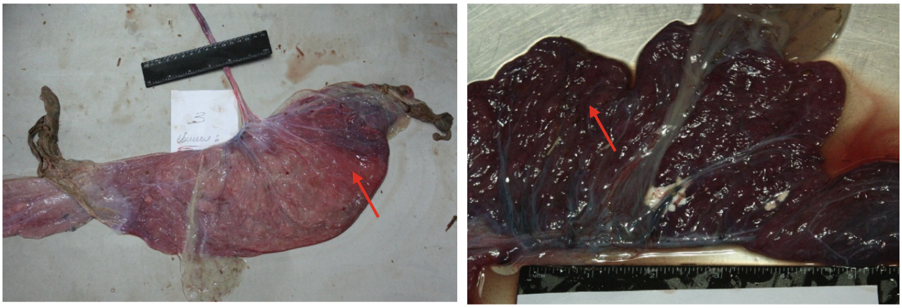

Fig. 1. Visual examination of the placenta in the experimental (pig № 11) and control groups (pig № 2)

In mature sows, stagnation and fragmentary disorders of the bloodstream (in the form of varicose veins) are visually noticeable in the superficial part of the fetal membrane.

When determining the thickness of the placenta, significant changes were revealed. Thus, in the control group, the total thickness of the placenta was 2.95 ± 0.11 cm, the thickness of the fetal part was 0.72 ± 0.09 cm, and the maternal part was 2.03 ± 0.04 cm. When comparing the data with the experimental group, these indicators were significantly lower: the total thickness was 2.07 ± 0.14, the fetal part was 0.48 ± 0.09 cm, the maternal part was 1.54 ± 0.06 cm, respectively.

A decrease in the thickness of the main regional elements of placental tissue indicates a thinning of the fetoplacental barrier complex. Various sizes of calcinates and petrificates located in the main part of the placenta were also observed (Fig. 2).

With high enzymatic activity of placental tissue (with the level of placental carboxypeptidase above 4.0 ± 0.18 units), the formation of syncytial nodes with the formation of syncytiocapillary membranes is observed in the villi of the placental tree (Fig. 3).

At the same time, in experimental animals, a decrease in the specific gravity of blood vessels is observed with the manifestation of their hypoplasia and cystic degeneration of the villous part of the placenta (Fig. 4).

With longitudinal sections of the villi in the animals of the experimental group, syncytiocapillary membranes with an enlarged stromal component prevail (Fig. 5).

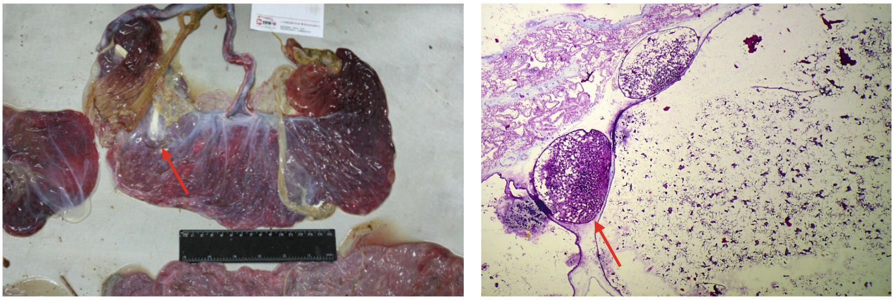

Fig. 2. Petrificate cysts in the chorionic stroma (pig № 11). The Mallory staining method. 40x magnification.

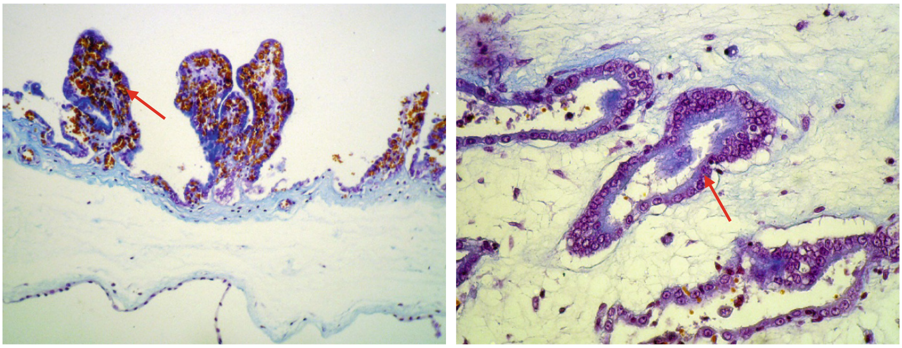

Fig. 3. Formation of syncytial nodes with syncytiocapillary membranes emergence (pig № 19). The Mallory staining method. 40 x magnification.

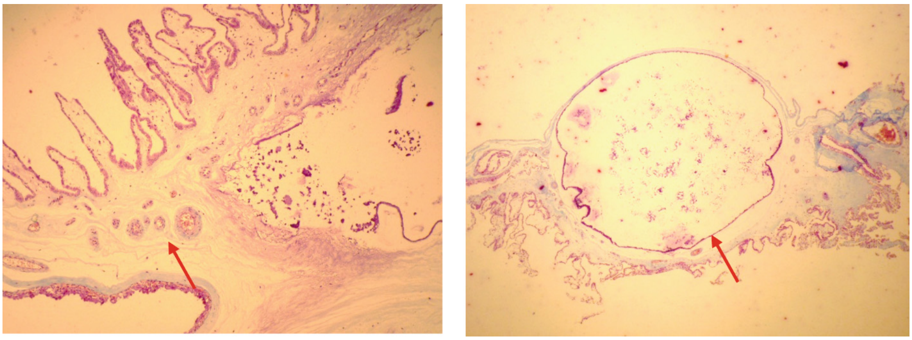

Fig. 4. Cystic degeneration of the villous part of the placenta (pig № 17). Hematoxylin and eosin stain. 40 x magnification.

We associate these structural morphofunctional changes with impaired interaction of syncytiotrophoblast in the fetoplacental complex.

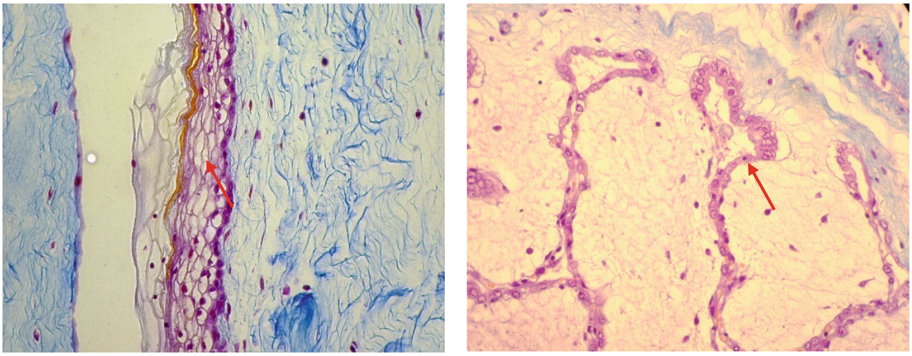

Fig. 5. Syncytiocapillary membranes formation with an enlarged stromal component (pig № 17). The Mallory staining method. 40x magnification.

In some cases, structural disorders of placental vascular circulation have been identified, manifested in the form of stagnation and swelling of the interstitial space (Table 1). According to the structural characteristics of morphofunctional changes in the receptive profile of the placental tissue, involutive-dystrophic transformations prevail in the form of fibrosis and hyalinosis of chorial plate vessels, calcification and petrification of chorionic villi, and increased fibrin output into the interstitial space.

Table 1. Structural characteristics of morphofunctional changes in the receptive profile of placental tissue in sows

Changes in the placenta	Morphofunctional changes of the placenta, %						
	Involutive and dystrophic changes				Circulatory disorders		
	vascular fibrosis of the chorial plate	hyalinosis of chorial plate vessels	calcification of chorionic villi	increased fibrin output into the interstitial space	hemorrhages	thrombosis	heart attacks
Experimental group (n = 10)	20.7 ± 0.15*	11.0 ± 0.21*	28.9 ± 0.18**	8.3 ± 0.12	15.2 ± 0.42	–	–
Control group (n = 10)	–	5.0 ± 0.11*	–	–	10.7 ± 0.36	–	–

** - (reliability of differences) -* $p \leq 0.05$

At the same time, in the group with high enzymatic activity of the placenta (with the level of placental carboxypeptidase above 4.0 ± 0.18 units), violations of the chorial epithelium with signs of focal desquamation and proliferation were found (Fig. 6.).

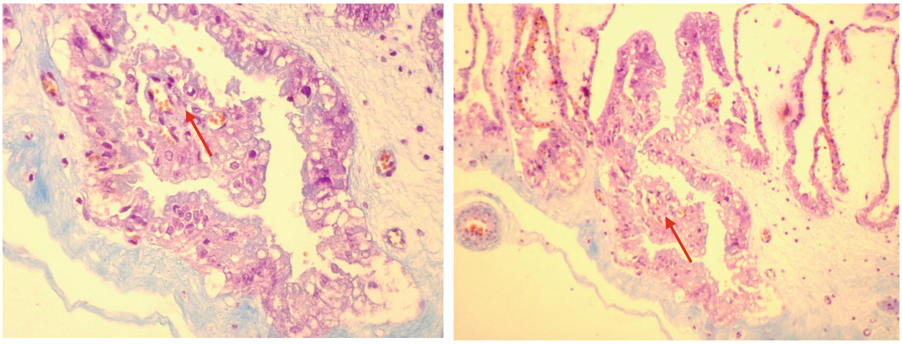

Fig. 6. Desquamation and proliferation of chorial epithelium (pig № 12). The Mallory staining method. 40 x magnification.

At the same time, extensive extravasates in the chorionic wall appeared on the vascular trunk in the placental tissue of experimental group animals (Fig. 7).

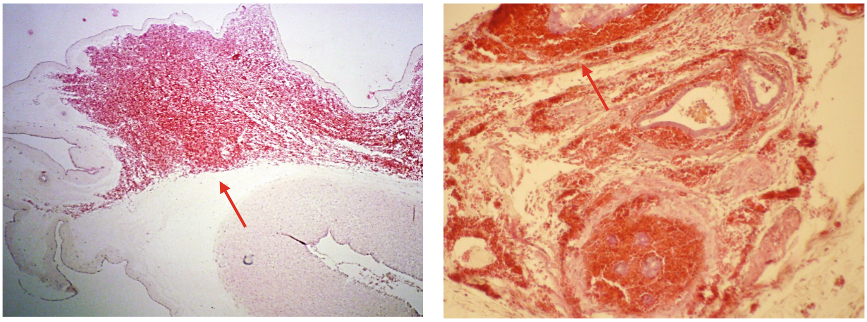

Fig. 7. Extensive extravasate in the chorion wall (pig № 14). Hematoxylin and eosin stain. 40 x magnification.

The study results of the dynamics of natural humoral defense mechanisms in sows with different levels of placental tissue immunoreceptivity in the postpartum periods are presented in Tables 2 and 3.

A certain pattern was noted in the change in the content of normal antibodies. Immediately after giving birth, it was relatively high. During this period, their titer averaged 51.1 + 0.16 units for the experimental group. For three days of the postpartum period, it significantly decreased relative to the first day and amounted to 28.1 + 0.22 units. At the same time, during the first ten days, there was a slight increase in the antibody titer, which was within 53.1 ± 0.15 units.

In the control group (with carboxypeptidase activity averaging 2.70 ± 0.25 units in the sample), the antibody titer was high to 108.0 ± 0.28 units. In the subsequent period, it was periodically changed. So, on the third day after farrowing, it was observed to increase to 110.5 ± 0.12 units, and in some individuals to 120 ± 0.41 units, then the

Table 2. Dynamics in the natural protective properties of the blood in the experimental group sows with an indicator of the proteolytic enzymatic activity of placental carboxypeptidase (8.45 ± 0.11 units)

Postpartum period, days	1	3	7	10
Normal antibodies, titer unit	65.1 + 0.16*	28.1 + 0.22*	32.4 ± 0.19*	53.1 ± 0.15
Complement, titer unit	0.31 ± 0.008	0.28 ± 0.015*	0.11 ± 0.020	0.17 ± 0.021
Bactericidal activity depending on the time of contact with the culture, hours				
0	100	100	100	100
1	84.8	34.8	31.2	41.1
2	76.3	26.3	24.4	26.5*
3	73.5	21.5	20.2	24.0*
4	64.0	21.7	21.0	19.0*
5	68.3	17.9	19.2	19.6*
6	82.0	24.3	29.5	23.3*
24	154.6*	95.0*	94.1*	179.0*

** - (reliability of differences) - $p \leq 0.05$*

titer decreased significantly and by the 10th day of the postpartum period it was 96.8 ± 0.41 units. This change does not undergo significant immunological changes in relation to the experimental group of animals.

In the control group (with carboxypeptidase activity averaging 2,70 ± 0,25 units in the sample), the antibody titer was high to 108.0 ± 0.28 units. In the subsequent period, it was periodically changed. So, on the third day after farrowing, an increase to 110.5 ± 0.12 units was observed, and in some individuals to 120 ± 0.41 units, then the titer decreased significantly and by the 10th day of the postpartum period it was 96.8 ± 0.41 units. This change does not undergo significant immunological shifts in relation to the experimental group of animals.

It can be assumed that the gradual increase in the number of normal antibodies observed in our study in the experimental group and their higher titer is due to increased synthesis processes caused by altered placental immunoreceptivity. It is known that the placenta acquires antigenic specificity already at the earliest stages of the development. These antigens are foreign to the mother's body, and the corresponding antibodies are produced to neutralize them.

During pregnancy, a large number of dissimilation products from the fetal blood accumulate in the blood and tissues of the mother's body. They seem to have a certain effect on the content of normal antibodies in the blood.

According to the results of the study, it can be said that the titer of normal antibodies as humoral factors of natural resistance in the blood varies depending on changes in the level of enzymatic activity of the placenta.

Table 3. Dynamics in the natural protective properties of the blood in control group sows with an indicator of the proteolytic enzymatic activity of placental carboxypeptidase (2.70 ± 0.25 units)

Postpartum period, days	1	3	7	10
Normal antibodies, titer unit	108.0 ± 0.28*	110.5 ± 0.12*	95.0 ± 0.32*	96.8 ± 0.41
Complement, titer unit	0.21 + 0.041	0.23 ± 0.009*	0.49 ± 0.010	0.45 ± 0.015
Bactericidal activity depending on the time of contact with the culture, hours				
0	100	100	100	100
1	64.2	27.7	58.2	79.1
2	64.0	19.4	48.3	83.0*
3	58.8	18.5	46.4	82.3*
4	65.0	21.0	45.0	83.8*
5	65.4	16.8	33.1	84.5*
6	74.5*	30.9*	37.5*	89.7*
24	106.0 + 2.2	30.5 ± 2.0	105.0 ± 2.3	94.5 ± 1.4

** - (reliability of differences) - p ≤ 0.05*

Specific changes are also noted in the level of complementary activity of sow serum in both groups. A significant decrease was found in the experimental group, as evidenced by the complement titer, which was at the level of 0.31 = 0.008 on the first day after farrowing, at $P < 0.05$.

The remaining nine days of the postpartum period were characterized by low complementary activity, as indicated by a low complement titer of 0.15 = 0.021 units on average.

The complement titer in the control group was high and amounted to 0.23 ± 0.016 – 0.49 ± 0.003 units. At the same time, it was found that their blood complement activity changes at a proportional rate in accordance with the study periods.

In our experiments, the serum bactericidal test (SBT), along with other indicators, was used to characterize the natural resistance of the body. The results of the studies showed that bactericidal activity was not the same in different periods after the farrowing. This reaction was taken into account by the number of colonies grown on Petri dishes, where the microbial culture was sown after incubation in a thermostat with blood serum. The bactericidal activity of the blood serum in experimental animals was most pronounced at 5-h contact with microbial culture.

If the blood serum was in contact with microbes for the first three hours or more than six hours, then its bactericidal activity was not fully manifested, especially during the 3-h incubation period. This property of the serum significantly decreased after six hours.

The degree of inhibition of colony growth after 5-h culture contact with blood serum averaged 68.3% (colony growth in control sown was taken as 100%) in the control group. The experimental animals did not have dynamic growth and increased bactericidal activity. The degree of suppression of colony growth by blood serum during this period of pregnancy significantly increased in control animals. In experimental sows with an increase in the immunoreceptivity of placental tissue, a decrease in the bactericidal activity of blood was observed, which indicates a weak degree of suppressive effect of serum on colony growth.

4 Discussion

According to the conducted studies, it was found that in the structural characteristics of morphofunctional changes in the receptive profile of placental tissue of sows with high enzymatic activity (with the level of placental carboxypeptidase above 4.0 ± 0.18 units), involutive-dystrophic transformations prevail: fibrosis and hyalinosis of chorial plate vessels, calcification and petrification of chorionic villi and increased fibrin output into the interstitial space.

A decrease in the thickness of the main regional elements of placental tissue in the experimental group of animals indicates a thinning of the fetoplacental barrier complex. Various sizes of calcinates and petrificates located in the main part of the placenta were revealed. At the same time, the formation of syncytial nodes with syncytiocapillary membranes in the villi of the placental tree was observed.

5 Conclusion

All identified morphofunctional changes may serve as a marker of an indirect pathological condition in the born offspring and a violation of the functional integrity in the placental barrier. It should be noted that the nature of the change of the antibody formation activity and complement coincides with the dynamics of the placenta enzymatic activity in experimental sows, which emphasizes a certain functional violation of this biological reaction. The results of our studies allow us to conclude that the dynamics of complementary blood activity is of a regular nature and changes due to an increase in the enzymatic activity of placental tissue of pigs. Blood bactericidal effect is directly dependent on the amount of complement and the amount of antibodies, as well as their activity.

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The System of Special Measures and Veterinary Sanitary Control of Products from the Slaughter of Farm Animals

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Abstract. The paper demonstrates that systematic control over agricultural products contributes to the sustainable development of this industry in the interests of food security and nutrition. A comprehensive approach has been implemented to the issue of assessing the quality of livestock slaughter products. The approach is based on various systems of specialized measures, as well as such important indicators associated with changes in skin diseases of various clinical, biochemical, anatomical, morphological and visual etiologies. These evaluation criteria are necessary to obtain an opinion on the quality of livestock products. Thus, they must be taken into account when conducting veterinary and sanitary examination in laboratories. To assess the state of health and predict changes in the quality of slaughter products, great importance belongs to the study of patterns in clinical, anamnestic, morphological, metric and anatomical indicators of the animal body. The use of their patterns and these characteristics of changes made it possible to identify certain chains of patterns that formed the basis of innovative rules in the veterinary and sanitary assessment of sheep slaughter products. These innovations make it possible to anticipate the occurrence of dermatitis of various etiologies, predict the incidence and indicate their causes. The improvement of the existing recommended standards will improve the quality of preventive and preventive measures against various types of diseases. It should be noted that all preventive measures should be carried out with strict observance of the rules, starting with pasture maintenance and ending with the stall period. Do not forget about observing the time, timing, seasonality of the use of forage lands, mandatory inspection of livestock and their parking places. One of the primary tasks is the immediate isolation of animals when identifying the primary signs of infection, followed by diagnostic and therapeutic procedures.

Keywords: farm animals · veterinary and sanitary control · slaughter products · morbidity prognosis · dermatitis

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1 Introduction

Since 2010, the Government of the Russian Federation has approved the concept of sustainable rural development and developed a system of special measures to restore the agricultural sector. The development of domestic beef cattle breeding will create conditions for the sustainable development of rural areas, which is one of the most important strategic goals of state policy, the achievement of which will ensure food security, increase the competitiveness of the Russian economy and the well-being of citizens.

Beef cattle breeding among all branches of agricultural production is most capable of leveling the difficulties with job creation and the formation of sustainable development of small rural settlements with a population of less than 200 inhabitants, which account for more than 70% of all rural settlements in the Russian Federation.

There are long-established rules for determining regulatory indicators that are used in veterinary and sanitary laboratory studies (VSLS) for expert evaluation of the main indicators of livestock products with subsequent approval for sale [1–3].

There is no such criterion indicator (CI) in the approved standards, which is associated with the detection of lesions of the skin of animals, which leads to a decrease in the quality of meat products allowed for processing. Also, very often they do not pay attention to the used drugs used during the life of animals.

The development of criteria indicators, starting from the stage of forecasting, and then assessing the quality in the veterinary and sanitary examination (VSE) of farm animal slaughter products, is an urgent and vital problem in veterinary practice. To date, there are no clear CI estimates of slaughter products for dermatitis of various etiologies, which would indicate certain changes associated with a deterioration in the quality of products for sale. Therefore, one of the tasks of the VSE in laboratory research is to develop a CI for evaluating and predicting the quality of slaughter products with the identification of even minor changes in the body [4–12]. The results of healthy animals obtained in a comprehensive study are always used as a basis for comparison.

Collection of all vital necessary characteristics, with subsequent emphasis on the selection of only those significant CI necessary to assess the quality of slaughter products. Clinical, anamnestic, morphological, metric, and anatomical indicators of the animal's body are used as CI assessments. But when it comes to assessing and predicting the quality of meat products, it must be remembered that animals already have various kinds of deviations caused by many factors with minor changes in CI [7, 8, 10–16].

To obtain anamnestic, clinical and morphometric indicators, various biopsies are very often used, in particular, as a universal indicator (blood), allowing to establish deviations from normative indicators and changes on the part of various vital body systems caused by various factors [7, 8, 10, 13–15].

The criteria indicators obtained at the entrance of the VSLI allow for comparison with the normative indicators, which will make it possible to predict the development of the disease before the appearance of its main signs [8, 10, 11, 15].

The main prognostic criterion that must be taken into account in any receipt of CI is the adaptive potential of the body. Any, even minor changes in adaptive potential, very often lead to a decrease, which is the main cause of the occurrence and development of diseases [17–20].

Classification of the levels of adaptation resistance of the organism, conditionally divided into:

– satisfactory adaptive potential to environmental conditions, in which the functional capabilities of the body are sufficient;
– state of stress of adaptive mechanisms;
– unsatisfactory adaptive capacity with reduced functional capabilities of the body;
– disruption of adaptive ability, characterized by a sharp decrease in the functional capabilities of the body.

This classification allows it to be used as a scale for measuring the adaptive potential, determined not only by the level of activity of functional systems, but also by functional reserves with a degree of voltage of regulatory systems.

The aim of the work was to identify criteria indicators based on the study of anamnestic, clinical and morphometric indicators for dermatitis of various etiologies and their use in veterinary and sanitary laboratory studies to obtain indicators of meat products obtained after slaughter of farm animals.

2 Materials and Methods

The conducted research was conducted in the Stavropol Territory, Russian Federation.

To assess the quality of livestock products in order to obtain admission to sale, the following regulatory documents adopted on the territory of the Russian Federation were used:

- State standard (GOST 7269-2015) “Meat. Sampling methods and organoleptic methods for determining freshness”.
- "Rules of veterinary inspection of slaughtered animals and veterinary and sanitary examination of meat and meat products” (as amended in 1988).
- State standard (GOST 9959-2015) “Meat and meat products. General conditions for conducting an organoleptic assessment”.
- State standard (GOST 9793-74) “Meat products. Methods for determining moisture”.
- State standard (GOST 29128-2019) Meat and meat-containing products. Terms and definitions for organoleptic quality assessment.

These documents do not clearly indicate the influence of exogenous and endogenous factors on aspects of diseases with signs of skin damage during the stable period of detention.

3 Results of Investigation

The study of dermatitis of non-infectious, infectious and parasitic etiology was carried out in the climatic zones of the Stavropol Territory (Fig. 1) in the period from 2010 to the present. The average percentage of diseases attributable to dermatitis of various etiologies ranged from 15–20% of the total. The average results of the identified dermatitis carried out in the course of our research are shown in Figs. 2 and 3. The prevalence of skin diseases of various etiologies in natural and climatic zones was established based on the results of our own research and veterinary reporting data.

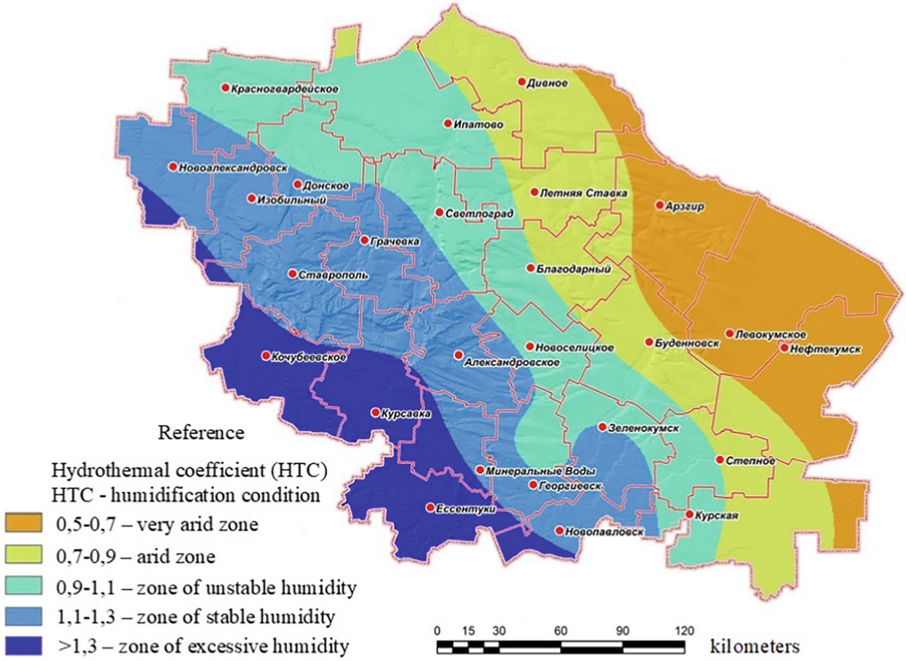

Fig. 1. Natural and climatic zones of the Stavropol Territory (The names of the settlements are given in Russian)

The data from the research results for 2010 to the present (Fig. 2) revealed for sheep [4, 6, 11, 12, 21, 22] a certain indicator of the extent of invasion, so in the zone of excessive humidity for dermatitis of various etiologies it was about 18% compared with a very arid zone ~9%. In a very arid zone, the prevalence of skin diseases of parasitic etiology was more than 60%, in the zone of excessive moisture more than 90%.

Figure 3 shows the results of research for 2010 to the present for cattle [7, 8, 10, 14, 15, 18]. For cattle, there is a similar pattern of prevalence of dermatitis of non-infectious and infectious origin with a slight deviation. The prevalence of skin diseases of parasitic etiology in the arid zone was higher and ranged from 88 to 91%.

From the presented data, it can be seen that the incidence pattern is almost similar for both sheep and cattle in the presented natural and climatic zones of the Stavropol Territory, and a larger percentage are dermatitis of parasitic origin, in second place mainly infectious.

Over the past period, we have examined more than 40 thousand sheep, of which 27% of patients with dermatitis of various etiologies have been identified. The examination of cattle over the same period amounted to slightly more than 5 thousand heads, of which about 30% had skin diseases of various etiologies. Sheep in farms were examined in the most detail. It should be noted that even in farms with isolated skin lesions, outbreaks of ectoparasitosis (psoroptosis, mallophagosis) of sheep were observed.

Systematic observations of the course of development of skin lesions among sheep and cattle under our supervision yielded the following. In the first half of winter, there

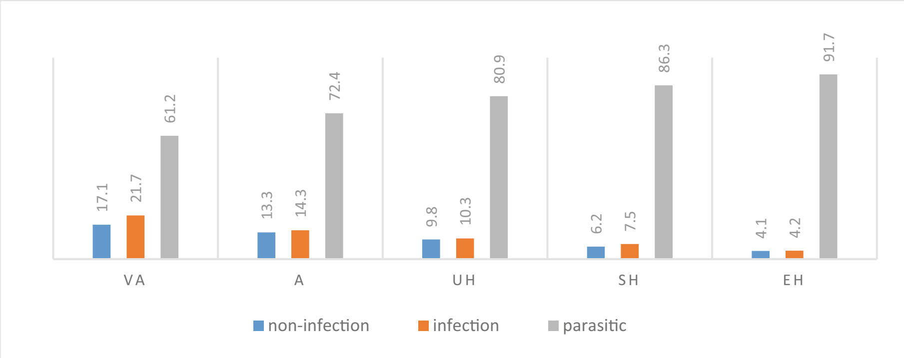

Fig. 2. Manifestation of sheep dermatitis of parasitic, non–infectious and infectious etiology, %: VA – very arid zone; A – arid zone; UH – zone of unstable humidity; SH - zone of stable humidity; EH – zone of excessive humidity.

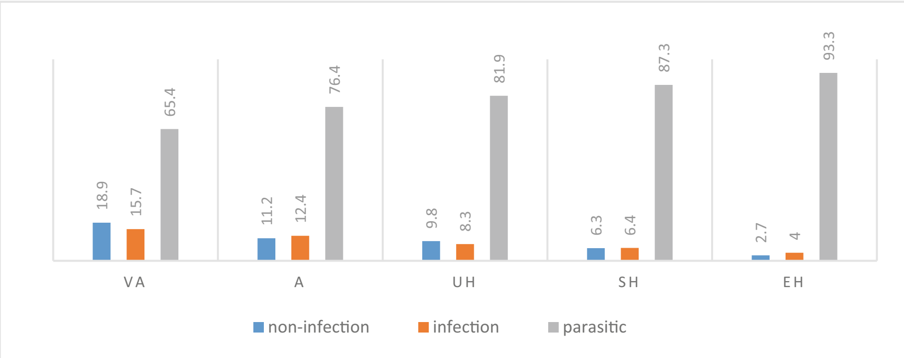

Fig. 3. Manifestation of cattle dermatitis of parasitic, non–infectious and infectious etiology, %: VA – very arid zone; A – arid zone; UH – zone of unstable humidity; SH - zone of stable humidity; EH – zone of excessive humidity.

was a slow increase in the number of patients, in the second – the process progressed the faster where the animals were kept closer and more crowded. The disease spread faster among young animals than among adult animals. It should be noted that the infection of lambs occurred when they were transferred to the bases and kept where previously there were sick or suspected infected animals. The incidence was lower in calves, as they were kept in more favorable conditions.

It should be noted that in previous years, preventive treatments of sheep and cattle in all farms of the Stavropol Territory were carried out according to the preventive treatment plan, almost 100% in the autumn period [21, 23–27].

For many years, the preventive treatment of animals in autumn in extremely arid, arid and unstable humidification zones covered 20–50% and less than 20% of the number of heads in areas of sufficient and excessive moisture.

In arid and extremely arid zones, there is an increase in the number of treatments in spring by 2–5%, an increase in this indicator in summer reached 31.4%, in winter treatments were carried out only when absolutely necessary, and the average value was 19.7%.

In the zone of sufficient moisture, a sharp increase in the number of treatments was observed in winter – up to 43.9%. In summer, the indicator varied between 5–15%, and an increase was noted every spring to 32.5%.

It should also be noted that in the periods from 2014 to 2017 and from 2020 to 2023, stall processing prevailed, especially during lambing of sheep. It is during this period (March – early May) that there is a shortage of both high-quality feed and premises for the accommodation of sakmans. Adverse weather and climatic conditions are a contributing factor. All this leads to a weakening of the body's reactivity and a decrease in resistance to external factors.

According to veterinary reports, it was noted that in 2015, in winter, the number of sheep and cattle treated against ectoparasites in all natural and climatic zones of the Stavropol Territory amounted to 570 thousand (almost 50% of the total livestock in the region), in 2018 - 410 thousand (32%), whereas In other years, this figure was in the range of 300–350 thousand (22–24%). In 2021 and 2023, there was also a slight increase in treatments against ectoparasites, respectively 450 thousand (35%) and 510 thousand (44%).

4 Discussion

In the farms of the Stavropol Territory, cases of parasitic dermatitis (psoroptosis and mallophagosis) have been identified, observed in areas of sufficient and excessive moisture.

It should be noted that the movement and regrouping of sheep in different climatic zones very often occur without the knowledge of the veterinary service. Ultimately, this leads to the occurrence of psoroptosis and mallophagosis during the pasture period of keeping animals in areas of sufficient and excessive moisture.

5 Conclusion

The assessment of the degree of prevalence and manifestation of skin diseases in the natural and climatic zones of the Stavropol Territory was carried out. Distinct data on the extent and intensity of invasion by ectoparasites in different periods of the year and in five different climatic zones of the region have been obtained. Thus, the extent of the invasion and the degree of manifestation were clarified, regardless of the pasture and stall period of the year.

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Chicken Skin of the Dominant CZ Cross System

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Abstract. Sustainable development of agricultural systems and livestock sectors includes the raising of productive poultry, including chickens, as an important aspect. To increase the efficiency of egg and meat poultry farming, the genetically determined viability and productivity of chickens should be ensured with optimal feeding and maintenance programs. The skin of the epidermis, dermis and subcutaneous layer protects the body of chickens from external damage, exposure to extreme temperatures, and the penetration of pathogenic microorganisms. Knowledge of the skin condition as a system of tissues and plumage, depending on the species, age, breed, cross and housing conditions of the bird, allows you to optimize the production of high-quality eggs and meat. Histology makes it possible to reveal the principles of the structural organization and development of tissues and their systems in order to control the life processes of the bird's body: metabolism, development, growth, heredity, reproduction, productivity. In this regard, the purpose of the study was a histomorphological assessment of the features of the chicken skin structure of the Dominant CZ cross system when reared on the floor. We used skin samples from the back of chickens "Sussex D-104" ("D-104"), "Blue D-107" ("D-107"), "Black D-849" ("D-849"). In a special laboratory, generally accepted pathomorphological and histological techniques were used. We found that significant differences in the skin structures of chickens were only at 28 days of age.

Keywords: chickens · cross breeding system · skin · epidermis · dermis · histology · plumage

1 Introduction

The planetary importance of poultry farming is to provide the population with high-quality eggs and meat with low material costs. Poultry products in the food market have always been a stabilizing factor as a socially significant and economically accessible product. For effective breeding of chickens, the main producers of edible eggs and meat, under different technologies, it is necessary to constantly develop new technological methods for keeping poultry based on a comprehensive study of the morphofunctional features of the functioning of organs and body systems of birds. The body of Galliformes, the most popular species of farm birds, is an integral system in which a number

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of interconnected, interacting and subordinate hierarchical levels of living matter organization can be distinguished: cells-tissues-organs-organ systems. Each of these levels of structural organization has morphofunctional features. Tissues have general biological patterns inherent in living matter, and at the same time their own peculiarities of structure, development, vital activity, intratissue and intertissue connections.

Skin and muscles shape the body of chickens like typical animals from the surface, give it a certain shape (exterior) and hold all the internal organs. The skin with its main derivative, plumage (up to 25,000 units), covers the entire body of birds, being the main barrier between the bird's body and the external environment. Plumage provides a light aerodynamic surface for the birds' body, passive protection from enemies (protective coloration), as well as interspecific and sexual recognition (signaling function) [1, 2]. Good plumage is important for bird health and welfare, productivity and feed conversion. Genetic improvement in feather quality cannot be as rapid as improvement in egg production, but is possible gradually through selection.

The skin of birds is thin, dry due to the absence of sweat and sebaceous glands, has well-developed subcutaneous tissue and forms folds. Connection with the external environment is carried out using a variety of sensitive nerve endings located in the skin, as a result of which it is an extensive receptor field. In addition, the skin deposits up to 30% of the blood and participates in thermoregulation - 70–80% of the heat generated by the bird's body is lost through it. The skin consists of the epidermis, the skin itself or dermis and the subcutaneous layer. In different parts of the body of birds, the structure of the skin and its thickness are different. The thinnest skin is found on the feathered areas (pterylia), but even there it is not the same. The thickest skin is on the apteria - areas where covert feathers do not grow. On the back of land birds the skin is thicker than on the belly, while in waterfowl it is the opposite. The cutaneous glands in birds are represented by a single gland - the coccygeal or non-caudal gland.

The epidermis serves as a place for the concentration of pigments, which partially pass into the plumage, forming its color. The skin color of different breeds of chickens varies from white and yellow to green, blue and black. Skin color is a defining characteristic of individual chicken breeds. In European countries, yellow- and white-skinned birds are preferred [3]. Phylogenetic analysis showed that the white skin allele comes from the domestic chicken ancestor, the red junglefowl, and the yellow skin allele, from the gray junglefowl [4]. It is believed that the variety of skin colors in chickens depends on a combination of specific genes that influence the deposition of xanthophylls (red and yellow-brown color), melanins (black, dark brown color), xanthophylls (yellow color) and environmental factors [5–9].

The dermis (Latin dermis, from the Greek δέρμα - skin) is the connective tissue part of the skin in vertebrates, including chickens, located between the epidermis and subcutaneous fatty tissue. It performs predominantly trophic and supporting functions, which determines the abundance of fibers and capillaries.

The greater mobility of the skin of galliformes is ensured by the loose structure of the subcutaneous layer. In this layer, fatty deposits accumulate, forming a fatty layer, the development of which is subject to strong fluctuations depending on the type of bird, breed, age, sex and especially the season of the year. The fat layer serves as an energy reserve, consumed during periods of growth, reproduction, and molting. In waterfowl, other things being equal, it is more developed than in chickens. At the same time, in chickens of meat breeds it is more developed compared to chickens of egg breeds.

Histology with cytology and embryology, like other biological sciences, solves the main problem - elucidating the sources of development, patterns of histogenesis, reactivity and regeneration of tissues and, in connection with this, the possibility of targeted influence on them.

In accordance with global trends in the development of organic (farm) poultry farming, almost all breeding companies in their line of breeding products have crosses (brands) of meat and egg chickens (dual-purpose breeding) with colored plumage and relatively slow growth and development [10, 11]. An example of meat and egg chickens with a large palette of plumage and egg colors are more than 30 "Dominant CZ" crosses [12]. With intensive and alternative breeding of Dominant CZ chickens, different degrees of plumage retention are noted as they grow and under the influence of environmental factors.

The aim of the study was to histomorphologically assess the characteristics of the skin structure of the Dominant CZ crosses chickens in the neonatal period.

2 Materials and Methods

The objects of the study were skin samples from 7- and 28-day-old hybrid chickens of the Dominant CZ crosses: feder sexing - Dominant Sussex D-104 (D-104), color sexing - Dominant Blue D -107" ("D-107"), "Dominant Black D-849" ("D-849"). The basis of the compared crosses of meat and egg chickens "Dominant CZ" are the classic breeds of chickens: "D-104" - ♂ and ♀Sussex silver (Sussex), "D-107" - ♂ Andalusian Blue and ♀Barred Plymouth Rock, "D-849" - ♂ Barred Plymouth Rock and ♀Red Rhode Island.

Chickens were raised in the scientific and educational animal room of the Federal State Budgetary Educational Institution of Higher Education "Stavropol State Agrarian University" on the floor, on litter in sections of 50 chickens of each cross. When raising poultry, the technological parameters, microclimate, and nutritional value of granulated feed complied with the recommendations of the originating company. Poultry productivity indicators were taken into account using generally accepted methods.

After slaughter of conditioned chickens (5 birds per cross), skin samples measuring 2 cm2 were obtained from the dorsal part of the body near the tail. Skin samples were fixed in 10% buffered formalin in accordance with the rules for pathological and histological studies. Subsequent histological studies of the chicken skin were carried out in the interdepartmental scientific and educational laboratory of experimental immunomorphology, immunopathology and immunobiotechnology of the medical and biological faculty of the North Caucasus Federal University. Skin tissue samples, after washing under running water for 24 h, were dehydrated in isopropyl alcohol, followed by soaking and embedding in Histomix medical paraffin (Biovitrum, Russia). Histological sections with a thickness of 5–7 μm were made on a rotary microtome NM 325 (Termo Fisher, USA). The finished sections were stained with hematoxylin and eosin, as well as Masson's trichrome, followed by a general histomorphological analysis. The evaluation of tissue micropreparations was carried out using a laboratory microscope Axio Imager 2 (A2) (Carl Zeiss Microscopy, Germany) at various magnifications with image recording using a specialized camera AxioCam MRc5 (Carl Zeiss Microscopy, Germany) and Zen software (Carl Zeiss Microscopy, Germany).

3 Results

Dual-purpose breeding or dual-purpose (meat and egg) chickens are populations of chickens that can produce both table eggs and meat from fattened roosters. Various projects have shown that meat-egg breeds and crosses effectively produce slightly fewer eggs than typical egg breeds and less meat than typical meat (broiler) breeds. However, they are most in demand for raising using extensive technologies without compromising the quality of the products.

The study used crosses of meat and egg chickens "Dominant CZ", differing in the color of juvenile and definitive plumage, method of sexing, growth and development rates. During the growing period, granulated feed was used to feed the birds - "Prestart" (first 7 days) and "Start" (8–28 days); the young animals were consistently fed from pasture paper and from bunker feeders. Vacuum and nipple drinkers were used for watering.

The study showed that there are some differences in the productivity of hybrid chickens of three Dominant CZ crosses under the same technological and feeding conditions (Table 1).

Table 1. Productivity of hybrid chickens "Dominant CZ"

Index	"D-104"	"D-107"	"D-849"
Initial livestock, 50 heads	50	50	50
Survival rate 0–28 days, %	100	100	100
Live weight at 0 days, g	37,8 ± 0,46	36,8 ± 0,52	36,3 ± 0,58
Live weight at 7 days, g	81,2 ± 1,37	85,3 ± 1,49	86,7 ± 0,86
Live weight at 27 days, g	354,5 ± 6,78	358,6 ± 6,39	345,9 ± 4,88
Average daily increase 0–28 days, g	11,3	11,5	11,1
Feed costs for growth, kg	2,20	2,09	2,29
Average rating	1,7	1,3	2,3

Through 28 days (neonatal or initial growing period), there was no mortality observed in the Dominant CZ hybrid chickens in all groups. Therefore, the survival rate of the bird was 100%, which indicates its high viability.

At 7 days of age (the end of the pre-start growing period), the live weight of the D-849 cross hens was 86.7 g, which is 5.5 g or 6.8% more than the D-104 cross, or 6.8% more than the D-cross -849" - by 1.4 g or 1.6%, norms of "Dominant CZ" - by 16.7 g or 23.9%. At 28 days of age (the end of the starting growing period), the picture changed. The live weight of the D-107 cross hens was higher than the level of the D-104 cross by 4.1 g or 1.2%, of the D-849 cross by 12.7 g or 3.7%, and norms of "Dominant CZ" - by 93.6 g or 35.3%.

Over 28 days of cultivation, the average daily gain of the D-107 cross hens was higher than the level of the compared D-104 and D-849 crosses by 1.8 and 3.6%.

From a production point of view, it is important that the costs of granulated feed for the increase in live weight of young animals were the lowest in the group of the D-107 cross. The difference with the crosses "D-104" and "D-849" was 5.0 and 8.7%.

Fig. 1. Skin structure of a 7-day-old chicken of the D-104 cross. Hematoxylin and eosin staining ×50

Based on the calculations, the average rating for six productivity indicators was the highest in the group with the D-107 cross. Consequently, it was in this group of birds that the conditions created had the best growth and development.

It is known that the upper or outer (epithelial) multilayer layer of bird skin is more or less keratinized and is characterized by a rather small thickness. Underneath it is the malpighian (germinal) layer, consisting of cells that retain the ability to divide. These two layers form the epidermis, which is characterized by a relatively smooth surface. Renewal of the epidermis is associated with specific transformations and migration of keratinocytes from deep to external layers during their differentiation. Together with the peeling scales, chemical and biological pathogens are removed from the surface of the skin. The epidermis contains some components of the immune system.

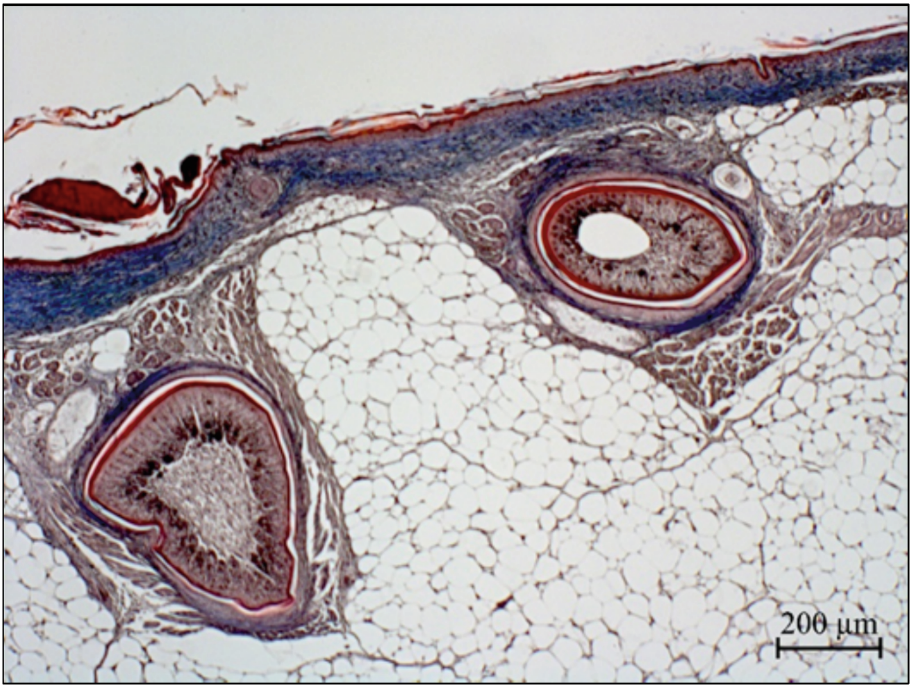

Fig. 2. Skin structure of a 7-day-old chicken of the D-107 cross. Masson trichrome staining ×50

Under the epidermis is the dermis or skin itself, consisting of dense subepithelial and loose subcutaneous layers. The subepithelial layer of the skin is characterized by the presence of muscles. True cutaneous muscles (smooth) move individual feathers, and false cutaneous muscles (striated) move entire areas of skin (pterylia). The latter received this name because they are only a branch of skeletal muscles. A feature of the subepithelial layer of some areas of the skin, where it is devoid of feathers (apteria), is its spongy structure and at the same time strong vascularization.

Feather papillae are on the skin mainly in a checkerboard pattern.

Histological studies showed that the microstructure of skin samples from 7-day-old chickens of the studied crosses "Dominant CZ" had a classic structure without pathologies. The epidermis included the superficial stratum corneum and the germinal layer. The dermis consisted of a well-defined layer of connective tissue fibers and subcutaneous fatty tissue. Blood vessels were visualized in the skin. In addition, feather sacs and feather rudiments were well fixed in the skin (Figs. 1 and 2).

On the 7th day, no significant difference in the morphological structures of the hybrid chicken skin was found in the three crosses compared.

In 28-day-old chickens of the D-107 cross, the layer of connective tissue fibers in the dermis and around the feather sacs is much wider compared to the D-104 and D-849 crosses (Fig. 3). This reveals a more significant blood supply to the skin, the presence of clusters of connective tissue cells around the fibers and clusters of lymphatic cells.

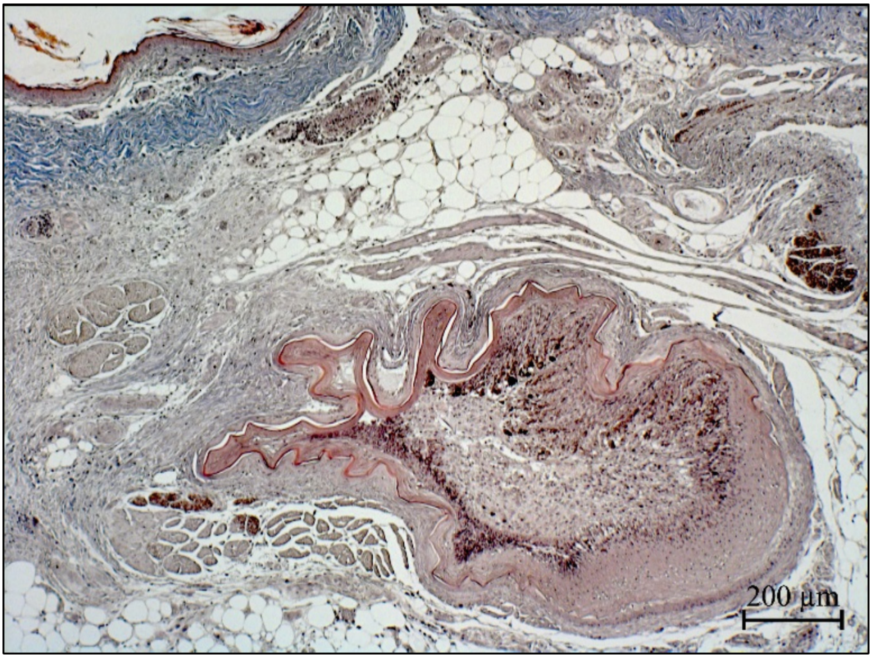

Fig. 3. Skin structure of a 28-day-old chicken of the D-107 cross. Masson trichrome staining × 50

In 28-day-old chickens of the D-849 cross, the connective tissue structures and blood vessels of the skin were characterized by the weakest development (Fig. 4).

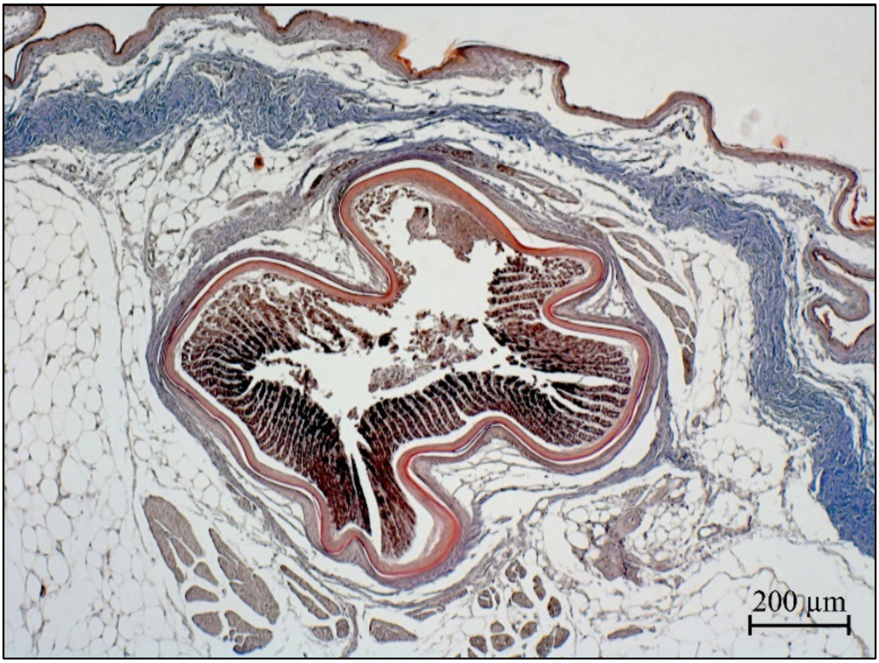

Fig. 4. Skin structure of a 28-day-old chicken of the D-849 cross. Masson trichrome staining × 50

4 Discussion

Growing under the same technological and feeding conditions showed differences in the growth and development rates of the studied crosses chickens of meat and egg chickens of the Dominant CZ system, which indicates their genetic characteristics, including the formation of tissues and organs.

During the pre-start and starting growing periods, the viability of hybrid chickens was high. The priority in terms of live weight, the initial growth indicator of young animals, as well as the conversion of feed into live weight gain were the hybrid chickens of the D-107 cross. It is logical that this affect the formation of the skin of the chickens.

The microstructure of the studied skin samples of hybrid chickens of the Dominant CZ crosses has a classic structure without pathologies.

At 7 days of age, no significant difference in the morphological structures of the chicken skin of the studied meat and egg crosses was found. When primordial pubescence is still significant, the beginning of active growth of flight and tail feathers is noted. From an ethological point of view, it is interesting that it is from this age that chickens actively move around the area of the room and make short flutters.

At 28 days of age, chickens of meat and egg crosses are characterized by the formation of integumentary feathers on the neck, chest and back. At this time, chickens begin to actively use elevated structures or perches for shelter from potential danger and rest, as well as actively "bathing" in the litter. Our studies have shown that at this age, in hens of the D-107 cross, in contrast to the D-104 and D-849 crosses, the layer of connective tissue fibers in the dermis of the skin and around the feather pouches is much wider. In addition, a more significant blood supply to the skin and the presence of clusters of connective tissue cells around the fibers are detected. In chickens of the D-849 cross, compared to the D-104 and D-107 crosses, the connective tissue structures and blood vessels are the most poorly developed. It can be assumed that the identified differences in the histomorphological structure of the skin of chickens of the D-107 cross to a certain extent explain their tendency to more active molting.

5 Conclusion

A study conducted while simultaneously raising chickens on litter revealed differences in the histomorphological structure of the skin of hybrid chickens of the Dominant CZ cross system at 28 days of age.

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Economic, Ecological and Social Systems for Human Development

Land Use Planning Education in the System for Providing Food Security: Exemplified by the Specific Higher Educational Establishment

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Abstract. The article explores the potential for innovative development of a modern higher educational establishment using the example of the State University of Land Use Planning, Moscow, Russia. Furthermore, the study takes into account the challenges, which are under consideration of the state in the food security field, their land management support, as well as the currently implemented state programs. The peculiarity of the educational establishment is presented and its two key strategic projects are characterized: creation of the agro(bio) technopark on the basis of the university geodesic experimental site (polygon) and repeated development of the abandoned agricultural lands with further demarcation thereof.

Keywords: land use planning · educational establishment · innovations · agro(bio)technopark · digitalization · land plot boundaries

1 Introduction

In post-Soviet Russia the topic of food security has already started to come into focus for several times.

For the first time, in the law of 1997 (cancelled in 2005) [14], in which food security provision was recognized as one of the tasks of state regulation of agro-industry (together with its stabilization and development – Art.1).

For the second time, in the state program of 2007 [17], in which the food security was highlighted with the statement of the problem and justification for elaboration of the program activities.

For the third time, in the very State Doctrine for Food Security, approved in 2010 by the head of the state [16].

And, finally, for the fourth time, in the current moment, starting from years of 2014–2015, that was formalized in the acting since 2020 version of the named Doctrine. Moreover, now, on the Doctrine level, the necessity for development of the export potential of the domestic agro-industrial complex was underlined [2, 5, 13]. For that purpose new or, at least, repeatedly reclaimed land plots are needed.

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It is important to consider also the situation of current concentration of lands in agroholdings and the work with unclaimed land shares (and their site allocation) from among key processes in domestic use of agricultural lands in line with systematical work of the last years as for repeated development of unused land plots [3, 4, 6, 11]. All these processes cannot be completed without proper implementation of land use planning (actually they can be completed, although without such proper implementation of land use planning, wrong decisions are almost inevitable, which can decrease the potential of the domestic agro-industrial complex) [7, 10]. Notably, that, namely, the land use planning is the key for solving all current challenges.

Thus, the critical component of the sustainable development of rural areas is the land conservation (as a basis for life and activity of population), as well as the efficient and economically reasonable placement of agricultural (or any other kind of) production on them. In order to get qualitative and consumer-safe food products (together with following all other, not less important, environmental conditions) it is necessary to avoid growing such food products on the contaminated territories (not limited by the growing, for example, only technical crops or keeping the contaminated territories preserved for some period of time). It is also important to keep the safe distance from the sources of contamination and other harmful impacts etc.

The key factor for success in plant-growing is the system of crop rotation, allowing not only to save the soils from excessive loss of nutritious elements but also to increase the soil fertility. Analysis of research of functioning of agricultural social and economic system implies the analysis of its economical efficiency as a mandatory element.

Digitalization issues are, among numerous varieties of agricultural fields, perhaps, to the fullest extent, applicable to the land registration and land monitoring nowadays, as well as to the land use planning. The same goes for different kinds of intelligent systems in agriculture. Finally, soil fertility and soil protection issues belong to the essential tasks of the land use planning.

The aim of the article is to consider the potential of modern educational system in view of food security support, using the example of the specific higher educational establishment, primarily functioning in the engineering, and then in the agricultural field.

2 Materials and Methods

The article uses normative and methodical documents, regulating the implementation of land use planning activities, as well as strategic projects for development of the State University of Land Use Planning (hereinafter called "the SULUP"), elaborated with direct participation of this article's authors. Abstract and logical, comparative and geographical, historical, computational and constructive, statistical methods are applied.

3 Results

3.1 Specific Features of Development of the SULUP

The SULUP was founded 250 years ago in the period of reign of the Empress Catherine II as a Land surveying school. It was called Konstantinovskaya, in honour of newly born in that year grandson of the empress. The main task of its graduates was and remains the land demarcation (boundaries) as "the activity bringing benefit and peace to land owners, and also as a State activity, containing own Imperial glory and benefit of calmness and quietness of the whole State". Therefore, since the day of school foundation, the state has always attached the special importance to the land use planning activities and specific land use planning education, and has always kept the educational establishment under the patronage.

The key peculiarity of the SULUP has become, on the one hand, that it is the main and the only in the country, the biggest in the world with specialization in land use planning and cadastres higher educational establishment, on which bases the corresponding federal Educational and Methodological Board is functioning, and on the other hand, it is one out of three agrarian higher educational establishments located in Moscow. In this regard, historically, the biggest part of training directions have rather universal than agrarian character, defined by the 250 years old decisions and the specificity of the largest megapolis of our country (and one of the largest in the world).

The necessary condition of both the demand for graduates of any university in any professional field, and successful competitiveness of the university for its applicants, is the constant development, close connections with scientific and manufacturing organizations, commitment for innovations (the university environment should be a priori predisposed to them). Thus, now the crucial factor for development of various spheres, primarily concerning management processes, has become digitalization. [15, 16]. Digital technologies are increasingly being applied [1] in the agricultural sector in Russia and other countries, and that is appropriate. Thus, according to the expert estimates, the digitalization of the sector will allow to decrease the prime cost of agricultural goods by a quarter [8]. Also it has become technically possible. If in the middle of 2000s only 13% of agricultural farms had access to the internet, now there are over 60% of them.

In modern agro-industrial complex the digital technologies allow, primarily, to implement spatial linking of agricultural production to the needs of precision farming on the basis of adaptive-and-landscape approaches [9]. The technologies are also a guarantee for implementing control over fields and crops on a constant mode. Both, implemented for a long time in land use planning digital solutions, connected with application of GIS (geo information system), SAE system (computer-aided engineering system) technologies and information and communication technologies (ICT), and also fundamentally new ways of obtaining and processing data on numerous factors, that are important in the process of project decisions making and display of them in graphic form, are aimed at mentioned above.

Land use planning, providing the agricultural sector, has been undergoing the digitalization for a long time. It is important that the process would allow, due to new technologies, to integrate autonomous functional software modules of various components of land use planning activity: 1) discrete models of organization of the most appropriate crop rotation (allow to generate arrays, optimal for application of modern farming technologies); 2) programs, analyzing the spatial changeability of characteristics of crop productivity, depending on agricultural landscape conditions; 3) systemized database of agro-chemical service of field experiments' results (including geo-network "Agrogeos"); 4) automated processing of cartographic information about agricultural lands and calculation of their cadastral value [12].

As stated above, the SULUP's departmental affiliation is agricultural, therefore the scientific researches, conducted by its scientists and lecturers, are aimed, obviously, at solving the tasks of the agricultural industry.

4 Perspective Directions for the SULUP Development

Taking into account all mentioned above factors, the basis for the further SULUP development was formed by the science-driven, practice-focused, and connected to the educational process strategic university projects.

The transformation project of founded in 1960s geodesic experimental site into high-tech **Chkalovskiy Agro(bio)technopark** has become the key project among all of them. This idea includes the elaborations (inventions) of scientists and specialist of the SULUP [2, 7, 14], allowing:

– to educate the students modern methods of gardening, crop growing and farming;
– to conduct scientific researches in farming, soil science, crop growing, ecology, and engineering on the agricultural territories;
– to use it as a demonstration site for innovative elaborations in agricultural branches of science;
– to receive own agricultural goods for the needs of the University (for the canteen, for example).

Beneficial (favourable) location of the geodesic experimental site (polygon) "Chkalovskiy" on the territory of the Losino-Petrovskiy city district of the Moscow region, at distance of 20 km of driving on the reconstructed Shchelkovskoye highway, will allow to attract the large number of investors and business partners. There is already a network of functioning engineering facilities (gas and water pipelines, electrical networks, roads) on the territory, except for the favourable location and proximity of the airport.

At present the scientific capacity of the polygon is used, mostly, for solving of geodesic challenges for aerophotocamera calibration, high-precision equipment certification; the testing of many geodesic devices (theodolites, levels, radio and electronic distance measuring equipment and others) and satellite receivers of different manufacturers etc., took place on the reference linear and high altitude basis of the polygon (and its main aim is the performance of the surveying trainings). Those activities are to be continued. The cluster approach will be applied in the Agro(bio)technopark. Wherein every cluster will have its unique atmosphere. Visitors and users will have an opportunity to enter and leave, and move freely, without crossing the entrance gates, gradually exploring the Agro(bio)technopark territory. Also, overall circle route of ecological transport, bicycle and pedestrian roads system will be organized.

As soon as the first of the clusters starts its work, the whole Chkalovskiy Agro(bio)technopark will start to function. Later, the other clusters of the Agro(bio)technopark will start to develop (according to the model of science-education-production). General territory of the created 60 years ago geodesic polygon allows to locate in the Agro(bio)technopark the following clusters.

Renovation of the **educational cluster** (on the territory of 18 ha), where the following activities will be combined: 1) holding classes and educational practices with students, retraining of cadaster engineers, surveyors and other specialists mastering the technologies of work with absolutely new devises; 2) research and innovative activities and performance of experimental researches and observations; 3) industrial and experimental use, verification and calibration of geodesic equipment and of unmanned aerial vehicles (UAV), their metrological testing in field conditions. Now this cluster includes 10 one-storey brick houses (general capacity makes up to 500 persons), 2 of which are used as an accommodation for professorial and teaching staff during the educational practice period, and also canteen, administrative building, garage, auxiliary facilities, sports grounds, recreation area. Over the next 5 years lecturers' houses will be completely renovated, showers and restrooms for students and lecturers will be built, quality hot and cold water supply will be constructed, overhaul (reconstruction) of student houses will be implemented, electrical wiring will be changed and heating of student houses will be organized, the all-year-round educational block (building) will be constructed on the territory of the educational cluster.

This will allow to create a solid foundation for training specialists not only according to already available specialties, but also to start up modern completely new educational programs, such as protected ground engineer, ornamental plant growing, greening of settlements, green architecture of city environment; unmanned aerial vehicles (UAV) in agriculture, cadastral activities, study of land resources with aerospace methods, judicial land management expertise, regulation of land use planning and cadastral activity, management of the forest fund lands, reforestation and others.

Further development of the **military cluster** (5.2 ha), where the training of officers, sergeants, and reserve soldiers takes place.

The UAV Sphera cluster (1.1 ha), including assembly hall and conference halls, a few workshops for assembly and maintenance of UAV, area for flights (now all those activities take place directly in the educational building of the University in urban conditions, that imposes certain limitations).

Totally new **Agrocluster** (47 ha), including 1) laboratories for plants microcloning; 2) area for so called "vertical" farms for growing vegetables, greens and berries in multilevel structures; 3) a few traditional greenhouses for growing crops and seedlings, and also experimental fields for vegetable crop rotation; 4) nursery of coniferous and decorative crops and area of perennial plantations. The cluster is relevant due to transfer of agro-industrial complex to innovative development, that includes rapid mastering of modern advanced technologies, which demands not only improvement in training of highly qualified personnel in the universities, but also, what is of the most importance now, formation of practical industrial skills of graduates in the chosen specialty. In this regard, demands for increased efficiency of use of available in the agricultural universities industrial bases are growing, as well as of production bases, industrial polygons, filed laboratories. It is a fundamentally new agricultural direction for development for the SULUP.

Scientific and educational cluster of the Glavgosexpertiza of Russia, the strategic partner of the SULUP (its total area is 25 ha, its development will be implemented according to separate plan).

In framework of Agro(bio)technopark **the eco-cluster** is also under consideration. Initially, the eco-cluster will consist only of the area for monitoring the condition of the environment, and gradually, with the implementation of the project, it will be supplemented by the experimental carbon polygon with the affiliate of the Moscow Pharmacy Garden and recreational cluster.

So, the comprehensive development of the Chkalovskiy Agro(bio)technopark is a kind of the prototype of the **"Smart land use planning"**, long-cherished in the University.

If creation of the Chkalovskiy Agro(bio)technopark has clearly specified (and rather limited) location on the territory of 96 ha, where educational geodesic practices are taking place now, and where the Military and Educational Center of the University is functioning, then the other one, but not less ambitious, project, named "Agricultural lands boundaries" covers almost all regions of the country. It is promising, as over the last decade the agro-industrial sector of the Russian economy has started to regain lost in 1990s positions; and involvement of unclaimed agricultural lands into use has become an important factor of its sustainable development. This project is included into federal State program [17]. In framework of the "Agricultural lands boundaries" project, after approval of the State program in 2021, specialists of the University, on the assignment of the Ministry of agriculture, elaborated the methodology for boundary setting of such lands with specification (allocation) of the most valuable ones. The methodology allows not only to set the appropriate boundaries, but also to introduce the data thereof to the Unified Federal Informational System on Agricultural Lands (UFIS AL), and then to use those data while organizing the taxation for the agro-holdings, regulating the agricultural activity, conducting the survey and defining the location of the most valuable lands.

In 2022, six piloting regions applied already the activities, based on the university-elaborated methodology. Remarkably, that in two of those regions the activities were performed directly by the University team. In 2023 the University team conducted the activities in two more regions of the North-West Federal District (Leningrad and Novgorod districts). The performance of the activities according to the university-elaborated methodology allows to form the whole set of materials, characterizing the condition of agricultural lands. Those are, including:

- digital map of their modern usage on a digital medium and in software of geoportals, created by the performers of the activities;
- annual winter and summer cloudless composites for the period of 2020–2021, received from satellite data on a digital medium and in software of geoportals;
- results of land survey in paper and on a digital medium;
- final and (updated) digital map of modern use of surveyed lands on a digital medium and in the software of the geoportals;
- their multi-layered digital model, uploaded into the UFIS AL.

The further work in frameworks of the "Agricultural lands boundaries" project will be carried out according to two directions: 1) correction of the methodology according to the results of its application and 2) continuation of implementation of activities by the created in the University specialized problems-focused laboratory.

5 Discussions and Debates

Stated in the article measures on land use planning ensuring the food security and on prioritized directions of the SULUP were mentioned multiple times on different scientific and production, and educational forums, nevertheless the measures with clear focus on directions of the university Agro(bio)technopark and of the realized in frameworks of the State Program “Agricultural lands boundaries” project, are mentioned for the first time. Moreover, the practical implementation of the considered in the article strategic university projects started only in 2022–2023.

6 Conclusions

In Russia, the land use planning has always decided overall state problems, has always been an instrument of the land policy of the government of the state. The SULUP, founded 245 years ago (called the Surveying school at those times), has been developed (transformed) in accordance with this challenges. Now, its prioritized directions of development are: 1) digitalization of the educational and all other university processes, 2) integration of scientific researches and training of the highly qualified specialists (the top priority goal is to create the Agro(bio)technopark as an incubator of the corresponding scientific developments), 3) participation in the State Program for the repeated development of the abandoned agricultural lands.

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The System of Integral Indices for Assessing Regions by the Level of Digital Economy Development

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Abstract. The combination of sustainable development and digital economy in regions contributes to the more efficient use of resources, the development of new technological solutions, improvement in the quality of life for citizens, and the maintenance of environmental sustainability. The purpose of the study is to assess regions according to the level of development of the digital economy, based on the calculation of the system of integral indices. The indices characterize the conditions of the use of digital technologies in commercial organizations, public sector and in households. The article analyzes existing approaches to assessing the level of the digital economy at the federal, regional and local levels. We presented a methodology for assessing Russian regions by the level of digital economy development based on the calculation of single, group and integral indices, which made it possible to analyze 85 constituent entities of the Russian Federation and identify current trends. 10 leading regions were identified, including Moscow, St. Petersburg, the Republic of Tatarstan, Stavropol and Perm territories. The index of the integral indicator exceeded the value of 0.758. On the basis of the comparative assessment we determined the presence of high differentiation between Russian regions in the use of digital technologies in organizations and public sector. Moreover, we concluded that regional digital economy increases if at least 45% of organizations in a region use specialized equipment designed to run service software without human intervention, and the "digital maturity" of government authorities is assessed at least 60 points.

Keywords: assessment · integral index · digital economy · region · rating

1 Introduction

The fourth industrial revolution affects a change in the technological structure and poses great challenges to the sustainability of territorial development. Production processes and economic relations are being transformed by the transition to digital technologies,

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and the level of digitalization is becoming a factor in regional competitiveness. The development of the digital economy is one of the state's priorities. According to Decrees of the President of the Russian Federation dated May 7, 2018 No. 204 "On national goals and strategic objectives of the development of the Russian Federation for the period until 2024" and dated July 21, 2020 No. 474 "On national development goals of the Russian Federation for the period until 2030", in order to solve ensuring the accelerated implementation of digital technologies in the economy and social sphere, the Government of the Russian Federation formed the national program "Digital Economy of the Russian Federation", approved by the presidium of the Council under the President of the Russian Federation for strategic development and national projects dated June 4, 2019 No. 7. The National Program "Digital Economy of the Russian Federation" includes the following federal projects: "Regulatory regulation of the digital environment", "Personnel for the digital economy", "Information infrastructure", "Information security", "Digital technologies", "Digital public administration", "Artificial intelligence", "Providing Internet access through the development of satellite communications", "Development of human resources in the IT industry" [1].

As part of the implementation of the national program "Digital Economy of the Russian Federation," there is a need for a comprehensive assessment of the region in terms of the potential for digital transformation. The current state of digital development in the regions of Russia should be analyzed using a special methodology, which should contain objective indicators that fully reflect the state of digital development in each region.

2 Theoretical Basis

Methodology for calculating the Digital Russia index, developed by researchers of the Center for Financial Innovation and Cashless Economy of the Moscow School of Management Skolkovo, includes 7 subindices: regulatory and administrative indicators of digitalization, specialized personnel and training programs, the presence and formation of research competencies and technological groundwork, information infrastructure, information security, economic indicators of digitalization, social effects from the introduction of digitalization [2]. Based on DECA methodology (Digital Economy Country Assessment), developed in 2017 by the World Bank in collaboration with the Institute for the Development of the Information Society, E. V. Bolgova, G. N. Grodskaya, M. V. Kournikova, D. S. Merkulov proposed indicators for the level of digital economy development of the region, combined into three groups - indicators characterizing non-digital and digital factors, the digital sector [3].

V. V. Stepanova, A. V. Ukhanova, A. V. Grigorishchin and D. B. Yakhyaev [4] include two indicators - the digital activity of subjects (population, organizations and the state) and the conditions of digitalization (digital infrastructure, digital competences of the population, digital education, spatial and territorial structure, development of science and innovation, resource availability). In accordance with the proposed methodology, the authors identify six types of digital ecosystems – innovative, advanced, actively involved, balanced, problematic and passive regions.

A. V. Kozlov proposed to evaluate the level of digital economy development from the point of view of the material and information subsystems, which characterize, respectively, the material conditions and technical prerequisites for the formation of the digital economy, and the degree of use of modern information and computer networks and systems [5].

S. N. Bobylev, V. S. Tikunov, O. Yu. Chereshnya, based on current Russian statistics in the field of information and communication technologies, consider indicators within the framework of infrastructure, human capital and digital government [6].

O. V. Kaurova, A. N. Maloletko, L. V. Matraeva, N. A. Korolkova proposed to determine the digitalization index of the region according to 48 indicators, combined into three groups: (i) perception of the processes of digital transformation of the region, (ii) readiness of the digital environment at the level of the regional economy and industries, (iii) the effects of digital transformation on the economy and social sphere of the region. The proposed index of digital transformation of the region provides to assess the development, controllability, efficiency and effectiveness in the context of the interests and involvement of the main participants in the digital transformation process (authorities (state); representatives of the business community, citizens) [7].

R. R. Sadyrtdinov assesses the level of development of digitalization of regions based on an integral indicator calculated according to the indicators of four blocks - digital mobility, digital equality, digital economy and digital interaction [8].

V. A. Kurkin proposed an assessment of the dynamics of the digital economy of the region using cluster analysis based on 14 indicators, combined into three subsystems: households, business structures, government and non-profit organizations. Based on the data obtained, the author gave characteristics to groups of regions in the context of subsystems [9].

The methodology for assessing the digital maturity of regions, proposed by the Ministry of International Development, Communications and Mass Communications of the Russian Federation, is based on three indicators - the number of specialists actively using information and communication technologies; expenses of organizations for the implementation and use of modern digital solutions; achieving the target value of 2030 in 12 sectors of the economy.

A similar methodology presented by the Government of the Russian Federation involves calculating the share of achievement by regional government authorities, local governments and organizations in the field of healthcare, education, urban management and construction, public transport, as well as public administration of target values of indicators characterizing the achievement of indicators of these industries and government management [10].

I. V. Pisarev, V. I. Byvshev, I. A. Panteleeva, K. V. Parfentyeva [11], based on the methodology developed by the Ministry of Digital Development of the Russian Federation, proposed an integral indicator - the information society development index, which is calculated taking into account factors in the development of the information society and the use of information and communication technologies by the population and organizations. The indicator characterizing the factors of development of the information society is calculated based on an assessment of the level of education, IT skills, scientific potential, IT specialists, and IT infrastructure. The second indicator, which reveals the level of IT use by the population and organizations, involves an assessment of IT in the activities of government bodies, the use of IT by the population and households, cultural institutions, access of enterprises to IT, the equipping of healthcare institutions with personal computers, the use of network technologies in healthcare, the development of e-commerce.

I. S. Glebova and Y. A. Anisheva propose to evaluate digital economy of the region based on the calculation of digitalization indices in the field of housing and communal services, transport, public safety, communications and the Internet, environmental safety, education and culture, healthcare, management [12].

To assess the level of development of the digital economy of the region, O. A. Potapova proposes to determine the digital readiness index, which includes the use of 17 indicators, divided into three blocks: the provision of the region with information and communication tools, the level of informatization of the region and the human resources potential of the region. Depending on the value of the digital readiness index, the author identifies regions with high digital dividends, digital growth and low readiness for the digital economy [13].

A. D. Golitsyna, based on their idea that the digital economy is a complex process that should affect both the digitalization indicators of business and citizens, as well as institutional barriers, proposed the following groups of indicators for assessing the level of development of the digital economy of the region: e-commerce, digital infrastructure, cultural and institutional barriers, media and public coverage of topics related to the digital economy [14].

A. A. Sidorov, P. V. Senchenko, V. F. Tarasenko presented a model for an integral assessment of the level of digitalization of territorial entities, which involves the calculation of 13 indicators collected by Rosstat and Eurostat to characterize the development of the information society [15].

N. V. Trofimova, E. R. Mamleeva and G. F. Shaikhutdinova use indicators characterizing the creation of digital technologies and related products and services, resources of the digital economy, involvement of organizations and the population in digitalization processes as static measurements of the region's digital economy, effects of digitalization. Using the matrix principle of assessing the level and pace of development of the digital economy allowed the authors to identify depressed, lagging, stable and progressive regions [16].

L. V. Glezman, S. S. Fedoseeva and D. A. Balandin proposed three groups of indicators: the development of digital infrastructure in the organizational sector of the region; availability and quality of digital infrastructure in the consumer sector; digitalization of infrastructure networks [17].

The high relevance of studying regions in terms of the level of development of the digital economy is evidenced by the presence of a large number of publications in the economic literature devoted to the methodology for assessing digital development [18]. However, a significant part of the proposed methods does not fully cover all spheres of life in the region, which does not allow us to judge the general level of digital development [19]. The methodology for assessing digital development of regions should objectively reflect the actual state of digital development of regions and include indicators of digital development covering all spheres of life in the region.

3 Materials and Methods

The study of various approaches to the study of digitalization of regions made it possible to formulate us the methodology for assessing regions according to the level of development of the digital economy, based on an information database of official and departmental statistics. Since digital transformation of a region requires the presence of digital knowledge among the population and organizations, as well as digital infrastructure, we recommended to divide the system of indicators for assessing regions according to the level of development of the digital economy into three groups.

1. In organizations:
   - the share of organizations using personal computers, servers, local computing and global information networks, broadband Internet access with a speed of at least 2 Mbit/s, and having a website;
   - the number of personal computers per 100 employees, including Internet access;
   - the share of organizations using electronic document management, electronic data exchange among internal and external information systems, by exchange formats, using the Internet to place orders for goods (work, services).
2. In households:
   - the proportion of households that have a personal computer, including those with access to and using broadband Internet, as well as those who are active Internet users;
   - the number of connected subscriber mobile communication devices per 1000 people;
   - number of active subscribers of fixed and mobile broadband Internet access;
   - the share of the population that uses the Internet to order goods and services and has digital skills at a basic or higher level.
3. In the public sector:
   - the share of registered users of the unified portal of state and municipal services;
   - the share of citizens using the mechanism for receiving state and municipal services in electronic form;
   - the share of socially significant objects with broadband Internet access;
   - the number of government services provided electronically on a single portal of state and municipal services;
   - the number of implemented functions of public authorities based on a single platform of services;
   - the share of requests for mass socially significant state and municipal services in electronic form using a single portal of state and municipal services without the need for a personal visit;
   - the share of public authorities with a data transmission speed via the Internet of at least 2 Mbit/s;
   - share of healthcare institutions using the Internet;
   - share of electronic document flow between government bodies;

– the number of state (municipal) and institutional employees trained in competencies in the field of digital transformation of state and municipal government;
– "digital maturity" of government bodies and organizations in the field of healthcare, education, urban management and construction, public transport;
– level of satisfaction with the quality of provision of mass socially significant state and municipal services in electronic form using a single portal of state and municipal services.

We propose to assess regions due to single, group and integral indices. Unit indices are determined by the ratio of the actual indicator to the reference one; group indices - as the average value of individual indices of indicators included in this group; integral index (I_{de}) – as the average value of group indices.

The formula for the integral index of development of the digital economy of the region is:

$$I_{de} = \frac{I_{org} + I_h + I_{pub}}{3}, \tag{1}$$

where I_{de} is the integral index of the development of the digital economy of the region;

I_{org}– group index of the use of digital technologies in organizations;

I_h– group index of the use of digital technologies in households;

I_{pub}– group index of the use of digital technologies in the public sector.

Group indices of the development of the digital economy of the region are determined by the formula:

$$I_{gr} = \frac{\sum_1^n i_{1,2,3...n}}{n}, \tag{2}$$

where $i_{1,2,3...n}$ are single indices of the development of the digital economy of the region;

n– the number of indicators for assessing regions according to the level of development of the digital economy in the group (for assessing the use of digital technologies in organizations n is 13, households – 11, public sector – 13).

Calculation of single indices is carried out using the formula:

$$i_{1,2,3...n} = \frac{X_a}{X_r}, \tag{3}$$

where X_a is the value of the actual indicator of the region's digital economy;

X_r– value of the reference indicator. The reference is the maximum value of the indicator achieved in the country.

The proposed methodology, based on the objectivity and complexity of the analysis, helps to compare regions according to the level of development of the digital economy and construct their rating, determine the strengths and weaknesses of regional digitalization, disproportions and identify trends and promising directions in this scope.

4 Research Results

The proposed methodology based on data in 2022 made it possible to formulate a rating of Russian regions. According to the results obtained, the highest rating of digital development was achieved in Moscow with the integral index 0.791 due to the high level of use of digital technologies in organizations and households. The second position in this ranking is occupied by St. Petersburg, the value of the integral index of which is slightly lower than the leader (0.790). The leading group of regions in terms of the level of development of the digital economy, in addition to cities of federal significance, includes Moscow region, the Republic of Tatarstan, Stavropol, Leningrad, Perm, Belgorod, Sverdlovsk regions and the Khanty-Mansiysk Autonomous Region (Table 1).

Table 1. Ranking of the 10 leading regions by the level of digital economy development

Place in the ranking	The subject of the Russian Federation	Group indices of digital technology use			Integral index of digital economy development
		in organizations	in households	in the public sector	
1	Moscow	0.833	0.835	0.705	0.791
2	Saint Petersburg	0.821	0.793	0.757	0.790
3	Moscow region	0.895	0.656	0.791	0.781
4	Republic of Tatarstan	0.859	0.753	0.712	0.775
5	Stavropol region	0.827	0.792	0.674	0.764
6	Leningrad region	0.789	0.760	0.751	0.766
7	Perm region	0.831	0.777	0.684	0.764
8	Belgorod region	0.784	0.778	0.729	0.763
9	Sverdlovsk region	0.773	0.738	0.767	0.759
10	Khanty-Mansiysk Autonomous Okrug	0.755	0.780	0.741	0.758

Source: calculated according to data [20]

The worst results are demonstrated by the Republic of Dagestan with an integral index equal to 0.620. The lowest group indicator is observed in the sphere of organizations - only 0.564. The development of the digital economy is low in the Jewish Autonomous Region, the Republic of Mordovia, the Komi Republic, the Republic of North Ossetia-Alania, the Republic of Buryatia, the Trans-Baikal Territory, the Republic of Tyva, the Nenets Autonomous Okrug and the Republic of Ingushetia. The value of the integral index of development of the digital economy of these regions does not exceed 0.7.

A comparative assessment of the level of development of the digital economy in the regions made it possible to determine the presence of high differentiation between the constituent entities of the Russian Federation in the use of digital technologies in organizations and in the public sector.

5 Discussion

A comparative assessment showed that in the commercial sector the highest disproportions are observed in the use of servers by organizations (46.1% versus 32.5%), local computer networks (61.4% versus 46.3%), access to the Internet with a speed of at least 2 Mbit/s (72.8% versus 57.4%). In the leading regions in terms of the level of development of the digital economy, compared to outsider regions, there is a higher proportion of organizations using electronic data exchange among internal and external information systems (59.6% versus 48.6%) and organizations using the Internet to place orders for goods, such as works, services (46.8% versus 32.9%).

In functioning of public authorities, significant differences between leading and lagging regions were identified in the share of citizens using the mechanism for receiving state and municipal services in electronic form (88.4% versus 72.3%), the number of government services provided electronically on a single portal of state and municipal services (199 versus 59 people), the share of requests for mass socially significant state and municipal services in electronic form using a single portal of state and municipal services without the need for a personal visit (68.3% versus 32.2%), share electronic document flow between public authorities (52.3% versus 31.8%), the amount of spending on digital technologies (more than 66 times higher), the level of "digital maturity" of public authorities and organizations in the field of healthcare, education, and municipal services and construction, public transport (4.3 points versus 3.7 points).

The differentiation of Russian regions in households is less pronounced. Significant difference between regions is observed in the number of connected subscriber mobile communication devices per 1000 population (2174 units versus 1122 units), the number of active subscribers of fixed and mobile broadband Internet access (by 13.6 and 63.7 units, respectively) and the share of the population with digital skills above the basic level (10.8% versus 7.1%).

The influence degree of the main formation indicators on the value of the integral index of the digital economy development in a region by correlation and regression analysis showed the greatest dependence of resulting indicator on the share of organizations that used servers (rxy = 0.615), active subscribers of mobile broadband Internet access (rxy = 0.535) and "digital maturity" of public authorities (rxy = 0.602). In general, changes in these factors strongly impact on the formation of the integral index (Rxy = 0.788) and determines 62.1% of the conversion of the indicator.

According to beta coefficients, the share of organizations that used servers and the "digital maturity" of public authorities have the greatest influence on the effective attribute.

The study made it possible to determine that a high level of development of the digital economy (integral index over 0.78) is achieved if at least 45% of organizations use specialized equipment designed to execute service software without human intervention, while the level of digitalization of public authorities is assessed at least 60 points.

6 Conclusion

Studying the development of the digital economy in Russia, there is a need to develop a methodology for a comprehensive assessment of the digital development of regions from the point of view of the potential of digital transformation, including a system of indicators in organizations, households, and the public sector. At the same time, the developed methodology revealed that digital economy development expanses when the majority of organizations in a region use specialized equipment designed to run service software without human intervention, and the "digital maturity" of the bodies state power is assessed at least 60 points. For the effective development of the digital economy, as directions for increasing the level of digitalization, it is necessary to increase the share of the population with digital skills, the use of the Internet to order goods and services, expand access to broadband Internet, increase the ability to use personal computers and the share of households with access to the Internet.

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The Contribution of the Agricultural Region to the Implementation of the State Project to Support and Develop the Export of Agricultural Products

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Abstract. The food problem remains one of the most important in the modern world: hundreds of millions of people in dozens of countries are experiencing food shortages or are in a state of chronic hunger. The way to solve the problem as soon as possible is to redistribute food from "food-surplus" regions of the world to "food-deficient" ones. It is carried out through the use of both market and non-market mechanisms of international export-import operations with agricultural products. An important role in ensuring the country's foreign economic processes is played by its main macro–regulator, the state. In federations, a significant part of the authority to organize the production and export of agricultural products is shifted to the level of regional government authorities, and this process is subject to scientific research. The paper uses an overview of regulatory, statistical and scientific data on the state and prospects of regional exports of agricultural products on the example of Stavropol Territory, Russian Federation. The authors relied on official sources of information and works published in peer-reviewed journals. The sources were selected in scientometric databases using search queries containing synonymous constructions. We analyzed the system of normative, organizational and administrative activities of the federal and regional authorities of the Russian Federation over the past twenty years, as well as the dynamics of the production and export components of the agro-industrial complex of the Stavropol Territory over the past five years. The work studied the contribution of the agricultural region to the implementation of the state project to support and develop the export of agricultural products. The project approach shows the effectiveness of solving the food problem at the domestic and foreign economic levels. The system of normative, methodological and organizational interaction of central and regional government authorities was proofed in the context of the "vertical of power" in the federation.

Keywords: agriculture · agro-industrial complex (agro-industrial complex) · export of agricultural products · program and project management method · federal programs and projects · region · subject of the federation · regional project

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1 Introduction

One of the Sustainable Development Goals (SDG) the UN is called "Eliminating hunger, ensuring food security and improving nutrition and promoting sustainable agricultural development". Currently, the main global exporters of crop and livestock products are countries such as China, the United States, Brazil, India, Russia and others. It is noteworthy that all of them are at the same time major powers with the largest territories – over three million square kilometers. However, the scale of the territories of the countries inevitably leads to their regionalization caused by climatic, economic, foreign policy and other factors.

When studying scientific publications of recent years on the stated topic, it was revealed that the greatest attention is paid to it in the countries – leading exporters of agricultural products. In the work of scholars investigates the impact on the volumes, dynamics, structure, the value of exports of agricultural products to global of scholars investigates the impact on the volumes, dynamics, structure, the value of exports of agricultural products to global warming [1], the epidemic of COVID-19 [2], financial instruments (decentralized Finance [3], specific tariffs [4], logistics [5, 6], trade facilitation [7], increasing the degree of openness of agriculture [8] (including the introduction of free trade zones [9]), foreign factors: global competition [10] and international conflicts [11].

At the same time, the vast majority of publications on the development of agricultural exports are devoted to issues at the national and international levels. Problems of intranational regionalization investigated in the above aspect, to a much lesser extent, as these works can be called the publication of the Chinese [1, 12, 13], Serbian [14], Russian [15] scientists. Relatively little attention is paid to the impact on the development of the agricultural sector (including regions of individual countries) on the part of state institutions.

The purpose of this study is to explore the possibilities of using state regulation to solve the problem of ensuring stable growth of regional exports of agricultural products. The object of the study was one of the traditionally agrarian regions of the largest country in the world – the Russian Federation, the subject is the mechanism of state regulation of exports of products of the agro–industrial complex of the subject of the Russian Federation.

2 Materials and Methods of Research

The socio-economic direction of the research led the authors to use a set of scientific methods. The study of the role of the state in the organization of exports of agricultural products, both at the national and regional levels, required the use of an institutional research method. Consideration of the role and activities of individual links of the state mechanism led to the inclusion of structural, functional and systemic methods in the methodological complex of work. The analysis of the regulatory legal and documentary reporting base for the design and programming of agricultural production and export over the past two decades has necessitated the involvement of normative, documentary, and historical approaches.

The databases of state authorities of the Russian Federation and its subjects served as information sources of secondary data: The Federal State Statistics Service, the Federal Customs Service, the Ministries of Agriculture of the Russian Federation and the Stavropol Territory, and others. The empirical basis of the study was the official economic and statistical data from 2017 to the first half of 2023.

The results of both domestic and foreign studies of the post-covid (after 2019) period in the field of agricultural development, primarily its regional and export aspects, were used.

3 Results

Russia has a rich, centuries-old experience in ensuring the development of agriculture, and the state began to pay special attention to this issue in the second half of the twentieth century. In the new century, socio-economic design received accelerated development and practical implementation in the country after the announcement of the human capital growth program by the President of the Russian Federation in 2005. In his address to the parliament, the government of the country, and the heads of its subjects, the head of state named housing, healthcare, education, and agriculture as priority areas for "investment in people." Later, this list was supplemented and formed the basis for the "Priority National Projects of Russia", which were implemented in the period from 2006 to 2018.

At the same time, the Presidential Council for the Implementation of Priority National Projects and Demographic Policy responsible for this area of activity was established. In 2018, it was transformed into the Council under the President of the Russian Federation for Strategic Development and National Projects.

In May 2018, President Vladimir Putin signed a decree "On national goals and strategic objectives for the development of the Russian Federation for the period up to 2024." The document provided for three strategic directions of the country's development: "Economic growth", "Human capital" and "A comfortable living environment". By the end of 2018, 13 new national projects were formed, approved by the relevant Decree of the head of state. In the future, despite all the obstacles that arose for the Russian state, this list only expanded.

One of the national projects was the International Cooperation and Export project, adopted in December 2018 for a six-year perspective. It became the development of priority projects approved in late 2016 – early 2017: "International cooperation and export in industry", "Export of agricultural products" and "Systemic measures for the development of international cooperation and exports". As a result, five federal projects were included in the national project "International cooperation and export": "Industrial export", "Logistics of international trade", "Export of services", "Systemic measures for the development of international cooperation and export" and "Export of agricultural products".

The last of these federal projects was first agreed upon at a meeting of the project committee of the national project (program) "International Cooperation and Export" on December 14, 2018, and then approved by the Presidium of the Presidential Council for Strategic Development and National Projects on December 24, 2018. The project was curated by the Deputy Chairman of the Government of the Russian Federation, the head was the Minister of Agriculture of the Russian Federation, the administrator was his deputy.

The passport of the federal project “Export of agricultural products” in 2018 consisted of five sections, two appendices, a number of additional and substantiating materials. Thus, Sect. 1 “Basic provisions” contained information about the curator of the project, its head and administrator, as well as about the “State Program for the development of agriculture and regulation of agricultural products, raw materials and food markets” adopted earlier (July 2012) in this area.

In Sect. 2, “The purpose and indicators of the federal project” its following goal was formulated: “Achieving the volume of exports of agricultural products (in value terms) in the amount of 45 billion US dollars by the end of 2024.” Simultaneously with the adoption of the national project “International Cooperation and Export”, the Ministry of Agriculture of the Russian Federation, by its order, approved the methodology for calculating the indicators of the named federal project. Currently, the document is valid in the wording of the Order of the Ministry of Agriculture of the Russian Federation of 2022 “On approval of the official statistical methodology for calculating indicators of the federal project “Export of agricultural products”.

Section 3 was devoted to the “Tasks and results of the federal project”, it includes four main tasks of the project, predetermined by its general purpose and divided into groups of more specific results.

In Sect. 4, it was planned to provide financial support (in millions of rubles) for the results presented in the previous section, with their differentiation by years of the entire project period (2019 – 2024).

Section 5 contained a list of 126 participants of the federal project distributed according to the results: the names and positions of responsible persons, their roles in the project, their direct supervisors and employment in the project (in percentages).

Section 6 “Additional information” included data on nine alleged risks of implementing the federal project, such as: “Decrease in crop yields under the influence of adverse natural factors”, “Risk of termination of supplies of imported machinery and equipment, breeding material, fertilizers, NWF, vaccines as a result of the negative impact of sanctions and restrictions against the Russian Federation” – and so on.

Several additional materials were attached to the passport of the federal project. First of all, this is Appendix No. 1 “Action plan for the implementation of the federal project” (specifying the provisions of the passport and exceeding it by almost two and a half times in volume) and Appendix No. 2 “Indicators of the federal project for the subjects of the Russian Federation” (in particular, the volume of exports, by subjects of Russia, from 2018 to 2024 years). Secondly, this is Appendix No. 3 “Additional and substantiating materials”: “Model of functioning of results and achievement of indicators”, “Methodology for calculating indicators of the federal project” and “Financial support for the implementation of the federal project in the subjects of the Russian Federation” (with distribution by federal and consolidated budgets of the subjects of Russia, including international transfers budgets).

For the purposes of our study, we will analyze the indicators related to one of the eighty–five (as of 2018) subjects of the Russian Federation - the Stavropol Territory.

According to the Federal State Statistics Service, the region is characterized by the following indicators of spatial and socio-economic development:

- area of the territory: 66.2 thousand km^2 (45th place out of 85 subjects of the Russian Federation, 1st place out of 7 subjects of the North Caucasus Federal District);
- population: 2.8 million people (14th place in Russia, 2nd place in the North Caucasus Federal District);
- population density: 42.3 people per km^2 (23rd place in Russia, 6th place in the North Caucasus Federal District);
- average salary: 33.9 thousand rubles (61st place in Russia, 1st place in the North Caucasus Federal District);
- the proportion of the population with incomes below the subsistence level: 13% (51st place in Russia, 2nd place in the North Caucasus Federal District);
- gross regional product: 863.2 billion rubles (29th place in Russia, 1st place in the North Caucasus Federal District);
- production of industrial products per capita: 202.0 thousand rubles (72nd place in Russia, 1st place in the North Caucasus Federal District);
- the share of innovative goods and services in the gross regional product: 7.7% (23rd place in Russia, 1st place in the North Caucasus Federal District);
- the cost of fixed assets per capita: 1.3 million rubles (72nd place in Russia, 1st place in the North Caucasus Federal District);
- gross regional product per capita: 295.4 thousand rubles (69th place in Russia, 1st place in the North Caucasus Federal District);
- investments in fixed assets per capita: 91.2 thousand rubles (47th place in Russia, 1st place in the North Caucasus Federal District);
- investment climate assessment index: medium (moderate risk) (70th place in Russia).

In the federal project "Export of agricultural products", mention of the Stavropol Territory occurs twice – in appendices 2 and 3. For example, Appendix No. 2 "Indicators of the federal project for the subjects of the Russian Federation" contains a table, a fragment of which is given below (Table 1).

It follows from the table that among the seven subjects of the Russian Federation classified as the North Caucasus Federal District, Stavropol Territory confidently occupies a leading place in terms of exports of agricultural products (11th place out of 85 subjects throughout the federation). This provision, as can be seen from the table, should have been maintained until the end of the project period: in all years (from 2018 to 2024), the share of the region in the federal district by this indicator exceeds 80%.

The planned project index of growth in the volume of exports of agricultural products from the Stavropol Territory is 3.46, i.e. almost three and a half times. To achieve this increase, appropriate financial support was planned – both from the federal budget and from the consolidated budgets of the constituent entities of the Russian Federation. We have selected data on the financial support of the federal project in the North Caucasus Federal District and Stavropol Territory in the following Table 2.

The analysis of the data in Appendix No. 3 allows us to draw several conclusions: firstly, in terms of project financing for the export of agricultural products, the North Caucasus Federal District ranks third in Russia - after the Southern and Volga regions. Secondly, within the North Caucasus Federal District, the Stavropol Territory was chosen

Table 1. The volume of exports of agricultural products by the subjects of the Russian Federation, which are part of the North Caucasus Federal District, billion dollars.

The subject of the Russian Federation	Basic value		The period of implementation of the federal project, year						
	Value	Date	2018	2019	2020	2021	2022	2023	2024
Kabardino-Balkarian Republic	0,0185	31.12.2017	0,0170	0,0185	0,0195	0,0224	0,0282	0,0350	0,0410
Karachay-Cherkess Republic	0,0027	31.12.2017	0,0000	0,0075	0,0076	0,0077	0,0077	0,0078	0,0080
Republic of Dagestan	0,0112	31.12.2017	0,0041	0,0044	0,0047	0,0051	0,0054	0,0058	0,0061
Republic of Ingushetia	0,0030	31.12.2017	0,0029	0,0123	0,0173	0,0249	0,0309	0,0373	0,0432
Republic of North Ossetia - Alania	0,0160	31.12.2017	0,0000	0,0406	0,0407	0,0416	0,0418	0,0423	0,0433
Stavropol Territory	0,3162	31.12.2017	0,3150	0,3620	0,4340	0,5420	0,6890	0,8780	1,0930
Chechen Republic	0,0006	31.12.2017	0,0033	0,0048	0,0141	0,0328	0,0519	0,0719	0,0939

Table 2. The Stavropol Territory's place in the structure of financial support for the federal project "Export of agricultural products" in the North Caucasus Federal District, million rubles.

The subject of the Russian Federation	The period of implementation of the federal project, year							Total, (million rubles)
	2018	2019	2020	2021	2022	2023	2024	
North Caucasus Federal District, including:	0,00	456,32	734,10	596,88	0,00	0,00	0,00	1 787,30
federal budget	0,00	227,01	365,21	296,94	0,00	0,00	0,00	889,16
consolidated budgets of the subjects of the Russian Federation	0,00	229,31	368,89	299,94	0,00	0,00	0,00	898,14
Stavropol Territory, including:	0,00	141,87	350,96	343,49	0,00	0,00	0,00	836,32
federal budget	0,00	70,58	174,60	170,88	0,00	0,00	0,00	416,06
consolidated budgets of the subjects of the Russian Federation	0,00	71,29	176,36	172,61	0,00	0,00	0,00	420,26

as the most funded subject of the Russian Federation – 46.8% of the total amount of funds, that is, the region accounts for almost half of all financial "injections" into the district. Thirdly, the "peak" of export financing – both in the North Caucasus Federal District and in the Stavropol Territory – was planned for 2020, after which its volume was supposed to decrease, and starting from 2022 it would stop altogether. Fourth, it is clear that the burden of financial expenses (both by district and by region) should have been divided almost equally between the federal budget and the consolidated budgets of the constituent entities of the Russian Federation.

Following the federal project "Export of agricultural products" in the next year, 2019, in almost all subjects of the Russian Federation, relevant regional projects were adopted, which, as a rule, have a similar name. In particular, on December 13, 2018, the Council under the Governor of the Stavropol Territory was approved, and next year the passport of the regional project "Export of agricultural products of the Stavropol Territory" was put into effect. The composition and structure of the passport of the federal project predetermined the corresponding characteristics of the passport of the project of the region, which consisted of five sections and one appendix.

The adoption of this document took place in conjunction with other programs and projects implemented and accepted in the region. In particular, almost simultaneously, on December 28, 2018, the regional government approved a new state program of the Stavropol Territory "Development of agriculture", which replaced the previous one of the same name, which had been in force since 2015.

It should be noted that by this time, the team of the Head of the Stavropol Territory had accumulated significant experience in socio-economic design. Already at the beginning of 2017, by his decree, the Department for Ensuring Project Activities of the Government of the Stavropol Territory was established, and soon the Council under the Governor of the Stavropol Territory for Project Activities was established. By 2019, these bodies had done significant work on regulatory, organizational and methodological support for the implementation of federal and regional projects adopted by that time.

Thus, the Department for Ensuring Project Activities of the Stavropol Territory Government Office acquired the status of a regional Project office, which was reflected on the main Internet portal of the Stavropol Territory government authorities stavregion.ru. The resolution of the regional Government "On the organization of project activities in the Stavropol Territory" approved the following functional structure of the management system for this area of activity (Fig. 1).

By resolutions and orders of the Government of the Stavropol Territory, the following provisions were put into effect: on the organization of electronic legally significant document management in the implementation of project activities, on the information system for monitoring national projects and programs – and a number of other regulatory legal acts serving the implementation of state and municipal projects and programs in the territory of the region.

To ensure the implementation of the regional project "Export of agricultural products of the Stavropol Territory" in the system of regional authorities were formed:

1) the working group of the Council under the Governor of the Stavropol Territory on project activities in the direction of "Development of the agro-industrial complex";

2) the project committee of regional projects in the direction of "Development of the agro-industrial complex";
3) the public expert council of regional projects in the direction of "Development of the agro-industrial complex".

Interim data on the implementation of the regional project "Export of agricultural products of the Stavropol Territory" are reflected in the latest edition of its passport (end of 2023) and certified by the head and administrator of the project (Minister and Deputy Minister of Agriculture of the Stavropol Territory). These data indicate that over the past five years since the start of the project, the work of the responsible ministry has been carried out in two main directions: 1) creation of an end-to-end system of financial and non-financial support; 2) creation of a new marketable mass of agricultural products.

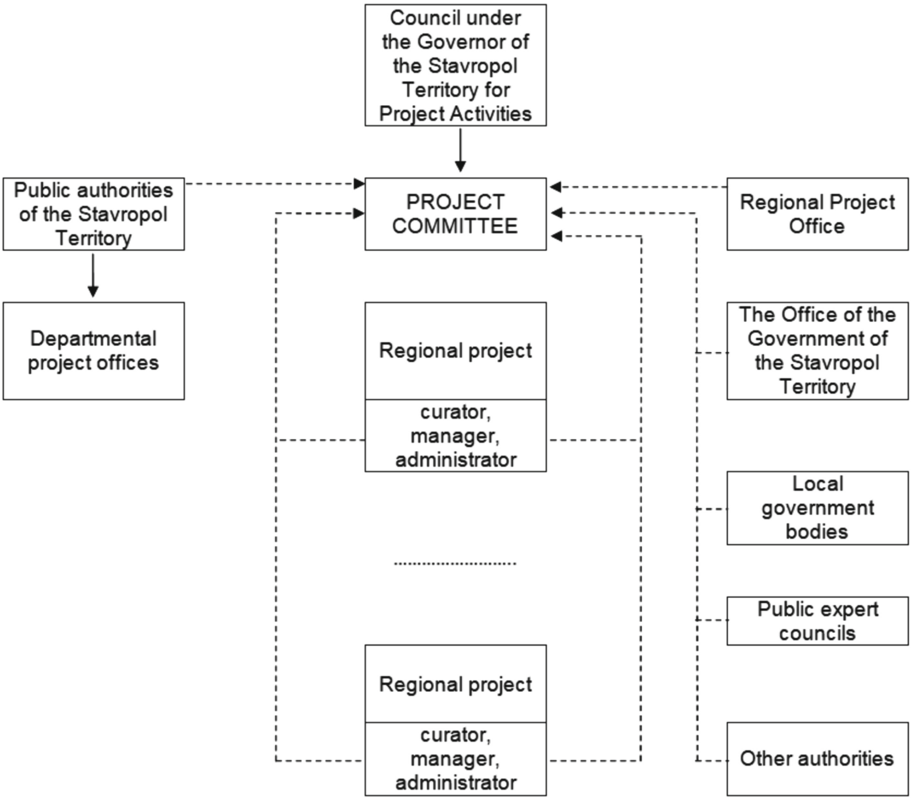

Fig. 1. The structure of project management in the Stavropol Territory

The specifics of the activity of the Ministry of Agriculture as an executive authority of a constituent entity of the Russian Federation determined the leading role of the first direction. It has been implemented in the following areas (results):

1. Commissioning of reclaimed lands.

2. The increase in the volume of oilseed production.
3. Accreditation of veterinary laboratories subordinated to the executive authorities of the subjects of the Russian Federation.
4. Conclusion of agreements on increasing competitiveness with agricultural producers engaged in production and processing of agricultural products in the Stavropol Territory and its sale.
5. Achieving the volume of grain production in agricultural organizations of 53.8 million tons.
6. Information campaign for media coverage of the results, key events and activities of the project.
7. Interaction with the infrastructure to support external supplies.
8. Monitoring of export volumes, achievement of foreign trade indicators and shipment of goods for export.
9. Commercial offers (export contracts) to enterprises exporting agricultural products of the Stavropol Territory.
10. Reimbursement of part of the direct costs incurred for the creation and (or) modernization of agricultural facilities.

As a result, already in 2022, according to the Center for the Development of Agricultural Exports of the Ministry of Agriculture of the Russian Federation, Stavropol Territory took the tenth place in the country in terms of the development of the export potential of the agro–industrial complex, twice ahead of Dagestan, the next Russian subject from the North Caucasus Federal District. The region is one of the largest exporters of agricultural products in the country (with a level of $600 million or more per year), and the cumulative average annual growth rate (CAGR) of this type of export amounted to 17% over five years.

According to the level of development of both agricultural production and export of agricultural products, the Stavropol Territory currently occupies one of the leading places in the Russian Federation. Favorable agro-climatic conditions determine the agricultural direction of the region's economy, in general, and its crop specialization, in particular: for example, it occupies the third place among the regions of the country in terms of grain production (cereals and sunflower). The key indicators of the "export profile" as of the end of 2022 were as follows:

– the ratio of exports and imports of agriculture – 9.74;
– the share of agricultural exports in the total volume of external supplies of the Stavropol Territory – 34.7% (21st place);
– the share of agricultural imports in the total imports of the region is 6.2% (47th place);
– the share of the region in the export of agricultural products of the Russian Federation is 1.4%, and the North Caucasus Federal District is 70.7%;
– the average contribution of agriculture to the GRP of the region in three years is 12.4% (in Russia as a whole – 4.3%);
– the index of the food concentration of the region is 0.22 (in Russia – 0.01);
– leadership among Russian regions in the export of certain types of agricultural products: grain sorghum – 1st place, poultry meat – 2nd place, etc.

According to the Federal Customs Service, the export of agricultural products of the Stavropol Territory has increased almost 2.3 times in five years (Fig. 2).

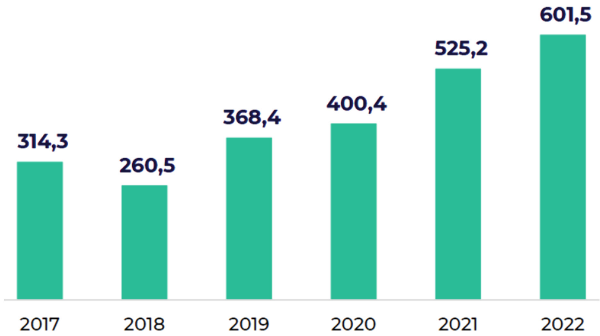

Fig. 2. Dynamics of exports of agricultural products of the Stavropol Territory (2017–2022)

First of all, this increase was achieved due to an increase in exports of fat and oil products, meat and cereals. A more detailed analysis of the region's external supplies shows that with the growth of the total volume of almost all its significant components (grain, meat, and fat-and-oil products), certain structural shifts have occurred within it over the past five years. Thus, with an increase in the volume of exports of grain products by 1.7 times, and meat products by 1.9 times, their shares in the total volume of external supplies of agricultural products of the Stavropol Territory decreased by 7.8 and 1.0 percentage points, respectively. The largest increase was observed in the segment of fat and oil products, where its volume increased by 18.5 times, and the share in exports of regional agricultural products increased by 15.3 percentage points (Fig. 3).

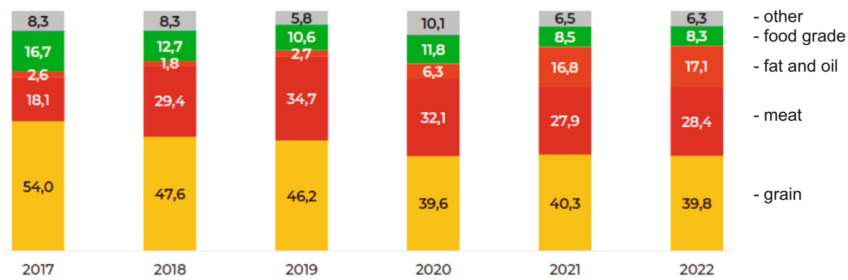

Fig. 3. Dynamics of the structure of agricultural products of the Stavropol Territory (2017–2022)

Currently, the Stavropol Territory carries out external deliveries of agricultural products in 46 positions of the Customs Code of foreign Economic Activity to 57 countries both near and far abroad. The product-country analysis of the region's export activities can be presented in the following table 3 below (three leading importing countries are listed for each product item).

The export of agricultural products of the Stavropol Territory is characterized by a fairly high degree of concentration: the first five positions of the list shown in the table (poultry meat, wheat, sunflower oil, wheat flour, corn) account for 83.2% of total exports, and the first ten positions – 91.6%. The main supply region (69% of the total value of the

Table 3. Countries – leading importers of agricultural products of the Stavropol Territory

Product Type	Azerbaijan	Armenia	Belarus	Georgia	Jordan	Kazakhstan	China	Lebanon	Saudi Arabia	USA	Tajikistan	Turkmenistan	Uzbekistan	Ukraine	Germany	South Ossetia
Poultry meat							+		+					+		
Wheat	+	+		+												
Sunflower oil		+		+	+											
Wheat flour		+										+				+
Corn	+											+				+
Sugar-free water			+			+								+		
Pasta		+		+								+				
Barley	+	+				+										
Meat products											+		+	+		
Animal feed		+		+				+								
Cake	+															+
Soybeans	+															

(*continued*)

Table 3. (*continued*)

Product Type	Azerbaijan	Armenia	Belarus	Georgia	Jordan	Kazakhstan	China	Lebanon	Saudi Arabia	USA	Tajikistan	Turkmenistan	Uzbekistan	Ukraine	Germany	South Ossetia
Water with sugar	+					+								+		
Flour confectionery products	+			+		+										
Margarine		+				+								+		
Grain sorghum			+													
Cereal		+		+		+										
Flax seeds							+								+	
Fruits, nuts		+	+							+						

region's exports) is currently Transcaucasia and the Middle East, while trade contacts with European countries are decreasing (the share of exports to unfriendly countries has decreased to 0.6%).

Azerbaijan, Saudi Arabia, China, Georgia, the United Arab Emirates, Armenia, Iraq can be named among the leading importers of agricultural products of the Stavropol Territory in terms of its volume, as well as Kazakhstan in terms of diversification. At the same time, other countries with which trade contacts have been established in the region could potentially become them: Belarus, Turkey, Egypt, India and other promising foreign economic partners from the regions of North Africa, Central and South Asia.

The annual increase in the average export price of regional agricultural products turned out to be $ 63.7 per ton. Nevertheless, the average export price of agricultural products of the Stavropol Territory in 2022 amounted to $ 536.9 per ton, while in the Russian Federation it was $ 577.1, which characterizes the region's goods as generally competitive.

4 Discussion

The study of domestic scientific publications of the last four years indicates a certain interest of Russian scientists in the issues brought to life by the adoption of the Russian projects "International Cooperation and Export" and "Export of agricultural products". Almost all the authors of articles in indexed scientific journals (M.V. Azzheurova, A.V. Alpatov, A.N. Osipov, A.N. Stavtsev, A.V. Kolesnikov, O.I. Karpova, K.A. Surovneva, I.V. Vasilyeva, A.P. Lyubimov, A.K. Markov, E.E. Mozhaev, A.S. Truba, V.V. Maslova, N.M. Svetlov, A.L. Sevostyanov, A.T. Stadnik, S.A. Shelkovnikov, K.V. Chepeleva, V.S. Chekalin, S.A. Shilovskaya and others) agree on the leading role of comprehensive support for agriculture (in particular, the export of its products) from the state.

In addition, the researchers point out the importance of an integrated and scientific approach to the development and implementation of programs and projects of this level, while taking into account forecast, market, budgetary, financial, logistical, organizational and a number of other factors. In this process, economic and statistical models, methods of multicriteria, functional and cost analysis and other mathematical methods of quantitative analysis should be used to a greater extent.

At the same time, very few authors explore and popularize the experience of individual regions of the Russian Federation – the Altai (A.V. Minenko, M.V. Seliverstov) and Krasnoyarsk (N.A. Dalisova, O.V. Zinina) territories, the Ural region (D.R. Krichker, O.A. Ruschitskaya), the Southern Federal District (V.N. Batova, I.V. Mitrofanova, E.A. Shkarupa). Nevertheless, this direction seems, as it has been shown, scientifically meaningful and practically promising for its further careful study.

5 Conclusion

Today, there are hundreds of targeted projects and programs at the federal, regional and municipal levels in the agro-industrial sector of Russia, in connection with which their mutual coordination becomes a new important state task. An example of such interaction is the experience of the Stavropol Territory, in the field of public administration of the agro-industrial complex, one of the main places is occupied by the regional Ministry of Agriculture. Therefore, after the adoption of the national project for the development of exports of agricultural products, it was this ministry that was entrusted with the tasks of first developing its "regional version", and then overseeing and administering its implementation.

Currently, the Stavropol Territory is an example of a successful solution of food problems at the regional level of a country that is large in territory and diverse in natural, climatic and socio-economic composition [16, 17]. Not being an absolute leader in any of the indicators of the development of the agro-industrial complex of the Russian Federation, the region not only fully provides its own population with food, but also has a positive export-import agricultural balance.

The steady growth of the main indicators of the state and development of the agro-industrial complex of the Stavropol Territory, including those related to its export component, testifies to the successful experience of the contribution of the agrarian region to the implementation of the state project to support and develop the export of agricultural products. This experience deserves further study and implementation in the development practice of other regions of the Russian Federation.

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Cutting-Edge Practices in the Management of the Resource Potential of Rural Areas

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Abstract. Sustainable development of rural areas is unattainable without the effective management of their resource potential, highlighting the significance of this research. It is argued that the resource potential of rural localities arises within a specific territory to which it is inherent, allowing the population living in rural settlements to engage in economic activities while considering cultural traditions, customs, and established living conditions. The objective of the study is to uncover advanced practices in managing the resource potential of rural areas from other countries that can be adapted to the Russian context without major transformations. The research utilized methods such as monograph study, logical analysis, synthesis, analogy, monitoring, comparison, and content analysis. The novelty of this work lies in the development of a methodology for selecting countries whose leading management practices of resource potential can be "imported" into the Russian management practices of rural areas. Additionally, it presents a pioneering study on the formation and effective use of the resource potential of rural areas in 20 countries. An increased interest among the rural population in preserving their cultural and religious traditions has been identified, facilitating the creation of "growth points" for rural areas that can attract both traditional and non-traditional development resources. It is demonstrated that high outcomes from utilizing the resource potential of rural areas are achievable through a strategic approach to its development and use. It has been determined that the practices are fairly open, with the community actively involved in shaping and developing these practices. The study reveals that the primary initiators of these practices are the rural population or business community representatives.

Keywords: resource potential · rural territories · rural tourism · cultural heritage · rural infrastructure · agrarian business

1 Introduction

One of the pivotal strategies for rural area development is the management of their resource potential. An effective combination of resources possessed by rural localities enables not only the advancement of rural areas but also supports the food security of the country. The government plays a key role in managing the resource potential of the countryside by providing support to agriculture and stimulating the introduction of innovations, and cutting-edge management approaches in the country's agrarian sector economy.

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Analysis of literature related to this research topic indicates that the majority of authors define resource potential as a pool of a territory's resources combined with the opportunities it possesses, which can be utilized for its development and achieving socio-economic effects. Notable contributions to the discourse on resource potential include works by Zelechenkova E.V. [2], Misko K.M. [3, 1–94], Komarov M.A. [4, 1–567], Golovochanskaya E.E. [7, 151–155], as well as the Great Soviet Encyclopedia [1].

The review of foreign scientific publications on the research theme has identified several approaches related to the issues of managing the resource potential of rural areas.

Among these, there is a significant focus on utilizing traditional resources such as human, natural, socio-infrastructure, and the productive capacity of agricultural organizations. Most studies on traditional rural resources employ various survey types, enabling the collection of authentic information from key stakeholders like rural inhabitants and state authorities at different levels.

Some highlighted research includes Rashid M. and Pandit D.'s study on wastewater management in rural India [11, 489–500]. This study determined the level of infrastructure services provision from the perspective of local communities using a selection of twelve attributes, which make the evaluation possible. The framework for evaluating infrastructure service quality developed in this study will help government authorities determine the level of infrastructure services provision in rural settings.

In their article, Oguzie J.O.C. and colleagues, examined the impact of stakeholder management on rural road construction projects [10, 439–443], identifying a correlation between the failure and abandonment of road construction projects and stakeholder management. The study underscores the importance of accurately identifying project stakeholders as critical to the success of rural road construction initiatives.

The scientific research led by Adil A. delves into stakeholder involvement in the development of organic farming in Bogor (West Java) [5, 16706]. The authors identified key players interested in the development of organic farming and maintaining food security. The study provided insights that promote understanding the role of stakeholders in managing organic farming and their contribution to formulation an organic farming development strategy.

This review of scientific works dedicated to the use of traditional resources of rural territories in other countries concludes that traditional resources are utilized based on he country's development, the level of government governance, and the interest of different stakeholder groups in utilizing and developing resource potential. It is observed that the poorer the country, the more issues related to effective management of resource potential, directly linked to investments in its development.

The analysis extends to non-traditional resources of rural territories, such as cultural-historical, entrepreneurial, and informational-legal resources.

Del Espino Hidalgo B. and others studied how the cultural heritage of two rural areas in Andalusia (Spain) – Western Andevalo and Sierra de Aracena, could be used for their sustainable development [6, 11375]. They found that the renown of cultural heritage to a wide audience directly impacts the territory's sustainable development, necessitating the development and implementation of tools for measuring the assets and heritage elements of the village. His approach aims to support decision-making processes related to territorial heritage.

A study led by Rosalina P.D. explores resource management strategies in two Balinese villages (Indonesia), noting the significant role of rural tourism in the effective use of resources [12, 101194]. It was found that community traditions play an important role in maintaining local control over resources, allowing not only for the preservation of resources but also their effective use, including existing infrastructure and the workforce.

Ma Y. and Lyu C. [8] utilized big data to conduct a cluster analysis of folklore sports tourism resources in the city of Lanzhou, identifying key tourist target groups, their travel behavior, and the possible level of financial expenditures they can afford when participating in sports tourism events, suggesting the development of a strategy to attract them to Lanzhou.

The research conducted by a team led by Nurliani Rosada aims to delineate the entrepreneurial characteristics and agribusiness behaviors of young Indonesian farmers, analyzing the connection between these characteristics and agribusiness behavior [9, 942–951]. The study reveals that young farmers are inclined toward adopting new business tools, are responsive to customer needs, and are more adept at participating in new ventures, showcasing creativity and innovation. The entrepreneurial traits and behaviors of young farmers in agribusiness are closely linked to the role of institutions that foster and support agribusiness development in the country. This connection could potentially shift the current situation, sparking increased interest among the youth in coffee plantation work.

This review of scientific literature on the use of non-traditional resources in rural territories abroad concludes that there are common trends in their conservation and development. These trends facilitate the replication of best practices not only within individual countries but also internationally.

It is noted that the primary aim of the discussed studies was not to uncover best practices for managing the resource potential of rural territories or to perform a comparative analysis to identify developmental patterns. Generally, the publications are descriptive, focusing on identifying causal relationships between developmental challenges in rural areas and solutions for overcoming these challenges. There's a recognized need for research on the specificities of forming and effectively utilizing the resource potential of rural territories, highlighting the timeliness and relevance of this study's theme.

The current research's goal is to uncover leading international practices in managing the resource potential of rural territories, which could be adapted for use in managing rural localities domestically.

The research tasks involve:

- Establishing criteria for selecting the best international practices in rural territory resource potential management;
- Identifying countries for best practice selection;
- Collecting and organizing information on the leading practices of international experience.

The study focuses on rural territories across various countries, examining the trends and patterns that emerge in managing their resource potential.

2 Materials and Methods

The rationale behind our study is based on the observation that not all practices positively impacting rural development and actively employed abroad are applicable to the Russian Federation. This led to the necessity of establishing criteria to identify practices that can be most seamlessly incorporated into the domestic rural development system. We justify the choice of criteria for grouping countries based on the following logic.

The first criterion selected was the prioritization of rural development by government bodies in various countries. It has been noted that in some countries, this task is not among the fundamental state function priorities, Countries not considering comprehensive rural development as one of their basic priorities have been categorized into the "red zone".

Countries that identify comprehensive rural development as a core priority, but whose experiences are considered non-transferable to Russia due to significant differences in natural, geographical, climatic, economic, and political factors, are classified in the "yellow zone". Conversely, the "green zone" comprises countries whose successful rural development practices are viewed as applicable within the Russian context, amounting to 34 countries.

Due to the article's space constraints, the authors presented fragments of tables for state zoning according to the research criteria. A fragment of the zoning table based on the first criterion is shown in Table 1.

Table 1. Preliminary Zoning of Countries Based on the Criterion of Implementing Rural Development Practices (Table Fragment)

Red zone	Yellow zone	Green zone
People's Democratic Republic of Algeria, Commonwealth of the Bahamas, People's Republic of Bangladesh, Barbados, Kingdom of Bahrain, Belize, Plurinational State of Bolivia, State of Brunei Darussalam, Burkina Faso, Republic of Burundi, Kingdom of Bhutan, Republic of Vanuatu	Republic of Austria, Republic of Azerbaijan, Republic of Albania, Republic of Armenia, Islamic Emirate of Afghanistan, Kingdom of Belgium, Republic of Benin, Bosnia and Herzegovina, Republic of Botswana, Hungary, Bolivarian Republic of Venezuela, Democratic Republic of East Timor, Republic of Guinea	Republic of Belarus, Republic of Bulgaria, Federative Republic of Brazil, United Kingdom of Great Britain and Northern Ireland, Socialist Republic of Vietnam, Federal Republic of Germany, Hellenic Republic, Kingdom of Denmark, Republic of India, Argentine Republic, Republic of Indonesia,

The share of the rural population was chosen as the pivotal criterion for categorizing countries into a high-interest category for evaluating positive rural development experience. Since this indicator stands at 25.1% in Russia, it is reasonable to set a range of 10–45% as the rural population share for creating a sample of states. After a comparative analysis at this research stage, 24 countries were identified for further exploration of best practices. A fragment of the zoning table according to the second criterion is presented in Table 2.

To set the final sample composition, it is prudent to examine the corresponding countries according to two criteria:

Table 2. Zoning of Countries by the Criterion of Rural Population Share (Fragment)

The share of the rural population of Russia is 25.05%		
Country	Rural population share	Compliance with interval 10–45%
Argentína	8,2	-
Belarus	22,7	+
Bulgaria	27,5	+
Brazil	15,0	+
Great Britain	18,0	+
Vietnam	66,4	-

1. The contribution of agriculture to GDP, which signals the country's orientation towards agricultural production and, consequently, rural development). In Russia, the agricultural sector accounts for approximately 4.5% of GDP, thus countries with a higher value of this indicator can be included in the final sample.
2. The Food Production Index, reflecting the state's level of food security, which is a priority in the comprehensive development of rural areas. In Russia, this indicator is valued at 85.4 index points. Accordingly, countries with a relatively high Food Production Index, exceeding 80 index points, will be included in the final sample (Table 3).

Table 3. Zoning of Countries by Food Production Index (Fragment)

The food production index in Russia is 85.4 pp.		
Country	Food production index	Compliance with the interval
Belarus	87,9	+
Bulgaria	65,7	
Brazil	48,4	
Great Britain	90,2	+
Germany	92,1	+

Next, the final composition of the foreign state sample for evaluating the positive experience in comprehensive rural development was compiled (Table 4).

Consequently, the final sample comprises 20 countries that meet one or both final criteria, suggesting the feasibility of utilizing positive experiences in the comprehensive development of rural areas. The search for exemplary practices was limited to those nations matching one or both chosen criteria.

In identifying the best practices for potential adoption, the authors set specific selection criteria, focusing on the relevance, effectiveness, and replicability of the practices under consideration.

Throughout the research process, the authors employed content analysis for identifying and collecting best practices:

Table 4. Final sample of foreign countries in the framework for assessing positive experience in managing rural areas (table fragment)

№	Country	Final criterion 1	Final criterion 2	Compliance level
1	Belarus	+	+	++
2	Bulgaria	+	-	+
3	Brazil	+	-	+
4	Great Britain	-	+	+
5	Germany	-	+	+

1. Monitoring Internet resources of the 20 selected foreign countries that meet the criteria outlined above.
2. Analyzing lists of winners of various competitions related to rural development.
3. Reviewing reports on the implementation of practices published on Internet portals.

3 Results

In the course of their study, the authors identified 20 leading practices for managing the resource potential of rural territories in other countries through content analysis. These practices align with the success criteria set early in the study and are primarily applicable to the development of Russia's rural resource potential. Due to article length constraints, only 10 of these leading practices will be detailed in Table 5 (Table 6).

Table 5. Advanced Practices in Managing the Resource Potential of Rural Territories

Name	Brief description
Open-Air Museum "Bimisha Museum" (England)	The project is focused on enhancing the cultural-historical direction of rural tourism
"Book Town" Hay-on-Wye (England)	Attractive tourist and festival center (with a year-round tourist season, peaking during the book festival days, and an operational tourist information office)
Rheingau Wine Museum (Germany)	A comprehensive multimedia center featuring a tasting area, auditoriums for workshops and themed evenings, as well as an space for temporary exhibitions
Cizhuan Village (China)	Organization of wine festivals and events within the framework of event tourism, utilizing ethnic flair

(*continued*)

Table 5. (*continued*)

Name	Brief description
Mykonos-Vioma Organic Farm (Greece)	The application of organic farming methods is complemented by the preservation of traditional land use practices, traditions, and customs associated with cultivating the island's healthy grapes
Pottery Village (Poland)	A thematic settlement that preserves local craft traditions through organized master classes and fairs
Xuanluo Ethnic Village (China)	Preservation of the traditions and customs of the Red Yao ethnic group through ethnic festivals and event tourism activities
Belovezh Villag (Poland)	Conservation of folk song traditions, cuisine, and crafts through eco-tourism
"Nachalo" Eco-Estate (Bulgaria)	Development of eco-tourism with a focus on eco-friendly land management practices of the estate
Folkestone Triennia (England)	An art venue that showcases artworks as a factor in enhancing the attractiveness of rural tourism

The analysis highlighted a predominant focus on non-traditional resources, such as cultural-historical and entrepreneurial assets, while not excluding traditional resources like socio-infrastructural, material-technical, and human resources. A distinctive feature of these practices is the active utilization of digital tools for promotion and the involvement of the wider community in their implementation, making these initiatives more accessible to both the local population and tourists.

The research found that all leading practices contribute to rural territory development, focus on creating employment opportunities with cultural or tourism orientations, increase tourist flows, and help preserve traditions and customs of ethnic groups living in rural areas.

Most of the examined leading practices adopt a strategic approach to leveraging the economic potential of rural territories. This approach is linked to the focus on utilizing non-traditional resources and preserving the traditions and customs of local ethnic groups. Practices oriented towards production activities conducted in rural areas are focused on achieving effective outcomes (Table 7).

Regarding the government funding of leading practices for managing resource potential, it's noteworthy that only 4 practices receive 100% financing (Ethnic Village Xuanluo, Cizhuan Village, Mykonos-Vioma Organic Farm, Rheingau Wine Museum). A minimal government funding contribution (15%) was noted for the Open Air Museum "Bimisha", with two practices receiving support in the form of land resources – Belovezh Village and the Pottery Village. The research results highlight a trend where financial support for non-traditional resources is primarily observed in China and Greece, while out of three

Table 6. Resources used in implementing best practices

Name	Mechanism for attracting the audience	Type
Open-Air Museum "Bimisha Museum"	Utilization of media partnerships and internet resources to implement practical engagement strategies.	Non-traditional
"Book Town" Hay-on-Wye	Hosting of festivals, leveraging social networks, and internet resources for promotional activities.	Non-traditional
Rheingau Wine Museum	Coordination of themed festivals and events as part of community tourism, employing internet resources for outreach.	Non-traditional
Cizhuan Village	Coordination of themed festivals and events as part of community tourism, employing internet resources for outreach.	Non-traditional
Mykonos-Vioma Organic Farm	Organization of themed festivals, events within the framework of community tourism, using Internet resources for promotion	Traditional
Pottery Village	Updating the news section on the official website, application of media partners, and use of Internet resources	Non-traditional
Xuanluo Ethnic Village	Conducting open festivals and their mass coverage, updating the news section on the official website, use of Internet resources	Non-traditional
Belovezh Villag	Organization of events in the framework of eco-tourism, application of media partners, use of Internet resources for promotion	Non-traditional
"Nachalo" Eco-Estate	Operation of a video blog, collaboration with local government authorities, and hosting of agricultural product tastings.	Traditional
Folkestone Triennia	Engagement of media partners and utilization of social networks and internet resources for promotion.	Non-traditional

Table 7. Approaches to Utilizing the Economic Potential in the Implementation of Advanced Practices

Name	Approach
Open-Air Museum "Bimisha Museum"	Strategic
"Book Town" Hay-on-Wye	Strategic
Rheingau Wine Museum	Strategic
Cizhuan Village	Strategic
Mykonos-Vioma Organic Farm	Result-oriented
Pottery Village	Strategic
Xuanluo Ethnic Village	Strategic
Belovezh Villag	Strategic
"Nachalo" Eco-Estate	Result-oriented
Folkestone Triennia	Strategic

English practices, only one received government financial support. Polish authorities, on the other hand, offer support for practices aimed at preserving cultural heritage through the provision of land plots.

4 Discussion

Comparing the outcomes of our study, we note that the data obtained align with the findings of foreign research focused on the utilization of non-traditional resources within rural territories. A direct comparison of the use of traditional resources within the identified leading practices was not feasible due to the limited information acquired during our investigation.

A noteworthy aspect is the increasing interest among rural populations in preserving their cultural and religious traditions. This interest facilitates the development of the ethno-economy of countries. The preservation of cultural heritage enhances the attractiveness of rural areas for various types of tourism, while the application of informational and legal resources not only aids to preserve the non-traditional resources of villages but also enhances their appeal through digital tools.

Furthermore, the preservation and development of non-traditional resources in rural areas contribute to the advancement of traditional resources. is suggests that the resource potential of rural areas should be cultivated through a strategic approach, encompassing a broader perspective than merely resource-based or outcome-focused methodologies.

5 Conclusion

The research identified leading practices in international experience of managing the resource potential of rural territories that meet the criteria of relevance, effectiveness, and replicability. This allowed for a comparative analysis, identifying of common patterns in the development of leading practices. These findings suggest that such practices could be integrated into Russia's rural management system, fulfilling the research objectives and tasks.

The practical significance of the study lies in the potential for transferring the advanced experience of managing the resource potential of rural territories, proven effective in other countries, to the Russian context of rural management. Going forward, the authors plan to further explore the specifics of managing the resource potential of rural territories in the Russian Federation using both quantitative and qualitative research methods.

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Digital Eco-Schemes as an Element of the Russian Agro-Industrial Complex Ecosystem

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Abstract. The article provides a retrospective analysis of the development of the theory of ecosystem sustainability in agriculture from simple ecosystems to digital ones. Modern digital ecosystems are used to the maximum to provide financial, logistical, marketing and other types of services to agricultural producers. At the same time, ecosystems do not provide such an element as the restoration of biological resources. It is proposed to form a state ecosystem consisting of small ecosystems of producers and supplement it with digitaleco-schemesthat allow theongoing restoration of biological resources used in small ecosystems for production.

Keywords: ecosystem · eco-scheme · agricultural ecosystem · ecosystem services · digital eco-scheme

1 Introduction

Agriculture represents the largest artificially created ecosystem of humanity, the role of which is difficult to overestimate. In recent years, researchers have noted the strengthening of relationsbetween agriculture and the rest of the economy, which have transformed into the creation of agricultural ecosystems or socio-ecological systems [1]. The modern understanding of the agricultural ecosystem [2, 3] includes a set of services to provide a market for manufactured products, as well as a number of related, non-market ecosystem services, such as regulation of water and climate systems, aesthetic and cultural services, as well as extended supporting services (for example, maintaining soil fertility). A great problem of such systems functioning is their stability and its assessment. Back in 2002, JohnM. Antleand SusanM. Capalbo [4] noted the need to analyze agriculture as a managed ecosystem, and move away from agricultural management policy based on taking into account the interests of individual groups to a science-based policy that recognizes the trade-offs associated with competing use of natural resources.

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Holling C. and Gunderson L., and later Folke C. [5–7] formulated the main ways to assess the sustainability of agricultural systems:

1. The degree of changes that the system may undergo while maintaining the same control over functions and structure;
2. The degree of the system's ability to self-organize;
3. The ability to create and develop the capacity to learn and adapt.

Berkes F. determines that sustainability assessment should be based on the identification of vulnerabilities in such systems in order to increase their sustainability in future [8]. Cabell J. and Oelofse M. for their part believe that agricultural systems are too complex to be measured in any precise way, and therefore it is better for them to develop empirical rules for sustainability, which are applicable on time and space scales [9]. Thayer, A., Vargas, A. and others note the interdependence of the social and ecological components of socio-ecological systems from each other, and Soulé E., Charbonnier R., Schlosser L., Michonneau P., Michel N., Bockstaller C. mark the need to achieve balancing ofinterests between social and environmental objectives [10, 11]. Hodbod J. and Eakin H. consider that agricultural ecosystems ensure the sustainability of agricultural landscapes by providing ecosystem services that humans need. At the same time, to increase sustainability, it is necessary to shift priorities from maximizing profits towards the reasonable use of ecosystem resources [12]. Taghikhah F, Borevitz J., Costanza R., Voinov A. while developing optimal ecosystem models believed that the results of interaction between the social and environmental components often depend on the goals of ecosystem management [13].

Modern ecosystems have a wide range of services and a sufficiently high level of sustainability, and with the introduction of digitalization, they also have an increasing ability to learn and improve themselves.

2 Materials and Methods

As noted above, socio-ecological systems are dynamic and often, as a consequenceof management errors, ecosystems aimed at commercial results cause irreparable harm to the ecology [14]. Researchers see the further development of agro ecosystems in network structures that will contribute not only to the development of the service sector, but also try to minimize the harm caused by the ecosystem [15]. According to P. Tixier, N. Peyrard, J.N. Aubertot, S. Gaba, J. Radoszycki, G. Caron-Lormier, F. Vinatier, G. Mollot and R. Sabbadin the task of agro ecologists, in perspective, will be to create models of network interaction between the natural environment and ecosystem services that will be sufficiently quantified and verified. Combining food network models with other types of models, such as crop models, decision-making and spatial models, will eventually result in a synergistic effect from the interaction of all elements. However, despite the proclamation of the need to develop mechanisms for balancing social and environmental interests, at present there is little research in this direction. In recent years, the European Union has attempted to develop ecological schemes that maximize the consideration of environmental interests in the exploitation of ecosystems, but these eco-schemes are aimed at maximum use within the EU. In addition, the system is based on remuneration payments for the use of eco-schemes. Undoubtedly, this is a big step forward in solving the problems of environmentally friendly agricultural production, but other regions of the planet need ecological programs as well. Nevertheless, the EU experience cannot always be used in other regions due to the impossibility of manufacturers to finance the use of eco-schemes. This limits the experience of using this option, including Russia, where the state cannot allocate additional funds to solve the problems of the ecosystems used.

The first ecosystems in agriculture looked like this (Fig. 1).

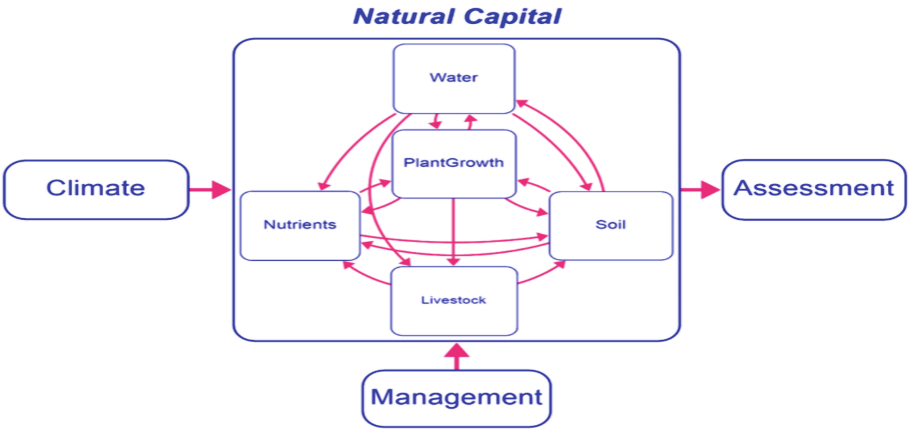

Fig. 1. Schematic representation of an ecosystem [16]

Wang X., Liu W., Wu W. proposed a theoretical basis of the agro ecosystemhealth model using four aspectsthat include: solid structure, stable functioning, safe maintenance and sustainable development [14]. The holistic approach proposed by the researchers made it possible to develop a simple and transparent system for assessing problems affecting the sustainable development of the ecosystem. To assess the state of the ecosystem, the authors suggest use of response indicators:

– annual change in land productivity;
– soil fertilitylevel;
– commodity ratio of agricultural products;
– cost-benefit ratio, etc.

With the development of digital technologies, ecosystems have been modernized into digital platforms that enable a whole range of activities for the production, processing, movement and sale of agricultural products. For example, Martins J., Gonçalves C., Silva J., Gonçalves R. and Branco F. proposed four blocks for ecosystems:

– smart environment (ensuring the preservation of resources);
– smart government (aimed at flexible solution of all ecosystem problems);
– smart economy (to promote innovative development);
– smart citizens (actively participating in all processes).

The proposed model, despite the high level of environmental friendliness of production, does not consider the issue of restoration of resources lost in the process of using, such as soil fertility restoration or water balance. It is assumed that eco-friendly water, energy and soil should be used as much as possible in the ecosystem, but the process of their restoration is not provided [17] (Fig. 2).

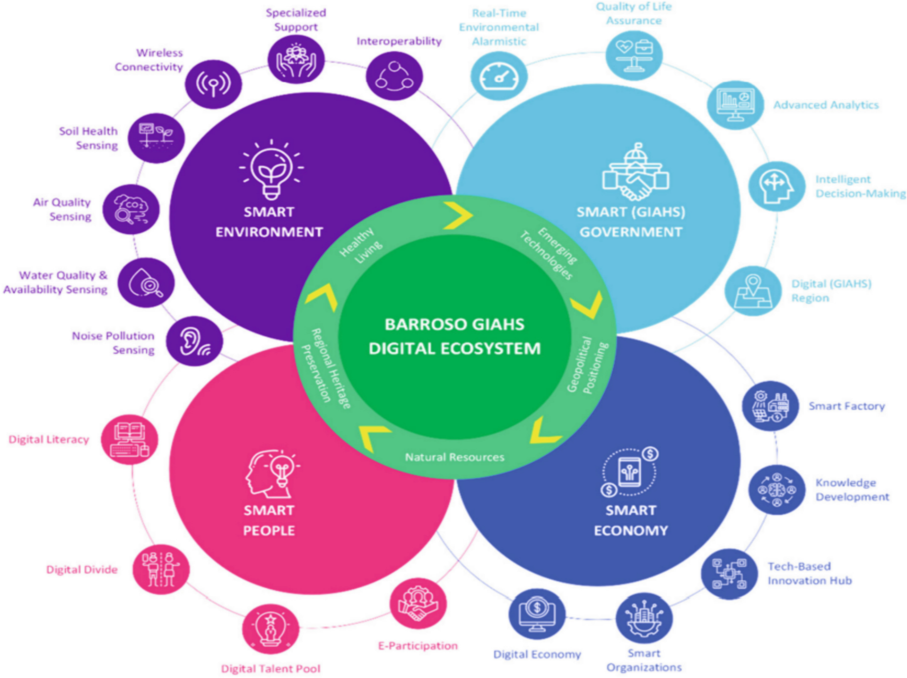

Fig. 2. Digital ecosystem [17]

However, the proposed digital model still lacks a block responsible for the restoration of bioresourcesused. In our opinion, the use of the experience of European countries on payment basis for environmentally friendly actions directly to participants of agricultural production is not always implemented in other regions. The solution may be the creation of a monitoring center and eco-schemes at the level of state structures that allow the restoration of natural resources with the help of statefinancing, without paying farmers for the use of environmentally friendly agricultural methods.

3 Results

Over the last decade, Russia has been working on the development of ecosystems in agriculture. In accordance with the Decree of the President of the Russian Federation dated May 9, 2017 N 203 "On the Strategy for the Development of the Information Society in the Russian Federation for 2017–2030," the ecosystem of the digital economy is understood as a partnership of organizations engaged in continuous interaction of their own:

- technological platforms;
- applied Internet services;
- analytical systems;
- information systems of government bodies of the Russian Federation, organizations and citizens.

In Russia, as well as throughout the world, such systems have already been developed, in particular, digital platforms are functioning in agriculture:

1. Digital technologies in agro-industrial complex management.
2. “Smart” field.
3. “Smart” greenhouse.
4. “Smart” land use.
5. “Smart” garden.
6. “Smart” farm.

Having analyzed the results achieved in the field of formation of ecosystem elements in agriculture, we believe that itis correct to include mandatorya regeneration block, which makes it possible to restore natural resources that were damaged during the exploitation of the ecosystem (Fig. 3).

Considering the importance of solving environmental problems in any state, a general ecological system of the state should be formed, which should consist of small ecosystems. The main elements of the state digital ecosystem in its modern understanding should include elements that ensure the manufacture of products, the search for sellers and buyers, financial infrastructure, logistics, the monitoring and restoration of ecosystem resources.

Yes, definitely, the ecosystem itself implies a careful attitude to resources and the use of environmentally friendly management methods, and, nevertheless, harm to resources often cannot be excluded. To restore natural resources, such as soils for agricultural work or animal grazing, water, it is necessary to develop unified eco-schemes. To organize the work, it is advisable to entrust such work to the environmental monitoring center, which should be an independent organization interacting with the Ministry of Agriculture and the entire digital ecosystem of the country’s agriculture.

At the initial stage, it is necessary to structure all existing territories of the country into groups, as well as according to existing environmental problems. To do this, it is necessary to carry out work in several stages (Fig. 4).

At the first stage, it is necessary to carry out an inventory of all existing small agricultural ecosystems of the country. Such ecosystems include grazings, farms, crop and livestock farms, etc. The assessment of the objects ecological state allows us to obtain information about the state of small ecosystems. The assessment of potential threats will help us understand how urgently it is necessary to carry out recreational activities in the ecosystem. At the second stage, it is necessary to develop criteria for assessing the ecological state of small ecosystems. At the third stage possible potential threats should be identifiedthat may arise as a resultof intensive use of ecosystems.

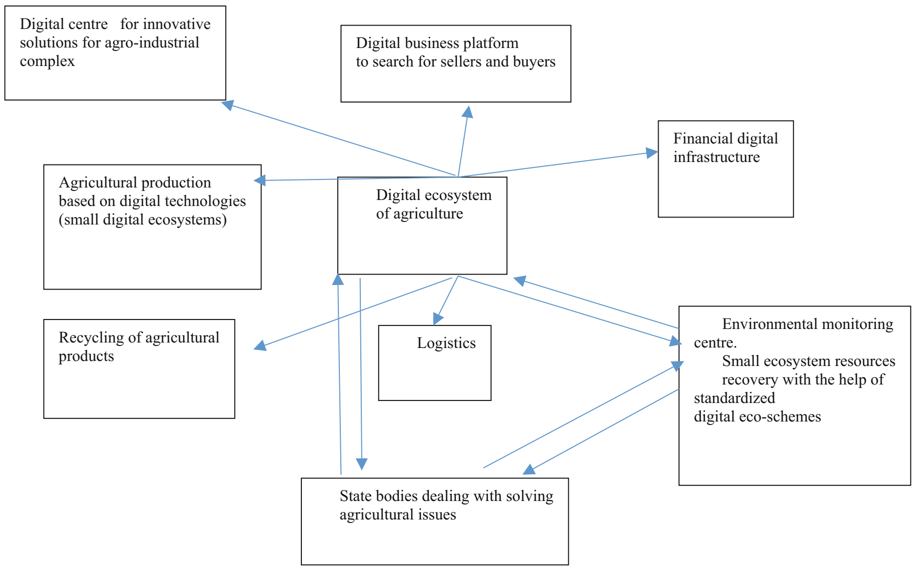

Fig. 3. Model of the digital state ecosystem of agriculture

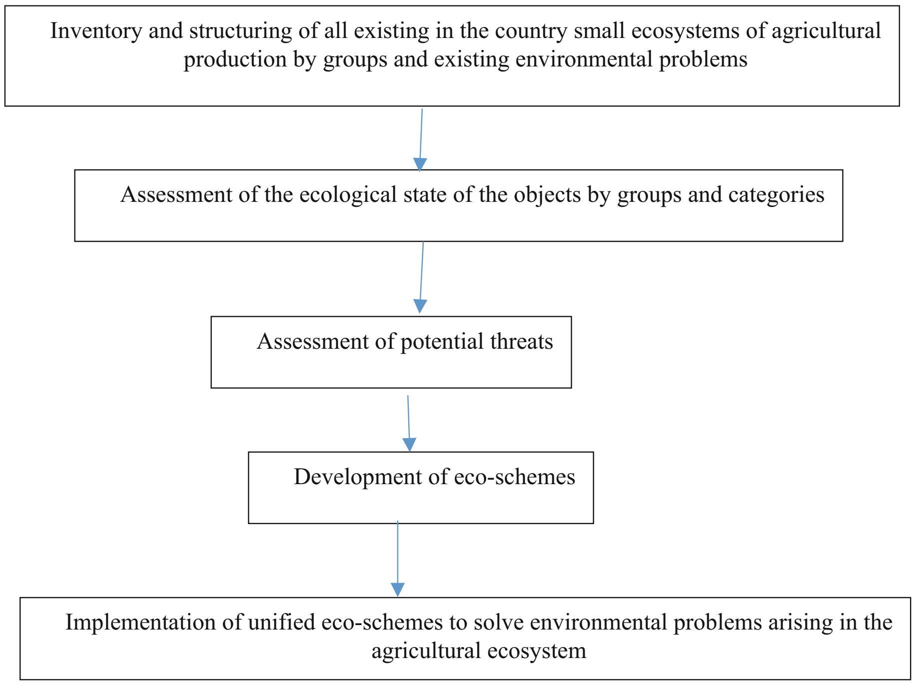

Fig. 4. Algorithm of eco-schemes developing within the state

At the fourth stage, it is necessary to develop eco-schemes for the restoration of ecosystem resources. This is the most important stage, since eco-schemes must provide performers with all the necessary information on the activities that should be carried out to restore the ecosystem. There is no need to develop a large number of eco-schemes. They should be unified and easy to implement, as only in this case we can talk about the success of their implementation without additional government funding which is not always possible to provide in developing countries and countries with emerging economies.

Eco-schemes should be developed for recreational activities to restore small ecosystems of agricultural production. The algorithm ofeco-schemes use (Fig. 5) provides for determining the amount of damage and making a decision on the feasibility of further operation or the need for recreational activities.

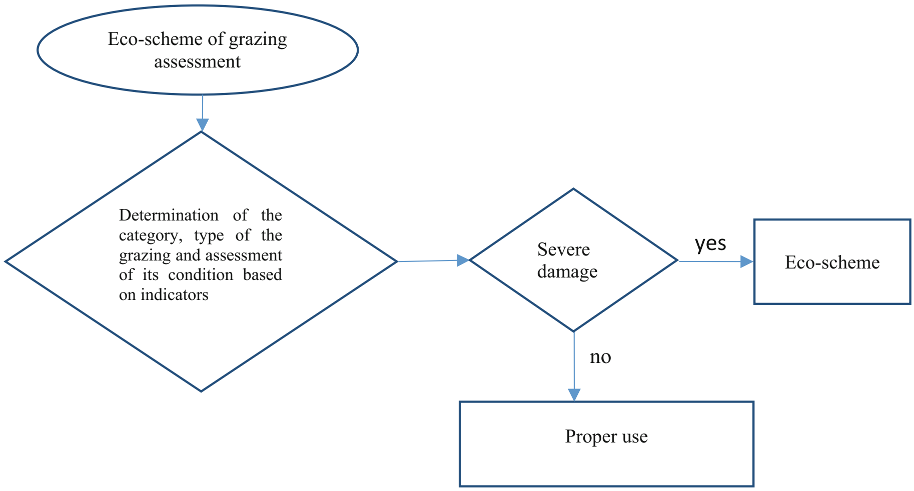

Fig. 5. Algorithm of eco-schemes use

Eco-schemes can be developed for the restoration of arable land, grazing land, the production of permanent crops, the development of livestock farming, etc. Their number should not be too large, and the restoration methods used should be as low-cost and environmentally friendly as possible.

4 Discussion

Solving environmental problems today is a major task not only for states, but also for agricultural and industrial enterprises. Moreover, if in developed countries the problem is solved not only at the state level, but is also recognized by all participants in production, then in developing countries and countries with transition economies this problem is often recognized only at the state level. The development of simple and understandable eco-schemes in the future can be an incentive for farmers in developing countries and countries with economies in transition to pay more attention to bioresources that allow them to manufacture products and make a profit. An important issue is the method of stimulating farmers to use eco-schemes. In the EU, the flagship of the use of eco-schemes, countries have taken different paths while choosing incentive options. The Netherlands uses a combined scoring system that allows mixing of eco-schemes, in Hungary it is necessary to comply fullywith the recommended eco-scheme, and in France it is required to choose between three main groups of eco-schemes [18].

It is advisable to start using eco-schemes in developing countries in such areas as the restoration of arable land and grazings, since their implementation in this case is less costly. Accordingly, farmers can start using eco-schemes without spending large amounts of money, and it is easier for states to organize monitoring of their use, analyzing the results and further disseminating this technology.

Digitalization makes its own adjustments to the development of bioresource restoration technologies, and in the future, the use of digital eco-schemes can reach a new level and will not only help restore bioresources, but also prevent the emergence of problems.

5 Conclusion

Thus, the development and implementation of eco-schemes as an element of conservation and restoration of ecosystem biodiversity is another mechanism aimed at solving environmental problems. Undoubtedly, the availability of government funding greatly facilitates the implementation of eco-schemes, but even in countries that do not have significant financing opportunities for solving environmental problems, the use of unified eco-schemes that do not require large financial costs for their implementation will improve the environmental situation in agriculture.

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Training of New-Format Specialists for the Agro-Industrial Complex as a Determinant of Sustainable Rural Development

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Abstract. The article analyses the functioning and principles of the agro-industrial complex (AIC). It conducts an economic and human characteristics analysis of different countries. It outlines the specifics of Russia and suggests ways to effectively develop and operate the entire agricultural sector. The development of new technologies must be accompanied by specialist training and retraining, as well as the creation of comprehensive infrastructure in rural areas, to generate new jobs in the agro-industrial sector. This requires the preparation of workers with new competencies and modern knowledge. Furthermore, it highlights the significance of all rural workers, particularly responsible landowners who prioritise environmental care and consider the future of their land for future generations.

Keywords: AIC · agricultural production · training of specialists · innovative technologies

1 Introduction

Education is currently the primary factor for the progressive development of Russian society. Therefore, it is necessary to address not only issues related to economic growth and improving people's well-being but also matters of morality and the moral character of citizens. The spiritual component directly influences overall economic growth. For centuries, philosophers, thinkers, and politicians have pondered over the question of what determines the prosperity of some countries and the poverty of others, regardless of natural and climatic conditions and resources. In other words, why are some countries poor while others are rich? Centuries of global experience demonstrate that the development of an economy and the prosperity of a state can be influenced by factors beyond natural resources and population size. Developed countries such as Japan and Switzerland prove this point, as they have achieved high levels of economic development despite lacking significant natural or human resources. Russia, the USA, Japan, and Germany are among the most populous countries in the world. It is worth noting that Russia is the third most populous country after China and India. Despite possessing vast natural resources, quality of life indicators in Russia remain relatively low compared to other countries. However, there are signs of improvement [13].

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2 Informal Statement of the Problem

The problem formulation is relevant and timely. The modernization processes in the Russian economy require a shift towards the reformatting of the sphere into information technology (IT). This transition is linked to the rearmament of the material-technical base of agricultural production and the preparation of agriculture specialists who can work in new conditions, utilize economic potential, and create competitive products. The dissolution of the socialist system in Russia resulted in the breakdown of both the political and economic systems of the state, as well as a decline in the reproduction of the workforce in both industry and agriculture. According to official data, industrial production volumes in Russia decreased by 2.2 times and in agriculture by 1.8 times between 1990 and 1998. These phenomena led to an outflow of skilled workers in engineering and agriculture. However, in the early 2000s, the growth of the Russian economy and increased demand for labor resulted in an increasing shortage of personnel. Numerous sociological studies conducted at that time demonstrate that during times of crisis, there is a reduction in staff, leading to a shortage of professionals and skilled workers, both in industry and agriculture. These processes occur during a 'demographic crisis,' characterized by a lack of workers in the middle and young age groups. According to forecasts by the Ministry of Education and Science, the shortage of skilled workers in engineering, metalworking, and the agricultural sector of the economy will persist until 2019, and this situation has not yet changed. Therefore, the main issue is the preparation of agricultural specialists through primary and secondary vocational education. Currently, the structure and quality of training for skilled workers and middle-level specialists do not meet modern employer requirements or correspond to the demands of the contemporary labor market. Currently, businesses collaborate with academic institutions and departments to train professionals in the fields of workforce, engineering-technical, and scientific personnel. They participate in developing projects and programs to enhance the efficiency of training future specialists in the agricultural sector of the economy. The development of agriculture requires the integration of science, education, and production, alongside the modernization of existing potential, facilities, and personnel. Skilled personnel preparation and analysis of issues related to the specifics of peasantry and agricultural relations in historical retrospect are directly linked to this [10].

3 Discussion

The preparation of agricultural personnel is crucial for ensuring national food security. This work aims to define the specifics of peasantry and agricultural relations, identify pathways for shaping the image and role of rural workers, and examine the infrastructure of rural territories within the country's macroeconomics. This paper aims to look into the historical context of this issue and to understand its peculiarities, which have been of interest to researchers for a long time.

Karl Marx believed that there cannot be a distinct peasant class and that it will inevitably disintegrate into rural bourgeoisie and proletariat [15]. Leon Trotsky referred to the peasant as a 'Janus in bast shoes' [2], while Konstantin Fedin considered peasantry to be 'as incomprehensible as a sea miracle' [3].

In Soviet history, the issue of peasantry was viewed solely from a class-based perspective, with a distinction made between the working class and the peasant class. However, there was no discussion about the specifics of peasantry. In contrast, Russian scientist A.V. Chayanov developed a theory suggesting that the peasant estate is stable, although distinct groups may emerge within it. Chayanov argued that differences in professional and personal qualities among people lead to natural differences in wealth, with some being poor, some middle-class, and some prosperous. He believed that traditions of agricultural thought from previous centuries, including domestic science, should be preserved and developed. However, his scientific approaches were not supported by Soviet ideologists [12, 14, 16].

During the Soviet period, scientific research in the field of agriculture also paid little attention to the peculiarities of the peasantry; from the 1930s onwards, all issues were resolved within the framework of the dominant Marxist ideology. From the 1930s onwards, all questions were resolved within the framework of the dominant Marxist ideology, without any consideration of the specificities of peasant life and agrarian relations. This is evident in the decisions made at the First All-Union Conference of Marxist Agrarians. The conference participants passed a resolution asserting that industry and agriculture should follow the same path [19].

During the following years in the USSR, the peasant's role as a subject of agrarian relations was downplayed, with only their immaturity being mentioned. The Soviet authorities focused on ensuring that living conditions in rural areas were on par with those in cities, aiming to eliminate the disparities between urban and rural areas. This led to the transformation of agricultural labor into a form of industry. However, some scientific works have focused on studying the specifics of peasantry as subjects of agrarian relations. In these studies, authors consider general economic laws. The main means of production in agriculture are land plots, and the technological process involves the use of factors such as plants and animals. Scientific studies on this topic emphasised the quality of land, its fertility and the influence of natural rhythms and climatic conditions on the whole agricultural process [8, 23].

Western scholars studying agricultural issues and agrarian sociology approach this question differently. In the West, the agrarian sector and agriculture are viewed as an informal economy with its own autonomy, influenced by the political-economic system dominant in a particular state. Simultaneously, this system can manipulate the environment [20–22].

In the Western world, Betriebslehre (translated as 'enterprise theory' in German) is a widely used theory that examines the organization of capitalist agricultural enterprises. This theory was presented in the works of German economists-agrarians T. Holtz, F. Ereb (Aereboe), F. Wasserstradt, and Swiss economist E. Laur in the early 20th century [11, 25]. A. V. Chayanov and other representatives of the organizational-production school introduced elements from a reworking of German authors' teachings. They concluded that peasant farming is non-capitalistic and based on personal labor [17, 18].

In his work 'Finance Capital', Rudolf Hilferding examines how financial capital penetrates the sphere of agricultural production and subjugates the peasantry in connection with the development of labor markets. According to Hilferding, this leads to the depopulation of villages and the formation of alliances with large landowners [5].

All the concepts discussed are related to the specificity of agricultural labour and agrarian relations. A crucial question in the sociology of the agrarian sphere is whether general economic laws manifest themselves extensively in agriculture or whether these laws possess their own content. The following aims to clarify this question.

In agricultural production, there are several characteristic groups of factors.

Firstly, the properties of agrobiocenoses play a crucial role. Agricultural systems are irreversible, although cyclical. Therefore, mistakes made at the initial stages of production will irreversibly impact the results, and they cannot be corrected.

Secondly, all these factors are tied to specific territories.

Thirdly, all living systems have numerous interconnections, both biological and physical, and not all of them are understood and known to humans. Therefore, in many cases, it may be difficult to make accurate predictions.

Peasant labour is stochastic and random in nature. This is why expressions and sayings such as "Perhaps it will pass…" or "Perhaps it will work out…" were introduced into the Russian language by Russian peasants.

Agricultural production is essential for human life and is inseparable from the reproduction of humanity, namely the family. In other words, agriculture is directly linked to the reproduction of human life. The agricultural process serves as both an economic and demographic factor. Working on the land and engaging in agricultural activities provide families with the means to live and raise children. Simultaneously, the family utilizes the labor of all its members to develop production, fostering the continuity of peasant generations. Alongside production development, family members receive education, upbringing, and initial professionalization.

Agricultural production is a complex field that involves economics, demography, culture, and ecology. It is crucial for farmers to maintain the fertility of the land on which crops are grown. Therefore, they must constantly consider the biogeocenoses, their productive qualities, and the preservation and improvement of the natural environment in rural areas. If the natural environment is not considered and there is no care for it, agricultural production in rural areas will not exist. The specifics of agriculture constitute a complex system that gives rise to essential principles concerning matters in the realm of agrarian policy. Ignoring many of these principles led to negative consequences observed during Soviet times, including a decline in agricultural production growth rates, rural depopulation, processes of spiritual degradation in rural areas resulting in the disappearance of many villages, settlements, hamlets, and even ecological disasters. It is important to note that economic laws only partially apply in the agricultural sector because a certain portion of the produced goods are not sold in the market but are instead used for personal consumption on-site. The results of A.V. Chayanov's research, based on years of observation, led him to the conclusion that peasant farms cannot, in principle, be run as capitalist enterprises. This is because a peasant working on their land, using their labour, cannot be considered an entrepreneur. The peasant operates within a subsistence economy, aiming not solely for maximum profit but rather for a reasonable balance between production and consumption. Additionally, their task involves evenly distributing the workload throughout the year [17]. The researcher further states: "The peasant family reduces its labour effort in proportion to the material results obtained and may agree to minimise these results while reducing the level of its consumption [18].

Agricultural activity has limitations in terms of supplying products to markets when compared to industry. As the national economy becomes more capitalised, changes occur in the agrarian sector. Individual peasants find it increasingly difficult to survive in harsh competitive conditions. Consequently, there is a trend towards the establishment of labour-based family farms that transition to the level of industrial agricultural production. These circumstances significantly influence both agricultural product prices and government subsidies in agriculture. Correspondingly, they also impact the entire infrastructure of rural settlements and the implementation of socio-demographic and environmental conservation programs.

The transformation processes taking place throughout all sectors of Russian society are linked to local self-government systems. The development of local self-government, based on citizens' participation, can help to overcome various crises and improve the social well-being of both rural workers and the entire population.

For effective sustainable development in rural areas across the regions of the Russian Federation, regional and municipal programs for the advancement of these rural territories are required. These programs should be based on strategies for the socio-economic development of rural settlements and the prospects for their socio-economic growth.

Municipal programs are expected to have a significant impact on achieving goals and accelerating the socio-economic development of municipal entities.

In the article 'Assessment of the Efficiency of Implementation of Regional and Municipal Programs', scientists analyze the implementation of regional and municipal targeted programs that address acute and urgent tasks across all spheres of public life. These programs are specific and short-term, capable of quickly demonstrating results and, most importantly, motivating employees to achieve set objectives [10].

Local self-government authorities are accountable to peasants in solving practical issues at both the regional and local levels. The effectiveness of reforms conducted in the country and rural areas directly depends on the work of local self-government authorities. The main objective is to develop agricultural production and rural territories in an effective, progressive, and innovative manner [6, 7, 9].

4 Results

In AIC, innovation must address three objectives:

– Ensuring food security;
– Resource conservation;
– Social well-being in rural areas.

To achieve these objectives, agricultural innovation should be complemented by projects that foster a cohesive environment and stimulate innovative change in rural areas to make better use of human potential. In other words, to implement innovations in agriculture, a comprehensive infrastructure needs to be established. Integrating the latest scientific and technological advancements is crucial for agricultural development. This involves creating technopark structures for high-level specialists to work in. implementing innovative projects to improve economic efficiency and address rural unemployment. Furthermore, the agricultural and agrarian sectors require professional training for agricultural specialists to ensure national food security and positively impact demographic indicators. Additionally, these sectors aim to cultivate a new generation that is closely connected to nature and embraces a paternal attitude towards it. These individuals should adopt a responsible attitude towards nature, preserving and promoting traditions and folk culture, and instilling a love for their home and native land.

The whole history of the Russian state proves that a developed economy is good, but without a spiritual component, such a country has no future. Therefore, modern policies aim to nurture new generations of rural laborers as the cornerstone of training agricultural specialists. Job opportunities will increase only through the systematic implementation of innovative projects in agribusiness. The development of rural infrastructure can create new jobs in the agro-industrial sector, which will require workers with modern skills and knowledge. It is important to note that rural labourers are responsible users of the land, caring for nature and thinking about the future of their land and the generations that will inhabit it. Such an approach to training specialists in AIC can have multiple positive effects and yield high results in the agrarian sector of the economy.

5 Conclusion

Based on the above, it can be concluded that the principles of professionalism and competence are essential for the effective functioning of the agricultural sector. These principles refer to the knowledge, skills, and abilities acquired by workers through education and the implementation of educational programs, methodologies, and technologies within continuous professional development in their field. In addition, developing rural areas and culture is important, as is instilling a love for one's native land and homeland in the younger generation. This can be achieved by returning to traditional peasant values and emphasizing the spirituality of rural production, which is directly linked to the reproduction of new generations. This approach has the potential to ensure sustainable and progressive development in the agricultural sector, while also contributing to national security in agricultural production.

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Features of the Organizational and Economic Management System of the Agro-Industrial Complex in the Russian Federation

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Abstract. The sustainable development of both agriculture and the agro-industrial complex as a whole is ensured through the effective functioning of the organizational and economic management system, which structures the relationships between management and production resources. The purpose of this article is to study the features of the organizational and economic management system of the agro-industrial complex, as well as to formulate proposals for its improvement. The research was based on monographic, abstract-logical, economic-statistical and calculation-analytical methods. As a result of the study, interpretations of the analyzed concept were considered. The factors and their influence on the interpretation and structure of the organizational and economic management system were identified. The role of state management methods in the Russian Federation in the formation of an organizational and economic management system is determined using the example of the agro-industrial complex of the Krasnodar region. An analysis of the socio-economic state of the Krasnodar region, the purchasing power of the main types of cash income of the region's population for the main types of agricultural products was carried out. The dynamics of the share of food expenses was studied in the overall structure of household expenses in the context of urban and rural areas. The efficiency assessment of the region's agro-industrial complex and recommendations were formulated for improving the organizational and economic management system. The result of the scientific research is to substantiate and expand the directions of modern scientific and practical development of problematic aspects and empirical features of improving the organizational and economic system of managing the agro-industrial complex of the region, as well as to deepen and develop the theoretical and methodological aspects of the optimal distribution of state support for subjects of the agro-industrial complex of economic zones of the region.

Keywords: sustainable development · organizational and economic system · agro-industrial complex · region · economic zones · distribution · government support · efficiency

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1 Introduction

Sustainable development of the agro-industrial complex is a necessary element both for ensuring food security of the country and for the economy as a whole. Sustainable development of the agro-industrial complex is ensured through the effective functioning of the organizational and economic management system, which structures the relationships between management and production resources. The study of the problems of the organizational and economic system of managing the agro-industrial complex is the subject of scientific work by scientists. The organizational and economic management system is an extensive structure consisting of two large groups of elements of management and production. The essence of the concept of "organizational-economic system" and its functional role are considered in the works of such scientists as L.I. Abalkina [1], V.V. Batmanova [2], E.A. Farvazova [5] and others. Therefore, according to the point of view of L.I. Abalkin, the essence of the organizational-economic system lies in the structuring of social production with its inherent forms, methods, incentives, etc. [1].

According to the opinion of a group of specialists Popova L.V., Batmanova V.V., an organizational-economic system is a system of relations under which interaction is realized between economic entities with different organizational and legal forms and other market agents [2]. As a result, a consensus on the essence of the organizational and economic system has not yet been formed, which confirms the need for further research on this topic. In addition to the above, the relevance of the research topic is determined by current global trends, namely the sanctions regime regarding the Russian economy, and the need to increase the country's food security. In this case, analysis and improvement of the organizational and economic mechanism of managing the agro-industrial complex is a necessary element of further effective strategic and tactical socio-economic development of both a separate region and the country as a whole.

Thus, the problems of the topic of this study are reflected in many works of scientists and specialists in the field of agricultural economics, and also in the circle of scientific interests of foreign researchers. However, it is worth noting that previously conducted studies met the needs of a certain state of the economy. Today, there are new requirements for argoeconomics and its development, which indicates the need for further research into improving the organizational and economic mechanism for managing the agro-industrial complex of the region.

According to the above justification, the purpose of this scientific research is to supplement the theoretical and economic apparatus of the organizational and economic mechanism of managing the agro-industrial complex of the region, as well as to provide scientifically based proposals for improving the elements of the mechanism under study.

Thus, to achieve this goal it is necessary to solve the following tasks:

– to explore the essence and significance of the organizational and economic mechanism of managing the agro-industrial complex of the region;
– analyze and assess the development of the organizational and economic mechanism for managing the agro-industrial complex of the Krasnodar region;
– formulate directions for the effective distribution of state support to subjects of the agro-industrial complex of the economic zones of the region.

2 Materials and Methods

The theoretical and methodological basis of the study consists of scientific developments and publications of scientists on the development of the organizational and economic mechanism of management in the agro-industrial complex of the region, federal and regional state programs of agricultural management bodies, recommendations of scientific organizations. When solving the problems posed in the scientific work, such scientific methods as monographic, abstract-logical, economic-statistical, calculation-analytical, as well as methods of economic-mathematical modeling, analysis, synthesis and comparison were used. The integrity and reliability of the data presented in this work is ensured by the information and empirical research base, which consists of official data from the Federal State Statistics Service, reports from the Ministry of Agriculture of the Russian Federation, the Ministry of Agriculture and Processing Industry of the Krasnodar region, information data from Krasnodarstat, data from the information network Internet.

3 Results

3.1 Factors in the Formation of the Organizational and Economic Management System

The problems of the issue under study are due to the fact that the organizational and economic mechanism of management is a product of one or another stage of the historical development of society, it is a unique structure that is filled with an exceptional set of elements, components, methods and tools that are characteristic of a particular economic system [4]. We agree with the formulation of E.A. Farvazova. about the purpose of such a mechanism, namely, the organizational and economic mechanism for managing the agro-industrial complex should be aimed at developing measures aimed at increasing the efficiency of agro-industrial enterprises, as well as their further economic and social development [5]. Based on the above, we consider it appropriate to schematically reflect the factor influence on the interpretation and structure of the organizational and economic system (Fig. 1).

Of the presented factors, in our opinion, the type of economic system occupies a priority position in the formation of both the essence of the organizational and economic mechanism and its composition. Thus, science knows two widespread types of economic systems, namely command-administrative or planned and market [6]. So, according to the typification of economic systems, significant changes are visible in the organizational and economic mechanism regarding the role of the state in this structure. To clarify, let us denote that for a planned economic system typical of the Soviet Union, the role of the state in the organizational and economic mechanism is much broader relative to the market economic system [9]. Today, in the conditions of market economic relations, the state, as a participant in the organizational and economic mechanism, implements its functions through strategic programs for the development of a particular sector of the economy, subsidizing the development of business entities, benefit programs and subsidies for priority sectors of the economy, etc. At the same time, within the framework of such economic relations, the organizational and economic mechanism is supplemented

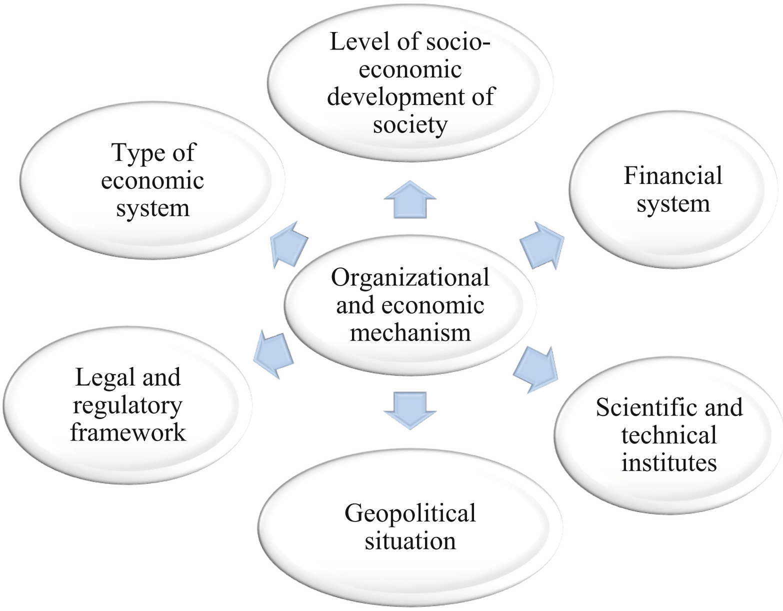

Fig. 1. Visualization of factor influence on the interpretation and structure of the organizational and economic management system

by such elements as public-private partnerships, industrial clusters, scientific and technological centers, financing and insurance structures, etc. Such transformations certainly influence the interpretation and structure of the organizational and economic system [2, 3].

The organizational and economic system of managing the agro-industrial complex of the region is a dual category, which has a synchronous character. In this context, attention should be paid to the nature and implementation of the synchronic aspect. Despite the fact that all the constituent elements of the mechanism are relatively independent, they are closely interconnected and changes in one element lead to reciprocal transformations of the other [8]. Otherwise, disruptions in relationships are likely to occur, which often leads to destabilization of the organizational and economic mechanism of managing the agro-industrial complex. For example, market conditions and government participation are the guiding elements of the organizational and economic management mechanism in the process of forming an internal system for managing the activities of an individual agro-industrial complex entity [10]. Pricing policy, taxation system, financial and credit system, investment policy has a direct and indirect impact on the processes of planning and forecasting the overall activities of an agro-industrial complex business entity.

3.2 Organizational and Economic System of Management of the Agro-Industrial Complex of the Krasnodar Region

Next, we will take a more detailed look at the organizational and economic mechanism of managing the agro-industrial complex of the Krasnodar region. The analyzed region has favorable natural and climatic conditions for efficient agricultural production. In addition, fertile soils provide agricultural enterprises with irreplaceable land resources. Diversified agriculture is developed in the Krasnodar region. The region produces both plant-growing and livestock products. Important sectors of the agricultural economy include the cultivation of grain crops (wheat, barley), vegetables and fruits (tomatoes, cucumbers, apples), milk and meat production, and their processing.

In Table 1, we consider the dynamics of the main socio-economic indicators of the Krasnodar region. The socio-economic situation of the region is characterized by many indicators. The population size is important for the region, due to the fact that labor resources are formed through this category. So in 2022, the population had a positive trend compared to 2018, namely the growth was 3%. At the same time, negative trends in natural population growth are noted, namely, during the study period, a natural population decline was revealed, so in 2022 relative to 2018 this figure increased 9 times, which will certainly have a negative impact on the economic development of the region in the future [7].

Table 1. Main socio-economic indicators of the Krasnodar region

Marker	2018 year	2019 year	2020 year	2021 year	2022 year	2022 year to 2018, %
Population (at the end of the year), thousand people	5648	5675	5684	5687	5819	103,0
Number of unemployed, thousand people	145	136	160	142	99	68,3
Number of pensioners, thousand people	1651,5	1651,4	1644,5	1617,6	1615,7	97,8
Average per capita cash income of the population (per month), rub	34861	36604	37352	41944	48279	138,5
Average monthly nominal accrued wages of employees of organizations (without social payments), rub	33846	36133	38499	43510	50252	148,5

(*continued*)

Table 1. (*continued*)

Marker	2018 year	2019 year	2020 year	2021 year	2022 year	2022 year to 2018, %
Average size of assigned pensions, rub	13037	13835	14627	15694	17917	137,4
Gross regional product: total, billion rub	2499,9	2577,1	2616,8	2098	3500	140,0
Investments in fixed assets, billion rub	515,3	477,6	502,1	543,0	690,7	134,0
Agricultural products, billion rub	382,5	417,2	433,0	549,5	660,3	172,6
Consumer price index (December compared to December of the previous year), %	104,3	102,6	105,1	109,3	111,0	x
Agricultural producer price index, %	123,6	96,8	122,8	110,7	98,3	x
Surplus, deficit (-), consolidated budget, billion rub	15,9	31,5	−0,9	39,4	10,9	68,6

As part of the analysis of the economic state of the agro-industrial complex of the Krasnodar region, it is important to pay attention to the dynamics of the consumer price index and the producer price index of agricultural products. So in 2022, the first index was at the level of 111%, which means that consumer prices in this year increased relative to 2021 by 11 percentage points. At the same time, the second analyzed index in 2022 was 98%, which is 12.4 percentage points lower than in 2021.

In continuation of the study of purchasing power, we will consider the dynamics of the purchasing power of the main types of cash income of the population of the Krasnodar region for the main types of agricultural products (Table 2).

Considering the purchasing power of the main types of income of the population of the Krasnodar region, we note that in 2022, the average per capita income of the region's population compared to 2021 increased by 15.1% and amounted to 48,279 rubles. At the same time, despite the growth of this type of income, purchasing power decreased significantly in 2022 relative to 2021. Thus, according to the average per capita income of the region's population in 2022, relative to 2021, they purchased 5.2%

Table 2. Purchasing power of the main types of cash income of the population of the Krasnodar region for the main types of agricultural products

Name of product type	Average per capita cash income of the population		Average monthly nominal accrued wages		Average size of assigned pensions	
	2021 г.	2022 г.	2021 г.	2022 г.	2021 г.	2022 г.
Food products, kg per month						
Beef	108,9	103,2	109,6	107,4	36,9	35,1
Chilled and frozen chickens	255,1	258,3	256,6	268,9	86,5	87,9
Frozen fish, cut	167,0	169,2	168,0	176,1	56,6	57,6
Butter	80,2	69,7	80,7	72,5	27,2	23,7
Sunflower oil	336,7	353,9	338,7	368,4	114,2	120,5
Pasteurized whole drinking milk 2.5–3.2% fat content, l	764,2	707,3	768,7	736,2	259,1	240,8
Dairy products	494,6	473,8	497,5	493,1	167,7	161,3
Chicken eggs, pcs	5539,8	6350,0	5572,5	6609,5	1878,3	2162,1
Granulated sugar	861,3	683,5	866,4	711,5	292,0	232,7
Bread and bakery products made from various types of wheat flour	714,1	603,9	718,3	628,6	242,1	205,6
Buckwheat – peeled buckwheat	404,5	350,3	406,9	364,6	137,1	119,3
Polished rice	550,2	454,3	553,4	472,8	186,5	154,7
Wheat flour	1000,1	939,5	1006,0	977,9	339,1	319,9
Potato	926,6	1005,2	932,1	1046,3	314,2	342,3
Fresh white cabbage	1106,5	943,5	1113,1	982,1	375,2	321,3

less beef, 3.4% less boiled sausage, and 13.1% less butter. There is also a decrease in purchasing power for such food products as fermented milk products (−7.4%), bread and bakery products made from various types of wheat flour (−20.6%), buckwheat (−15.4%), and polished rice (−13.4%), wheat flour (−17.4%), fresh white cabbage (−14.7%), margarine (−27.5%).

Food products have been identified for which the purchasing power of the average per capita income of the region's population has increased, such products include chilled and frozen chicken (+3.4%), cut frozen fish (except salmon) (+1.3%), sunflower oil (+5.1%), potatoes (+8.5%).

In Fig. 3 we present the dynamics of the share of food expenses in the overall structure of household expenses in urban and rural areas.

According to the data presented in Fig. 3, we conclude that in the overall structure of household expenses of the urban population, food expenses amounted to 39.9% in 2022, which is 4.5 percentage points more than in 2018. As for the share of food expenses for households of the rural population of the Krasnodar region in the overall structure of expenses, in this case in 2022, the category occupied 37.7%, which is 1 percentage point less than in 2018.

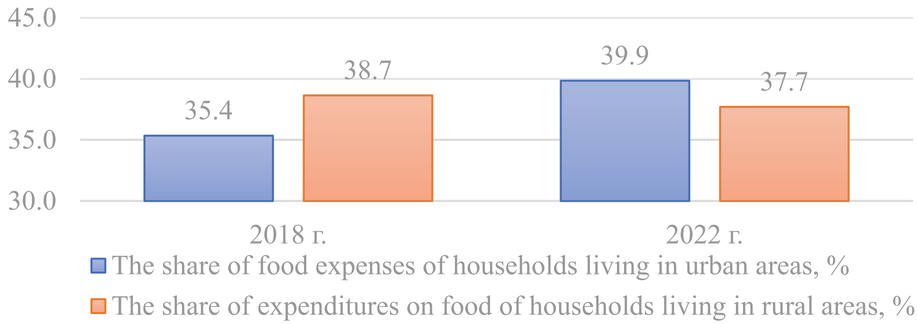

Fig. 3. Dynamics of the share of food expenses in the overall structure of household expenses by urban and rural areas, 2018–2022, %

The analysis, according to the situation developing in 2022, did not reveal significant differences between food expenses among urban and rural households, this suggests that food consumption is shifting towards large producers of agricultural products through retail chains.

In Fig. 4 we present the dynamics of the agricultural production index by farm category.

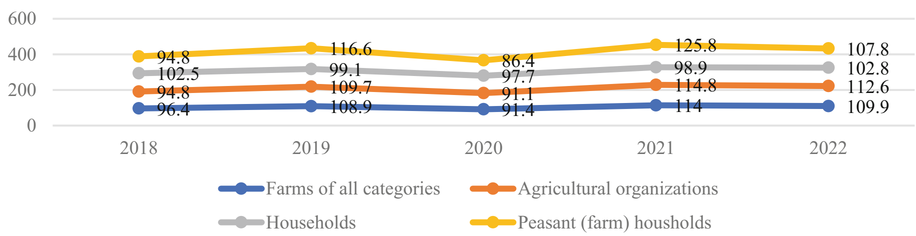

Fig. 4. Dynamics of the agricultural production index by farm category, 2018–2022,%

According to Fig. 4, in 2022 the index of agricultural production for all categories of farms was 109.9%, which means that in 2022 the volume of agricultural products in value terms exceeded the same indicator in 2021 by 9.9%. The largest increase in the analyzed index was found among agricultural organizations, which in 2022 amounted to 112.6%. Thus, as a result of an economic analysis of the state of the agro-industrial complex of the Krasnodar region, we come to the conclusion that in dynamics from 2018 to 2022, the share in the gross regional product of the industrial complex under study is quite large (at the time of 2022, about 12.5%). The volumes of the main agricultural products produced tend to grow, however, the purchasing power of the population is declining. As for the raw material base of the agro-industrial complex - agriculture, production in this industry is also increasing; the main leaders in the production of agricultural products are agricultural organizations, mainly provided with agricultural land, financial resources, and also with access to the introduction of innovative techniques and technologies.

The organizational and economic system of managing the agro-industrial complex of the Krasnodar region is a multifactorial and diverse structure. This system has many areas of activity and depends on a large number of factors. Next, in Fig. 5, we schematically visualize state participation in the organizational and economic system of managing the agro-industrial complex of the Krasnodar region.

Fig. 5. State participation in the organizational and economic management system of the agro-industrial complex of the Krasnodar region

The distribution of state support among subjects of the agro-industrial complex in the context of economic zones of the Krasnodar region is one of the key issues facing the authorities. In the context of constant changes in the economic situation and the need to improve the efficiency of the industry, this problem becomes especially relevant. Redistribution of government support is a complex process that requires careful analysis and consideration of all factors. The main goal of this process is to provide equal opportunities for the development of the agro-industrial complex in the economic zones of the region and contribute to the creation of favorable conditions for business [11–13].

One of the main problems of the current system of distribution of state support to subjects of the agro-industrial complex in the economic zones of the Krasnodar region is the insufficient efficiency of this process. Firstly, there is no clear understanding of the criteria and mechanisms for allocating funds, which leads to an uneven distribution of government support between the economic zones of the region. As a result, some economic zones in the region receive significantly more government support, while others experience deficits. Secondly, difficulties arise in the process of control and monitoring the use of allocated subsidies. The lack of effective control mechanisms can lead to abuse and inappropriate use of public funds. Non-administrative methods also reduce the incentive to improve the effectiveness of support use [14]. In addition, the current system for distributing state support in the economic zones of the region does not take into account seasonality and the specifics of agricultural sectors. For example, some economic zones may only need support at certain times of the year or for specific crops.

To ensure the effective functioning of the agro-industrial complex in the economic zones of the region, it is necessary to optimize the mechanisms for distributing state support. First of all, a clear strategy for allocating funds should be developed, taking into account the characteristics of each economic zone and priority areas of development. Let us present in Fig. 6 the main positions of the strategy for distributing state support for agricultural entities across economic zones of the region.

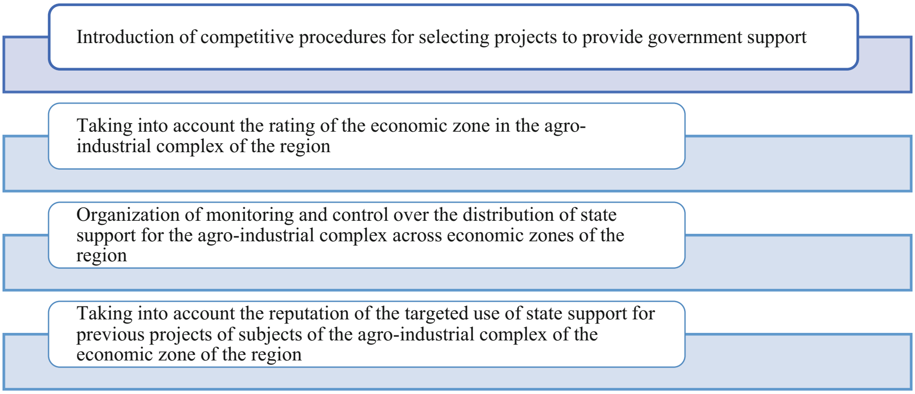

Fig. 6. The main positions of the strategy for distributing state support for agricultural entities across economic zones of the region

After improving the mechanism for distributing state support to subjects of the agro-industrial complex of the economic zones of the region, it is expected that there will be a positive and uniform dynamics in the efficiency of the organizational and economic mechanism of managing the agro-industrial complex in the context of economic zones of the Krasnodar region. Firstly, more efficient use of government resources will improve the competitiveness of regional agricultural producers. Thanks to this, the turnover of agricultural products can increase, which in turn will have a positive impact on food security in both the region and the country as a whole.

Secondly, the updated mechanism for distributing state support will allow us to focus on the development of innovative technologies and the provision of financial assistance for projects in the field of agricultural production in the context of economic zones of the region. This contributes to the modernization of production, increasing its efficiency and competitiveness. As a result, a favorable climate will be created to attract investment in the agro-industrial complex of the economic zones of the region, both from government agencies and the private sector.

Thirdly, improving the mechanism for distributing government support contributes to the development of small and medium-sized businesses in rural areas. Thanks to access to equal financing and support from the state, agricultural enterprises will have access to new tools for conducting agricultural production. This will reduce migration from rural areas to cities and promote uniform development of the region.

4 Discussion

Farvazova E.A. based on the study of the works of Borovinsky V.A. and Bukhtiyarova T.I. applied the method of schematic grouping of elements of the organizational and economic system of managing the agro-industrial complex, separating organizational structures from economic ones, building a connection between them based on the general purpose of functioning. According to this scheme, Farvazova E.A. paid attention to the process and role of digitalization of the agro-industrial complex, as a common element of the organizational economic mechanism for managing the agro-industrial complex between two groups of elements of the organizational and economic mechanisms. We agree with the formulation of E.A. Farvazova about the purpose of such a mechanism, namely the organizational and economic mechanism for managing the agro-industrial complex should be aimed at developing measures aimed at increasing the efficiency of agro-industrial enterprises, as well as their further economic and social development. Between this study and the works of Farvazova E.A. there is a consensus of opinions, however, the author of this study clarifies the concept of the organizational mechanism of management in accordance with current global trends, while maintaining its dual essence.

5 Conclusion

As a result of the study, the interpretation of the organizational and economic mechanism of managing the agro-industrial complex of the region was clarified as a complex, multifactor structure, which is characterized by duality and synchronous features of functioning, including a complex of interaction between government methods, methods of management and the interests of economic entities regarding the effective activity and development of the agro-industrial complex of the region. The role of state participation in the functioning of the organizational and economic mechanism of managing the agro-industrial complex of the region, as a regulator of risk resistance of agricultural enterprises, a source of additional financing for agricultural activities, and a stimulator of flexibility in financial and credit policy, has been clarified.

The practical significance of the study lies in the fact that the substantiated scientific and applied recommendations obtained in it can be used to improve the process of development of organizational and economic mechanisms for managing the agro-industrial complex of the region, increase the effectiveness of assessing their effectiveness, as well as develop a mechanism for the uniform distribution of state support for agro-industrial complex subjects in the context economic zones of the region.

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Development of China's Agricultural System in the Context of Climate Change: Implications and Prospects

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Abstract. The study summarized the current works of Chinese researchers investigating the impact of global climate warming on agriculture development in China. Research methods included system, structural and functional analysis, categorization and ascent from the abstract to the concrete. The article summarizes the most relevant social and economic implications of global climate change for China's agriculture. It is revealed that the country's agriculture experiences both positive and negative effects of climate change. On the one hand, the annual average increase in temperature readings will lead to increased wheat yield, and the increase in annual average precipitation in certain regions of China will boost soybean yield. On the other hand, negative consequences will manifest themselves in the form of changing life cycles of cultivated plants, emerging droughts, restricted access to water resources and an aggravation of the epidemiological situation. Climate change also contributes to the emergence of multiple social and economic problems: deepening disproportions in regional development, unemployment and rising food prices. The article analyzes the key implications and prospects of global climate change for crop production in China in the light of current research by Chinese scientists.

Keywords: China · agriculture · food security · global warming · crop production

1 Introduction

China is a country with the largest population on Earth and a world leader in the agricultural industry. However, it is common knowledge that China's arable lands which account for less than 9% of the world's total provide food for about 20% of the world's population. In the period from the late 1970s to the 2020s, China's agricultural industry grew (in real terms) at a rate of 4.6% per annum (with over 60% of this growth caused by the overall increase in factor productivity) which is a lot higher than the annual average population growth rate over the same period of time [26, p. 2]. This massive growth of China's agricultural economy is accompanied by a significant deterioration in the environmental situation in the country. As the World Bank's Country Climate and

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Development Report for China points out, China's development and climatic instability are deeply and increasingly interconnected. The country both contributes to the rising global greenhouse gas emissions that cause climate change and is greatly affected by its adverse effects. Although China is not the main source of cumulative atmospheric emissions, it currently accounts for 27% of annual global carbon dioxide emissions and a third of global greenhouse gas emissions. However, a significant part of China's population and economic infrastructure is highly exposed to climate risks. China, as well as other countries, will have to adapt and increase the stability of its social system in order to protect human lives and avoid economic losses [29, p. 2].

Chinese scientists have been registering climate warming in the northern hemisphere since early XX c. until the end of the XX c., especially in the northern regions of East Asia and China. Changes in precipitation may become more complicated in the future, as various models and scenarios predict [23, p. 6]. Based on the forecasts of temperature changes in China, its readings will be significantly higher than the global average. Experts estimate that the annual average temperature will increase by 5 °C over the current century, and this rise may reach 5.2 °C and 5.4 °C by the end of the century [7, p. 11]. We believe that global climate warming may change the approach taken by the Chinese authorities in food security matters as a social and economic category.

The main goal of China's agriculture development is to ensure national food security and supplies of the major agricultural products to consumer markets [34, p. 1889]. The concept of "food security" was first defined at 1996 World Food Summit as a situation "when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [18, p. 363]. Jie Zou, Shiqin Guo and others write that food security is the foundation of national security which China's key policy choices depend on [43, p. 447]. A group of international researchers notes that food security depends on factors such as national production growth, as well as export and import trends. Food security is determined by such indicators as the community's food self-sufficiency, food prices and consumption levels [20, p. 9]. Ye, Liming & Xiong, Wei & li write that food security assessment should account for parameters related not only to food production, but also to food consumption [18, p. 363]. Yuke Hou and Xin Liang indicate that improvement in the well-being of Chinese citizens will change the patterns of food consumption by the population which will inevitably contribute to radical changes in China's food demand profile [39, p. 1].

Chinese researchers write about two main vectors of ensuring food security in present-day China. In terms of the internal economic approach, satisfaction of the population's needs is studied in the context of the idea of providing for the national market using national resources. Due to the historical specifics of national agriculture development, crop production is China's most significant agricultural complex. Within this complex, such groups of cultivated plants as grains, oil plants and technical-use plants are the most important. Chinese scientists note that despite the fact that the national food consumption patterns will shift from grain to animal products in 2018–2030, the pace of these changes will slow down over time. If the consumption of rice and wheat increases slightly, the consumption of corn and soybeans will see a significant growth. If the consumption of food grains decreases slightly, and the demand for feed grains increases significantly, the overall grain consumption will increase. In general terms, the total grain production in the PRC will increase significantly by 2030. Grain consumption will amount to 864.2 million tons, of which feed grains will have the most significant share in the market supply [6, pp. 8–9].

A number of Chinese scientists point out the significant impact of climate change on crop production development and, therefore, significant threat to national food security. Asian peoples have been consuming soybeans in various ways for over 1,000 years, according to Chinese researchers [5, p. 9]. Historically, grains are the staple diet for the Chinese. Soybeans are the third most popular food in China used to produce sauce, flour and a range of @@ground products. According to FAO, in 2018, the PRC was the world's fourth largest producer of soybeans (14.1 million tons) followed by the United States, Brazil and Argentina [8]. China is the leading soybean importer. The Chinese demand for soybeans can be explained by dietary customs. Today, over 80% of soybeans consumed in the country is imported which accounts for 60% of the global soybean trade volume. The rising demand for soybeans in China is the main driving force behind its cultivation in South America [40, p. 4]. Qinyan Zhu, Fumin Wanga, Qiuxiang Yi and others indicate that soybean cultivation is primarily influenced by the height of the field surface above sea level, amount of precipitation in the three warmest months, share of clay, slope, range of average daily temperatures $\geq$ 10 °C, solar radiation level and share of gravel in the topsoil. Zhu, Qinyan & Wang, Fumin & Yi, Qiuxiang suggest that legume cultivation in northeast China will improve due to climate change trends. However, climate change will increase extreme precipitation in the long term which may have an adverse impact on yields. Thus, the macroregion will be forced to continue to closely monitor climate change [42, p. 1].

In terms of the external economic approach, Chinese researchers indicate that the state must seriously rationalize the use of foreign resources and the need for importing the products that cannot be produced domestically due to the lack of suitable conditions. Writing about foreign investment, Yu Lu mentions the significant challenges of attracting foreign direct investment to China's agricultural sector [19, p. 844]. Nowadays, China is actively seeking access to foreign agricultural and food resources and is striving to maintain domestic food production at a high level. This strategy ensures China has an advantageous position in the global food system [41, p. 19]. However, Dong Yinguo and Shen Yihao Chen Jiayu emphasize that, overall, the quality of imported crop products is quite high [37, p. 19] which will certainly contribute to China's best prospects in achieving its food security goals.

Chinese scientists also explore the possibilities of supplying the PRC's food market with foreign agricultural and food resources to maintain the required level of food production. China is actively developing foreign trade to ensure its food security. Due to the high level of consumer demand for legumes in China's national market, the country is looking for opportunities to use foreign resources to maintain an adequate level of food security.

For example, a study by Tariq Ali, Bo Zhou and David Cleary argues that in the short term soybean cultivation in Brazil and its gross exports may decrease by 13.1% and 15.2% under scenarios involving the highest temperature readings. Consequently, China will face a reduction in soybean imports from Brazil (-9.94 million tons) [2, p. 12].

Indeed, the achievement of China's current goals in terms of increasing GDP per capita to the levels of medium development index countries announced by the Chinese leaders at the 20th CPC National Congress in 2022 [31] will fundamentally change the parameters and requirements for national food security. An improvement in the quality and standard of living of the population, technical upgrade of the agricultural sector against the changes in the international food markets will have a significant impact on the country's food security characteristics.

The **purpose** of this article is to summarize the work of the PRC's leading researchers in the context of various climatic impacts on China's agriculture development.

1.1 Strategy of China's Agriculture Adaptation to Climate Change Effects

Bao Lun, Yu Lingxue, Li Ying and others write that the greatest danger of climate change for China's crop production is the volatility of temperature changes and the most important task of the country's agricultural sector is to mitigate the adverse effects undermining economic stability [3, p. 1]. Thus, Liming Ye, Wei Xiong, Zhengguo Li and others note that crop production is affected by climatic and biological variables. Among the climatic impact factors, the researchers point to temperature increase, precipitation changes and rising CO2 levels in the atmosphere. Biological variables include duration of crop growth periods and sowing cycles [36, p. 363]. Chaoqing Yu, Xiao Huang, Han Chen and others studied the vulnerability of China's agriculture to extreme droughts. Therefore, the development of a complex of irrigation systems, in conditions of limited opportunities for expanding crop acreage, is presented by the researchers as an important method to increase agricultural productivity [38, p. 701]. This conclusion is further confirmed by a study by Tengcong Jiang, Bin Wang, Xiaoning Duan and others. The researchers also note that in the context of climate change, changing the timing for watering and fertilizing should be a priority as compared to adjusting the timing for sowing in the northern and central parts of China [17, p. 13]. Thus, the conclusion by Haowei Sun, Yanhui Wang, Li Wang on the creation of protective strips on agricultural land, breeding of crop varieties resistant to extreme climatic conditions and improvement of moisture-retaining properties of the soil as the leading method to overcome the climatic transit consequences seems to be largely justified [27, p. 13].

1.2 Social and Economic Implications

A number of scientists assessing the impact of climate change on crop farming note significant demographic implications. Haowei Sun, Jinghan Ma and Li Wang explored the potential of national crop production to meet the needs of the population and improve the social and economic sustainability of the PRC. Research results showed that climate change would lead to an increase in total wheat production in China. However, population changes would partially offset the benefits of this process for the grain market. Social and economic factors, primarily demographic ones, will be important for ensuring China's food security since, as the population grows, the need for food will increase [27, p. 609]. Meanwhile, the demographers Guo, Aijun & Ding, Xiaojiang & Zhong, Fanglei & Cheng, Qingping & Huang, Chunlin analyzed the data of the Sixth National Population Census of the People's Republic of China (2010) and revealed that China's population would first rise and then drop from 2010 to 2050 [14, p. 1]. Russian scientists confirmed the forecasts of Chinese researchers using the date of the Seventh National Population Census (2021). Indeed, the pension burden is currently increasing in China: providing for an increasing number of elderly people is becoming a severe trial for the working population [1, pp. 724–732]. The data of the Seventh National Population Census do not contradict the previous forecasts by Chinese researchers since the change in the ratio of the working and retired population in favor of the latter will significantly increase the burden on the national economy. The probability of the negative demographic scenario, the social and economic disparity of certain regions and poverty issues that are traditional in some areas can become a lot more aggravated with further climate warming. Shahrajabian, M. Hesam & Sun, Wenli & Cheng, Qi have determined that China may need to invest more in anti-poverty policies. The Chinese government should also help the poorest farmers adapt to climate change. Rising annual average temperatures can potentially contribute to a radical gap between agricultural products supply and demand in regional markets. With the increasing negative impact of climate change on agricultural production, the yield of major grain crops may decrease which might lead to higher crop prices and, ultimately, to reduced levels and qualities of consumption among the most vulnerable social groups [25, p. 1812]. This conclusion by the scientists looks all the more reasonable because other researchers confirm it. Yifeng Xie, Haitao Wu and Ruikuan Yao also noted that climate change has a significant impact on the income gap between urban and rural areas, and the Chinese government needs to continue to promote greater urbanization and optimize labor force employment, reduce the vulnerability of rural residents to climate change [33, p. 14]. However, while being strongly focused on the social and economic implications of global warming for China, national researchers such as Jun Yang, Maigeng Zhou and Zhoupeng Ren and others predict excess mortality depending on age, region and education. Scientists believe that these processes are associated with future high temperatures in 161 Chinese regions/counties [35, p. 1]. Indeed, excess mortality in the context of climate variability may have a huge impact on the demographic processes, affect the potential of agricultural sector labor resources and the labor market in the crop farming sector.

1.3 Epidemiological Implications

Climate change in China may have an adverse impact on the epidemiological status of the economy. It can have an especially negative effect in the southeastern provinces that have better conditions for agriculture. Hongmei Liu, Xiaodan Huang, Xiuxia Guo and others note that dengue outbreaks have become more frequent in northern China where climate is temperate. The scientists warn that the spread of the disease caused by increasing temperatures is likely to progress. This is especially true for high-latitude areas which is confirmed by the data from field epidemiological surveillance of mosquitoes, carriers of the disease. The increase in the recorded cases of dengue fever will certainly be a more urgent problem in the era of climate change [21, p. 15]. Over the past 50 years, climate warming has led to the rapid spread of Aedes Albopictus mosquitoes. It is not surprising as scientists previously wrote that larvae usually develop in small reservoirs, tree hollows and artificial containers. Detritus, in particular rotting leaves, is their main source of carbon. Overall, rapidly decomposing leaf litter contributes to an increase in the number of mosquitoes which leads to faster development and increase in their population [9, p. 31]. Rising levels of annual average precipitation, especially in the southeastern agricultural regions, will contribute to the expansion of hotbeds of dengue fever affecting agricultural workers which may have an adverse effect on labor supply in the agricultural sector.

2 Materials and Methods

This study examines the achievements of modern Chinese science in terms of understanding the phenomena and processes that are both directly and indirectly related to agriculture development in China in the context of climate change. It reviews present-day research by modern Chinese scientists through analysis of benchmark studies in the field included in the Scopus databases. The article uses several scientific methods that allowed us to achieve the research goal.

System Analysis. In the context of this study, this method allows us to produce a systemic picture of the current state of knowledge about the climate change process and its impact on agriculture in Chinese science. Using system analysis, this work examines the major approaches to the problem of ensuring food security as the main goal of agriculture in China. This method helps us present the main areas and implications of climate change for the agricultural sector in the country's economy. Research by Chinese scientists has also been categorized through the use of the **typological analysis method** in the context of multiple approaches to understanding the prospects for ensuring food security in China in the course of climate change. Along with system analysis, the study uses the **structural and functional approach** to characterize major Chinese agricultural complexes. We studied crop production as the most significant structural element of China's agricultural sector, as well as the totality of sustainable relations and interrelations between other agricultural complexes of the agricultural sector, their roles and functions relative to one another. Using the **method of ascent from the abstract to the concrete**, we found that it is advisable to explore various aspects of the phenomenon under study in more detail in the future. First and foremost, a wide range of social and economic, social and political factors should be taken into account. In this study, we found that by expanding the understanding of the impact of climate transit on the agricultural sector of the PRC, we can formulate its comprehensive model for the future.

3 New Approaches to Forecasting and Modeling Agriculture Development in China

Climate change affects multiple sectors of the economy and exacerbates social and economic inequalities in Chinese regions. Therefore, Chinese agricultural researchers develop models to be used to forecast, adapt and prevent risks for the agricultural sector of the country's economy caused by the adverse effects of climate change in the present and future.

Global atmospheric changes carry factors that can both increase productivity and have an adverse effect on it. For example, positive prospects for agriculture may naturally arise from an increase CO2 levels in the atmosphere. However, negative implications may be just as significant. For example, it could reduce the duration of growth for cultivated plants [16, p. 24]. Scientists in the PRC study cause-and-effect relations in the natural and geographical environment of China's agricultural regions. The researchers use and develop models for agriculture development, analyze the mechanisms for executive decision-making in the industry.

The Chinese researchers also explore the retrospective processes of climate change over the past 2,000 years in the country, using scientific modeling resources. Scientists develop and use such models as ENSO [4, p. 10], Energy Balance Model (EBM) [22, p. 52], schematic representations of climate change by one of China's leading climatologists Wang Shaowu [30, p. 1148], etc. The researchers note that temperature fluctuations over the last millennium can primarily be explained by natural processes, especially in the first 850 years. However, according to the researchers, climate change in the last 150 years is due to man-caused impact which is confirmed by CO2 concentration in the atmosphere [23, p. 20].

Ren Guoyu, Ding Yihui, Zhao Zongci and others note that climate models have generally worked well in predicting changes in the annual average values of SAT (surface air temperatures) in China. They were also used to predict future SAT changes for multiple greenhouse gas emission scenarios. However, according to Chinese scientists, these model-based forecasts still have significant ambiguities, especially with regard to projected trends in precipitation and climatic extremes [24, p. 958].

By way of example, the models used by Chinese researchers also include APSIM (Agricultural Production Systems Simulator). This is an integrated model that is often used to simulate biophysical processes of cultivated plants. It is useful for studying appropriate agricultural measures to ensure food security and climate change adaptation (https://www.apsim.info). The Agricultural Production Systems Simulator (APSIM) is recognized internationally as a highly developed platform for agricultural systems modeling. It contains a set of modules that can be used to simulate systems based on a wide range of data related to plants, animals and soil [10, p. 1].

The EPIC plant growth model was originally developed to estimate the productivity of erosion-prone soils in the United States. The EPIC model can be used to plan growth of various plant varieties based on unique parameters. Modeling helps represent and plan the absorption of solar radiation by leaves; the transformation of foliage into biomass; economic productivity; root growth; water use parameters; nutrient uptake by plants [31, p. 2].

The WheatGrow wheat growth simulation model uses annual average temperature increase trends to better forecast wheat growth, reproduce the structure of leaves, wheat stalks, etc. [15, p. 2].

These three models estimating changes in crop yields are used in the works by Chinese scientists. Using modeling, the researchers were able to compare the timing of the observed wheat harvests with the dates predicted by these models [28, p. 601].

One of the most important social and economic implications of climate change in China is the excess mortality of the population. Chinese researchers are also actively engaged in forecasting and modeling this process. When making mortality estimates, scientists, usually demographers, often use the negative binomial model that takes impact on human health into account. It accounts for the long-term effects of climate change, flu seasons and heat waves. The simulated mortality curves from this model are analyzed using simple methods. These include, for example, WHO, Acosta and Irizarry methods [12, p. 5]. The current climate change scenarios reflect a variety of social and economic events, as well as various methods of changing greenhouse gases concentration in the atmosphere. A new set of climate scenarios was developed for the IPCC Sixth Assessment Report which, as of 2023, is the latest Report of the Intergovernmental Panel on Climate Change (IPCC) (AR6 IPCC) on Shared Socioeconomic Paths (SSP) [11, p. 773]. Using five SSP scenarios, Chinese scientists Yang, Jun & Zhou, Maigeng & Ren, Zhoupeng predict an increase in excess mortality with an increase in average temperature readings depending on the climate and region of China. Using socioeconomic modeling, experts predict that heat-related mortality will significantly rise in the future, especially in RCP8.5 scenario, while in the 2090s mortality due to excessive heat will nearly double in RCP4.5 scenario. RCP8.5 scenario assumes that greenhouse gas concentrations will increase continuously in combination with high energy consumption, excessive land use and high population growth. Given the complexity of the challenges associated with future global warming, integrated multi-sector and interdisciplinary cooperation linking power generation, transport, industry and agriculture is required to develop policies to reduce man-made greenhouse gas emissions in order to slow the pace of global warming [35, p. 1]. In calculating the conditions for ensuring China's food security, Chinese scientists have developed a unique approach to modeling climate development, taking into account agricultural productivity indicators in China and other countries depending on CO2 emissions into the atmosphere [2, p. 1].

4 Discussion

We agree with the conclusions of Chinese researchers who note the relative uncertainty of studying climate change results through modeling [13, p. 8]. Therefore, to predict food security sustainability and agriculture development in China, an integrated approach is required that would take into account not only climatic and biological, but also social, economic and political factors. We believe that there are broad opportunities for developing models to predict food security sustainability in China in the context of climate change. In particular, scientists need to have integrated, interdisciplinary descriptions of the prospects for the development of agricultural chemistry and machinery, as well as comprehensive descriptions of the current state of the soil and all water resources. Moreover, a new integrated model of agriculture development in the PRC in the context of climate change should take present-day social and economic factors into account. First and foremost, it should include the impact of the potential threat of a new COVID-19 pandemic or the emergence of new epidemiological challenges on agriculture.

The social and political factors that need to be taken into account in the new model are equally important. With regard to China's unique political characteristics, it is advisable to take into account a set of measures taken by the Chinese authorities in order to adapt to and prevent the adverse effects of climate change. In his report at the 20th CPC National Congress in 2022, President Xi Jinping stated his intentions to "carry out coordinated industrial restructuring, pollution control, ecological conservation and climate response;

to promote concerted efforts to cut carbon emissions, reduce pollution, expand green development and pursue economic growth; prioritize ecological protection, conserve resources and use them efficiently, and pursue green and low-carbon development" [32].

Therefore, food security in both China and many countries of the world will depend on the successful implementation of the plans of the Communist Party leaders to regulate the effects of climate change on agriculture.

The model should also take into account qualitative changes in consumption levels of Chinese population. New consumer standards and food security parameters, in our opinion, will undergo significant changes due to the achievement of China's new development goals for the XXI century announced in the light of the decisions made at the 20th CPC National Congress in 2022. These include the completion of socialist modernization and transformation of the People's Republic of China into a prosperous, democratic and socialist state. The plans of the Chinese leaders envisage carrying out socialist modernization from 2020 to 2035; turning China into a prosperous and powerful, democratic and civilized, harmonious and beautifully modernized socialist power where a modern economic system will be created and a new development architectonics will be formed, from 2035 until the middle of this century; carrying out new-type industrialization, digitization, urbanization and agriculture modernization [32].

Once the plans of the Chinese leaders are executed, by the middle of the XXI century, better conditions will be created for regulating national agriculture, taking into account the uncontrollable effects of climate change.

5 Conclusion

The challenges of adaptation to and prevention of uncontrollable climate changes are currently of crucial importance for China. It is not fortuitous that the issues of climate change were mentioned in the report by China's President Xi Jinping at the 20th National Congress of the Chinese Communist Party on October 16, 2022. It should be noted that new government approaches to regulating the economy and the agricultural sector, in particular, will have a positive impact on the social and economic development of China. The accomplishment of the long-term goals of the Chinese authorities will lead to an increase in the material well-being of citizens, positive agriculture development and sustainable food security.

This work summarizes the key social and economic implications of climate change for agriculture in present-day China. We studied the results of current research by the PRC scientists. The challenge of preventing adverse climatic effects on agriculture requires close attention on the part of the researchers. To run an unbiased and most reasonable assessment of the state of agriculture in China in the context of climate change, an interdisciplinary, multi-factor approach needs to be used, to take into account the methodological advantages of all studies presented herein.

The results of this study can be used to formulate a comprehensive and multi-factor model that could account for all actions taken by the community to prevent and adapt to global climate change in China. Taking into account the country's contribution to the world economy and the size of its population, China's experience in interacting with the global warming effects could be used in other countries and regions of the Earth.

Therefore, the key prospect for further research on the presented problem should be the formulation of a new model that would account for the most complete list of climate change effects in terms of their impact on agriculture development in China.

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Sustainable Agricultural Development: Theoretical Aspects

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Abstract. Sustainable agricultural development is an important theme in current economic debates, focusing on the link between food production, natural resource conservation, and land use efficiency. Sustainable agriculture is a resource management approach that aims to sustain agricultural production and efficiency over time while also ensuring food security, environmental conservation, and social development in rural areas. This method is founded on the belief that agriculture is a critical component of economic growth and must increase consistently over time. In this essay, we looked at the theoretical elements of sustainable agricultural growth, as well as the fundamental concepts and practices that can assist attain it. This purpose is achieved by the application of monographic, abstract-logical approaches, as well as analysis and comparison. The study's findings included a determination of agriculture's position in the agro-industrial complex structure, the essence of sustainable agricultural development, and a justification of the main factors influencing the considered sustainability, with a focus on the unique role of social infrastructure and human capital.

Keywords: sustainable development · agriculture · social infrastructure · rural areas · human capital

1 Introduction

The idea of sustainable rural development has grown in favor in the economic realm since it allows for economic activity while maintaining ecological and social balance. Achieving rural sustainability is an essential prerequisite for assuring the long-term development of agriculture, one of the country's most important industries.

The Russian Federation's vast lands have predetermined the agricultural and industrial growth of the national economy, contributing to the country's well-being.

The agro-industrial complex (AIC) contributes significantly to the economy by providing:

– food security entails increasing food availability and diversity while also combating hunger;

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– employment of the people - decreasing unemployment and poverty by creating jobs and boosting rural inhabitants' incomes;
– export revenues - exporting agricultural goods may help the country build its foreign exchange reserves, attract investment, and encourage economic development.;
– encouraging innovation and technical progress—the introduction of modern land cultivation methods, the use of contemporary agricultural machinery, and the creation of novel plant types and hybrids may boost production efficiency, cut costs, and improve product quality.

Agriculture is the foundation of the agro-industrial complex, which is a collection of activities connected to plant cultivation and animal breeding for the production of food, raw materials for industry, livestock feed, and other agricultural products. It plays a major part in the country's economy, performing the most crucial functions: maintaining food security, developing areas, providing new employment, and assuring technical advancement.

2 Materials and Methods

The research's methodological foundation was the work of local and international scientists in the fields of sustainable agriculture, rural regions, and the link between the development of social infrastructure and human capital and agricultural sustainability. The study included monographic and abstract-logical approaches, as well as analysis and comparison.

3 Results

The agro-industrial complex is a "integrated structure that includes all sectors of the economy involved in the production of agricultural products, their processing and delivery to the consumer" [18], i.e. the agro-industrial complex is a "functional multi-sectoral system due to the close interconnection and interaction of agriculture and related sectors of the economy for the production of means of production for agriculture processing and sale of agricultural product [11].

These categories represent the agro-industrial complex's content, which comprises sectoral, functional, geographical, and product-raw material structures (see Fig. 1).

The expanded industrial structure of the agro-industrial complex consists of: the production of plant and animal products, including cattle breeding, poultry farming, horticulture and vegetable growing, fishing; enterprises for the processing of agricultural products, including milling, dairy, oilseed, meat and fish industries, the production of canned food, beverages, confectionery, etc.; enterprises for the harvesting, processing and use of forest products resources, including woodworking enterprises, production of wood, paper, pulp, furniture, etc.; enterprises for the production of textiles, clothing, footwear and other goods; enterprises for the production of fertilizers, pesticides, chemicals, plastics, rubber, varnishes and paints, etc.; production of agricultural machinery and equipment, tractors, agricultural vehicles, as well as metallurgical enterprises;

enterprises for the extraction and processing of oil, fuel production and energy companies; enterprises providing services in the field of agriculture, such as veterinary and agrotechnical services, as well as trading companies engaged in the sale and distribution of agricultural products [12, 17].

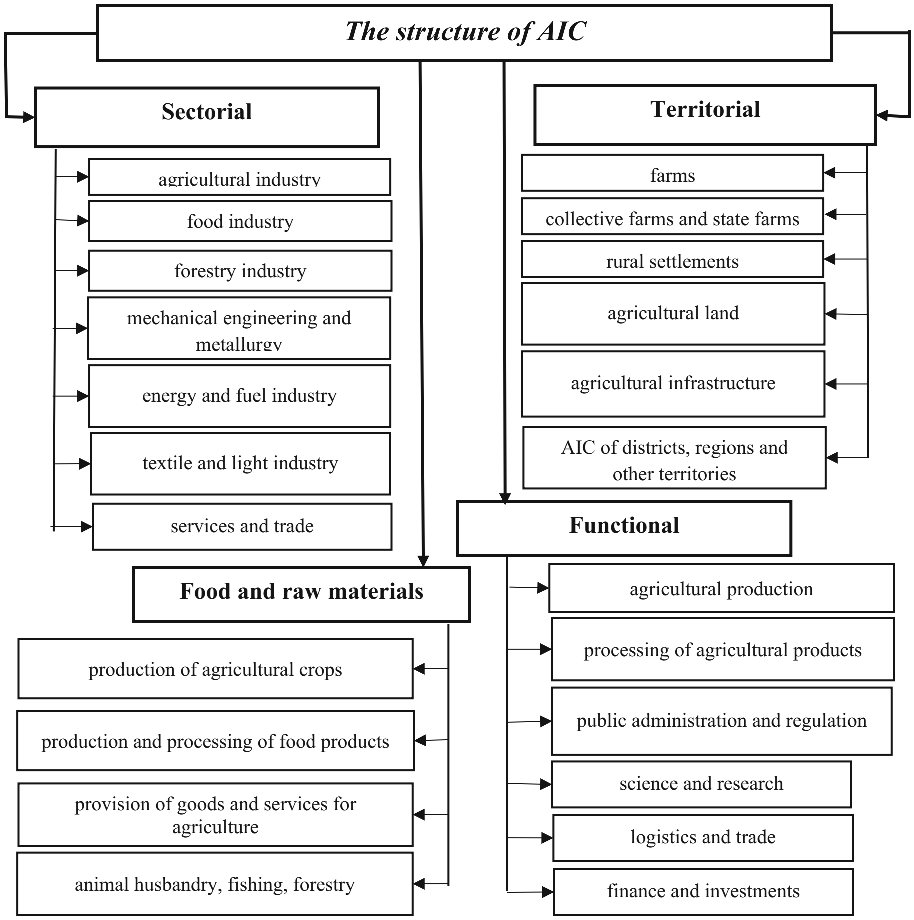

Fig. 1. The structure of the agroindustrial complex. Source: compiled by the author according to the data: [24]

The functional structure of agro-industrial complex includes farms, agricultural enterprises, cooperatives, and other organizations engaged in the production and processing of agricultural products; transport companies, warehouses, and distributors engaged in the transportation and storage of agricultural products; enterprises engaged in the wholesale and retail trade of agricultural products; enterprises providing financial support to the agro-industrial complex, including attracting investments and providing loans to agricultural organizations; enterprises engaged in agricultural research, the development of new technologies and production methods, professional development of industry employees, as well as government agencies that control and regulate activities in the agro-industrial complex, the development and implementation of legislation.

The territorial structure of the agro-industrial complex covers all the main components of the agricultural system and related infrastructure that operate in a certain territory. These are: agricultural enterprises operating on individual farm plots or in small agricultural homesteads; settlements in which the rural population lives and provides its social and household services; lands exploited for agricultural activities, including land for crops, pastures, farm plots; production units consisting of agricultural enterprises, processing enterprises, warehouses, transport and communal services, as well as financial and trade organizations associated with the agro-industrial complex; specialized places where the purchase and sale of agricultural products, seeds, fertilizers and other agricultural goods takes place; a system of roads, energy networks, water supply, sewerage, storages and other facilities that ensure the functioning of agricultural activities in a certain area.

The product and raw material structure consists of: production of agricultural crops, breeding and rearing of animals for milk, meat, eggs, and other livestock products, fishing and producing fish products in artificially created conditions, cutting, processing, and selling of wood, production of oil, flour, milk, meat, and other food products, including the production of agricultural machinery, fertilizers, seeds, and other resources.

Thus, agriculture holds a unique position in the framework of the agro-industrial complex, fulfilling the most significant functions for the national economy (Fig. 2).

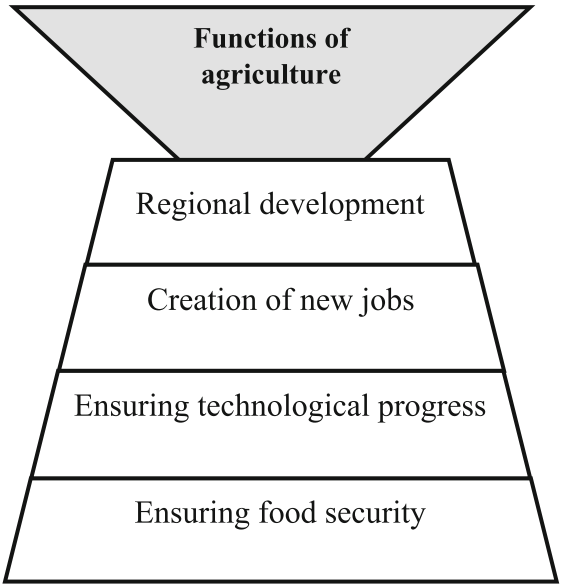

Fig. 2. Functions of agriculture as the main sector of the country's economy. Source: compiled by the author

Agriculture generates work in rural regions, which is especially important given that peasants constitute a sizable proportion of the Russian population. Agricultural development improves people's lives, discourages mass migration to cities, and encourages rural growth.

Agriculture development encourages the use of new technology and ideas, increasing agricultural output and efficiency. This can result in the growth of associated businesses such as mechanical engineering, the chemical industry, and transportation.

Agriculture provides the foundation for rural development. It helps to improve infrastructure, create jobs, and provide educational and medical services. As a result, it contributes promote economic development in remote and undeveloped areas. Finally, improving food security minimizes the level of dependence on foreign goods.

However, the agricultural sector of the economy can only carry out the functions described above if it continues to develop sustainably. The concept of sustainable development has specific relevance in the interaction between the expansion of human wants and the necessity for them to justify their usage of finite resources.

The modern concept of the Russian Federation's transition to sustainable development notes that "sustainable development provides a balanced solution to socio-economic problems and problems of preserving a favorable environment and natural resource potential in order to meet the needs of current and future generations of people" [3].

4 Discussion

The phenomena of "sustainable development" is interpreted differently by researchers studying the subject at hand. Tatarkin A.I. and Lvov D.S. define "sustainable development" as "stable socio-economic development that does not destroy its natural basis" [18].

Ursul A.D. and Los V.A. equate the terms "sustainable development" and "sustainable growth". We believe that this identification is not totally right, given that sustainable growth is a quantitative shift in economic indicators, whereas sustainable development is related with qualitative alterations of same indicators [3, 21].

Sustainable development is a term that refers to "transformations where the consumption of natural resources, scientific and technological development, personal development and institutional changes are interconnected and strengthen the current and future potential to meet human needs and aspirations" [10].

Ursul A.D. and Romanovich A.L. believe that sustainable development is a balanced improvement of society that operates without damaging the natural environment, ensuring civilization's continuous progress. The new sustainable development of civilization necessitates the integration of the economic, environmental, and social sectors of society. The biosphere is more than just a source of resources; it is also the foundation of life, and its preservation should be the primary prerequisite for the socioeconomic system's continued development [3; 22].

The intricacy of the notion of "sustainable development" has resulted in the establishment of several approaches to its interpretation (Table 1).

Of all the alternatives provided, we believe that the three-pronged notion of sustainable development best captures the content of this definition, emphasizing on the interrelationship of the factors that comprise sustainable development: economic, environmental, and social. Thus, we have defined sustainable development as a process aimed at meeting the social and economic demands of society with a level of accumulated labor potential that will protect and grow natural resources for future generations [3].

The conservation and enhancement of natural resources is especially important for agricultural activity. Human impact on nature during the farming process has had only negative consequences throughout history, resulting in the poisoning of the environment (water and soil), the extinction of some animal and plant species, and the violation of the ecological balance. Therefore, today the study of the notion of SD in connection with agricultural and rural areas (CT) is becoming very relevant.

Table 1. Main approaches to interpreting the term of "sustainable development."

№	The name of the approach (concept) to the definition of SD	Representatives	Content
1	Ecological and systematic approach [5]	V.I. Danilov-Danilyan, A.G. Granberg, V.I. Vernadsky, A.D. Ursul, F.B. Golley and others	Sustainable development entails having an impact on the environment while maintaining the biosphere's capability. The environment comprises both the economic and social worlds, which are stable thanks to a well-developed ecological system. Man and nature are harmonious
2	The concept of "weak" and "strong" sustainability [4, 25]	R. Costanza, G. Daly, K. Williams, E. Millington, R. Turner, and others	G. Dailey and R. Kosanza were the first to develop the main principles of the "ecological economy," i.e. the notion of strong sustainability, suggesting that the level of economic growth corresponds to the level of the life support system, i.e. economic indicators cannot exceed this system The term "weak" sustainability refers to the possibility of replacing natural resources with technology that promote economic growth

(*continued*)

Table 1. (*continued*)

№	The name of the approach (concept) to the definition of SD	Representatives	Content
3	The three-pronged concept of sustainable development [1]	E. Barbier, D. Sachs	The most widely used notion of sustainable development, which emphasizes three essential interrelated elements: economics, sociology, and ecological. The interdependent relationship of these three components should ensure a high standard of life for the population, economic development, and a favorable environment. Later, D. Sachs added another component to this triangle - the managerial one
4	The concept of corporate sustainability [2, 7, 6, 8]	J. Elkington, R. Stoire, T. Dillick, K. Hockerts, K. Y. Belousov, etc	The notion proposes that sustainable development will be evaluated via the lens of corporate development; that is, if sustainable development has previously only been considered at the macroeconomic level, its principles will now be implemented at the micro level
5	Cluster approach [15, 16]	M. Porter, M. Kramer, A. Carroll, V.M. Kapitsyn, O.I. Timofeeva I.E. Barsukov et al.	According to proponents of this approach, ensuring sustainable development is only possible through the formation of "clusters" - groups of interconnected corporations united by a common type of activity and focused on improving the economic performance of those enterprises that belong to a specific group (cluster)

Source: compiled by the author based on [1, 2, 4, 5, 7, 8, 14, 15, 16, 25]

V.A. Ivanov and A.S. Ponomareva define sustainable agriculture as having "three closely interrelated components: economic, social, and environmental" [9]. They believe that the agriculture sector's sustainability can be debated as long as the three components remain united in the future. Ushachev I.G. adds to previous researchers' work by discussing not only the presence of economic, social, and environmental components for the sustainable development of the agricultural sector, but also the presence of such a level of economic, social, and environmental development that leads to economic growth and an increase in the level of satisfaction of the population's needs [23]. Agriculture is described by Vasilyeva N.K. as "a complex system that includes the population, industrial and social spheres, as well as natural resources, and such agriculture when it is able to sustainably reproduce (sustainably develop) its full potential - soil fertility, means of production, as well as humans, throughout its occupied territory and indefinitely long time" [24]. This term, in our opinion, most thoroughly captures the content of this definition, emphasizing the necessity to replicate the maximum potential of agriculture.

5 Conclusion

Thus, sustainable agricultural development, in our opinion, is a three-pronged ecological, socioeconomic concept that aspires to maintain food security, enhance the standard and quality of life of rural inhabitants, and protect natural resources in the long run [20]. The agricultural sector's unique development is its capacity to adapt and retain production capacities in an ever-changing environment (see Fig. 3).

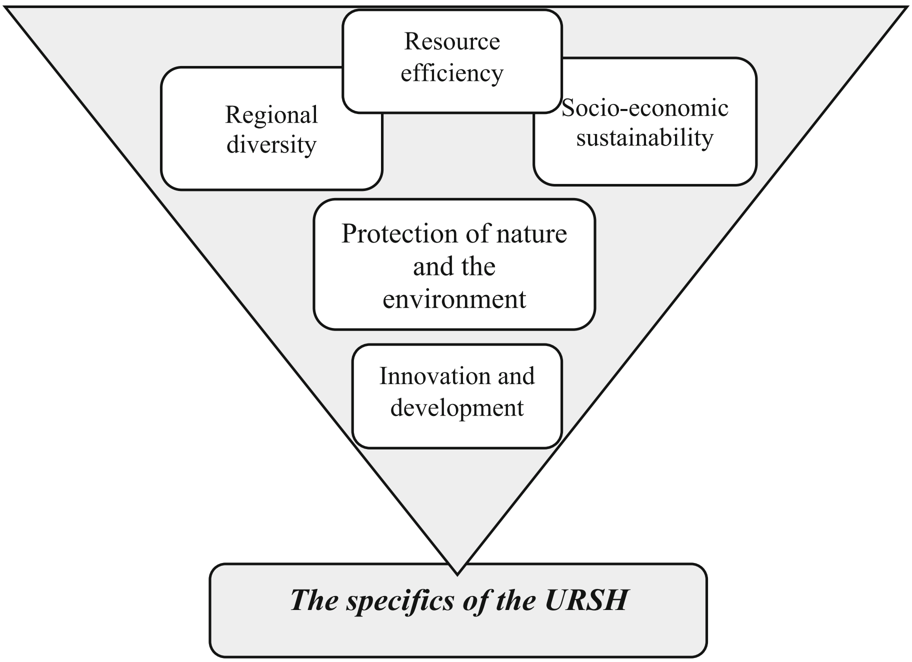

Fig. 3. The specifics of the URSH. Source: compiled by the author

The aim for efficient use of resources such as land, water, energy, and labor is referred to as resource efficiency as a specific aspect of agriculture sector sustainable development. To do this, sophisticated technologies are applied to increase the productivity of natural resources.

Each region has its own soil, climate, cultures, and traditions, and sustainable agriculture must adapt to these characteristics in order to ensure productivity while also maintaining a balance with the environment by minimizing the negative impact on natural resources (soil, water, air) and biological diversity, using effective cultivation and storage methods. Reduce the usage of chemical fertilizers and insecticides.

Agriculture should also provide a sustainable source of income for rural communities, create jobs, and encourage rural development. It is critical that agricultural output is economically efficient and competitive.

Thus, sustainable agricultural development is a modern concept based on the agricultural sector's ability to easily adapt to rapidly changing economic conditions while simultaneously achieving and maintaining a level of socioeconomic development and ecological balance capable of realizing one of the national economy's primary goals - ensuring food security - without disrupting the ecological balance.

For the progressive sustainable growth of the agricultural sector, it appears important to evaluate the elements influencing the realization of such development (Fig. 4).

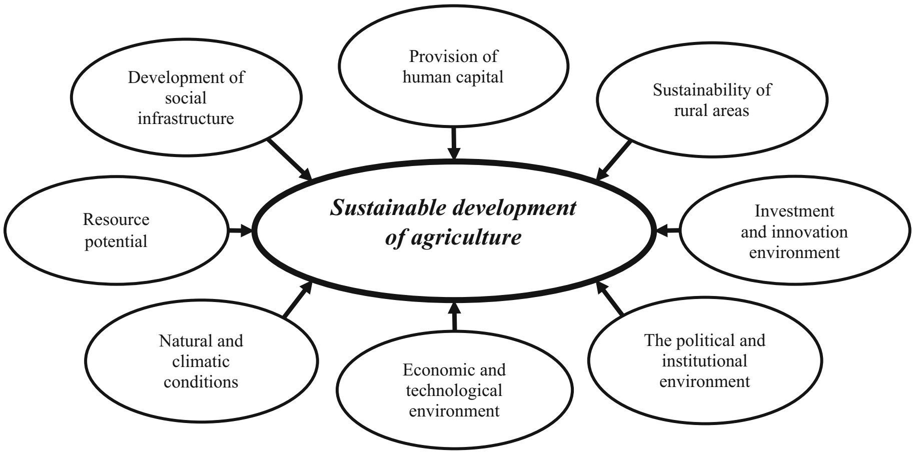

Fig. 4. Factors influencing the formation of sustainable agricultural development. Source: compiled by the author

The development of social infrastructure is one of the most important variables determining agriculture's sustainability. It is critical to the sustainability of agriculture for a variety of reasons:

1. Improving access to education through social infrastructure, such as preschools, schools, and colleges, helps rural residents develop skills and knowledge for modern agriculture, including land cultivation, technology, financial management, and marketing.

2. Improving access to health care, particularly for rural communities who typically have restricted access. The construction of social infrastructure such as hospitals, outpatient clinics, and medical centers facilitates access to high-quality medical treatment. Healthy rural dwellers have greater opportunity to work and engage in agricultural activities.
3. Improving transportation and communication infrastructure, including road networks and telecommunications, improves the flow of products and services in rural regions. This lowers the cost of transportation for agricultural products while also improving market access. Furthermore, improved transportation and communication infrastructure enables remote farmers to learn about new technology, market trends, and training programs.
4. Developing sports and leisure infrastructure, including facilities, parks, libraries, and cultural centers, improves the quality of life for rural communities. This, in turn, adds to recruiting and maintaining young people in rural regions. In other words, we may talk about delivering high-quality human capital capable of raising productivity, introducing innovations, and managing risks in rural areas [13].

Natural and climatic circumstances are another important component influencing agriculture's long-term growth. Weather occurrences such as droughts, floods, and unexpected temperature variations can severely influence yields and lead to losses for agriculture; soil quality and its capacity to sustain plant development directly affect yields. Insufficient soil fertility might result in decreased yields and the need for more fertilizer. The availability of fresh water for irrigation has a significant impact on agricultural production and plant health. Water scarcity or restricted availability can be detrimental to agriculture.

Agriculture's sustainability is influenced by economic stability and production technology. These variables influence agricultural investment prospects and profitability.

Rural sustainability is critical to agriculture's long-term viability. The functioning of sustainable rural regions is fairly broad.:

1. ensures the preservation of natural resources including soil, water, plants, and animals. The careful utilization of these resources helps to the length of agricultural production.
2. provides a conducive climate for agricultural operations such as animal husbandry, plant cultivation, and food production. Agriculture can supply the population's demands for food items under sustainable settings.
3. helps to raise rural inhabitants' earnings and improve rural communities. The presence of sustainable agriculture allows for employment creation, improving the economic position of rural populations, and promoting sustainable socioeconomic development.
4. reduces the harmful environmental effect of agricultural activities. The application of gentle agricultural technology and practices helps to decrease pollution emissions, conserve biodiversity, and prevent deterioration of soil and water resources.
5. Contributes to food security and reduces reliance on food imports.

Thus, agriculture is the core area of the agro–industrial complex, defined by its complex and multifunctional structure. The sustainable development of agriculture is a pressing issue in our day. Natural resource conservation, food security, and rural community development require the combined efforts of governments, international organizations, and the entire population. Agriculture may become a suitable environment for economic growth, environmental sustainability, and social development if approached correctly and implemented in accordance with sustainable principles.

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The Impact of Innovation Systems on Agricultural Sustainability

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Abstract. The growth of the world's population, climate change, in fact, today presents us with more and more reasons that make agriculture an increasingly important industry. In today's rapidly changing world, the sustainability of agriculture is an urgent issue. As the world's population continues to grow, the demand for food and resources is only increasing. At the same time, climate change, resource depletion and environmental degradation pose serious challenges to agricultural practices. However, there is hope on the horizon - innovations in the field of agriculture are changing the rules of the game, having a positive impact on the sustainability of the industry. The purpose of this article is to study the importance of innovations in agriculture and their impact on the sustainability of the industry. The article will explore various aspects of these innovations, including technological advances, sustainable practices, and policy frameworks. By understanding the role of innovation in agriculture, we can gain insight into how it can pave the way for sustainable farming practices and a secure future for generations to come.

Keywords: Sustainability of agriculture · innovation · innovative activity · impact of innovation · sustainability of agricultural systems

1 Introduction

Today, there are many negative external and internal factors that negatively affect the world around us. At the same time, these factors influence the increasing importance of the agricultural sector of the economy. But even though people understand the importance of the agricultural sector, we increasingly understand that the current state of this sector leaves much to be desired. There is growing concern about the sustainability of existing agricultural systems related to their management methods due to resource consumption and environmental destruction.

Nowadays, our generation is most clearly aware of what human greed and insatiability have led to. The state of the environment is in a very deplorable state. Thousands of plastic waste tons, gas emissions in the atmospheric air, the rapid absorption of natural resources by people - all this has brought us to our current position. Now the whole world is actively looking for ways to, if not restore, then at least slow down the "death" of the world around us. As they say "breaking is not making", so with regard to our planet, we can come to the conclusion that what has been "broken" for hundreds, if not

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thousands of years, it will be very difficult, if not impossible, to restore. But we are still trying to overcome this "impossible". Almost all countries of the world place an active emphasis on environmental protection and restoration, various bills, social projects are being adopted and volunteer and environmental movements are being created.

First of all, we are to determine what exactly is meant by sustainable agriculture. Agriculture has undergone quite a lot of changes, but this industry has changed especially quickly and massively after the World War II. Due to technological progress, the emergence of new technologies and mechanisms, the development of various chemical and biological compositions, and government policies to maximize production, food and fiber production increased rapidly [1].

Sustainability of agriculture is the use of renewable and non—renewable resources for agriculture by minimizing the negative impact on the environment. Sustainable agriculture combines three main goals: sustainability of the natural environment (environmental protection - planet), sustainability of economic enterprises (economic profitability - profit), sustainability of human social life (economic equality - people). These are the three categories that determine the sustainability of agriculture today. They are separate from each other, but at the same time inextricably linked and any changes in one will lead to movement in the other - sometimes it can be progress, sometimes regression, and sometimes stagnation of development [2].

The principle of sustainable development is the need to meet today's human needs while maintaining the ability to meet the needs of future generations. It is precisely this kind of resource management that comes first today, due to the limited and exhaustibility, as well as the non-renewable nature of resources. Human resource management is a concept that includes consideration of social responsibilities, including the working and living conditions of the working population, the needs of rural groups, as well as "today's" and "tomorrow's" consumer health and safety [5].

First of all, the need to manage land and natural resources is to maintain and (or) increase them in the long term. The consideration of agricultural sustainability issues is a voluminous concept that covers everything from individual small, sometimes even private farms, to the local ecosystem and even groups affected by the ecosystem, both locally and internationally. The modern focus on farming systems provides us with a more complete understanding of how farming practices affect the human community and the environment [4].

2 Materials and Methods

In this article the authors applied the following materials and methods:

- Literary review: The study and analysis of existing studies, articles, reports, books and other sources of information related to the introduction of innovations in agriculture and their impact on this branch of the economy.
- Theoretical analysis: The study and generalization of various theories and concepts related to the impact of innovation on agriculture and its sustainability, such as theories of economic growth, theories of innovation, theories of sustainable development.

- Qualitative and quantitative analysis: The application of data analysis methods to study the impact of innovation on agricultural sustainability, including statistical methods such as correlation analysis, regression analysis, time series analysis, and so on.
- Comparative analysis: Conducting a comparative analysis between countries or regions with different levels of innovation and their impact on sustainable agricultural development.
- Case analysis: The study of specific examples of successful innovation in agriculture and their impact on sustainability.
- Statistical data: Using data from international organizations, national statistical services and other open sources to analyze and illustrate trends and patterns in the field of innovation and sustainability of agriculture.
- Conclusions and recommendations: Formulation of conclusions based on the conducted research and development of recommendations for improving the sustainability of agriculture through innovation.

2.1 The Agriculture Sector: Its Importance for the Countries' Economies

Today the agricultural sector is actively developing all over the world. And Russia is no exception here. Agriculture in Russia is one of the most important sectors due to its economic, social and environmental contribution [1]. The agricultural sector is also one of the main "employers" of our country - about 7 million people are employed in the agricultural sector in Russia, and it is also one of the few viable activities in rural areas. The contribution of the agricultural sector to the country's GDP today, despite sanctions and other negative external effects, is almost 6%, of course, this does not compare with revenues in the oil and gas industry, but something else is important here. The Russian Federation almost completely ensures its food security.

We can see an active growth in the indicators of the agricultural sector in Table 1 below.

Table 1. Agricultural production in monetary terms for 2015–2022, production growth rate

The name of the indicator	2015	2016	2017	2018	2019	2020	2021	2022
Agricultural products, billion rubles	4794,6	5112,3	5109,5	2348,8	5801,4	6468,8	7710,3	8850,9
Growth rate, %	18,9	6,6	−0,1	4,7	8,5	11,5	19,2	14,8
Crop production, billion rubles	2487,3	2710,3	2599,7	2756,1	3056,4	3612,7	4464,7	5265,6
Growth rate, %	25,2	9,0	−4,1	6,0	10,9	18,2	23,6	17,9
Livestock production, billion rubles	2307,3	2402,0	2509,8	2592,7	2745,0	2856,1	3245,6	3585,3
Growth rate, %	12,9	4,1	4,5	3,3	5,9	4,0	13,6	10,5

https://rosstat.gov.ru/folder/210/document/13226.

In 2022, according to Rosstat, the growth rate of agricultural production in the industry as a whole increased by 14.8% compared to the level of 2021. In crop production, the growth was 17.9%, in livestock production 10.5% by 2021. Compared to the figures for 2021, there is a slight decline, but the industry is still one of the fastest growing in the economy. The growth in crop production was ensured by high grain yields, and poultry and pig farming in animal husbandry. In 2021, the number of profitable agricultural enterprises was 86%, in 2022 the increase was slightly more than 5%. The state is actively supporting the agricultural sector.

2.2 Current Problems of the Agricultural Sector of the Economy

Despite the rather good results in this industry. The problems of its productive development can be defined in four fundamental categories:

1. Institutional issues related to rules, concepts, agreements and coordination that affect the development of this sector [9];
2. Environmental sustainability associated with the need to create development paths that make the agricultural sector more environmentally sustainable [7], i.e. it is necessary to pay special attention to mitigating climate change, restoring the mineral resource base, mitigating the effects of human impact on the soil and nature as a whole;
3. Commercialization - market conditions affecting the way products and services enter the general economic market, as well as manufacturers' access to all levels of the market;
4. Productivity and innovation. The factors influencing them are: the size of enterprises, technological indicators, education and training, the development of innovative activities and financing.

2.3 Innovation as a Factor of Agricultural Sustainability: Benefit or Harm

Today's agricultural sustainability strategies focus on increasing the overall productivity of agricultural factors. It is the productivity in this industry that affects the profitability and rate of return on investment. This is where the interconnectedness of three categories comes into force: the sustainability of the natural environment (environmental protection - planet), the sustainability of economic enterprises (economic profitability - profit), the sustainability of human social life (economic equality- people). Profit depends on the productivity of human labor, labor productivity depends on the standard of living, which in turn again depends on profit, which is directly related to the state of the natural environment, and that in turn depends on human attitudes. If we use the resources given to us by nature unwisely, sooner or later they will decline, which in turn will entail a chain of negative consequences, in accordance with the previously indicated chain.

Agricultural research and development is a key factor in achieving agricultural sustainability achievements in the industry through a wide range of mechanisms and tools, including technological innovations.

The development of the modern world, digitalization and globalization, determines that innovation is a necessary part of the development of the agricultural industry. They contribute to the dynamic and sustainable development of the industry [3].

But we have not defined the interpretation of "innovation". They involve the process of commissioning a new or significantly updated and optimized product, product or service. Innovative activity is an activity that is directly aimed at the introduction and implementation of innovative projects, and innovation itself is its final result, presented in the form of a new improved product, product or service.

As mentioned earlier, the rapid development of all economic spheres has led to the fact that for the stability and sustainability of these very spheres, targeted innovation is necessary. The main and, undoubtedly, the defining goal of introducing innovations in the agricultural sector, and indeed in any other, is to increase productivity, and as a result, the profitability of the industry. Innovation is a concept that solves problems and satisfies needs, provides great benefits. The development and implementation of innovations in the agricultural sector has increased, to date, mainly due to favorable market conditions, national policies and the availability of scientific knowledge. The spread and introduction of innovations in this industry is increasing due to the increase in its investment attractiveness - both public and private sectors are interested in involving their capital in the industry, realizing its importance today, and actually the growth of this importance in the future [11].

But is innovation always a key to benefits when applied? We are to say that the answer is 'no'. In our opinion, innovative activity is often aimed solely at increasing productivity, but the specifics of the agricultural industry in this case is that it directly depends on the ecological state of the planet. When introducing various kinds of innovations, we often forget that what we "took" from nature must be restored so that in the future humanity does not have to exist on the verge of extinction.

Let's go into more details with the issue. The areas of agricultural innovation in each country vary to one degree or another. Their focus depends on the priority established in a given country by the state and the market. Considering this priority in Russia, we can say that, in general, we, like many developing countries, are focused on providing higher-quality and diverse agricultural products, as well as making production processes more efficient, improving the working conditions of employees and reducing the negative impact on the environment.

In recent years, the agricultural sector has undergone significant transformations due to innovations. Innovations in the field of agriculture have not only revolutionized the practice of farming, but also contributed to the sustainable development of the industry [12]. However, despite the many positive consequences of such achievements, there are also negative consequences that need to be taken into account. This article will address both aspects, provide examples and statistics to provide a comprehensive understanding of the impact of innovation on agricultural sustainability.

One of the most significant positive effects of innovations in the agricultural sector is an increase in crop yields [4]. Thanks to the use of modern methods and technologies, farmers have been able to significantly increase their productivity. For example, the introduction of precision farming, which uses data and technology to optimize resources, has led to increased yields and reduced resource losses. According to the Food and Agriculture Organization (FAO), precision farming has the potential to increase crop yields by up to 20% while reducing water consumption by 50%.

Another positive effect of innovation is the creation of sustainable farming methods. Agricultural innovations have paved the way for eco-friendly approaches such as organic farming and integrated pest control. These methods reduce dependence on harmful chemicals and increase biodiversity on farms, while ensuring long-term sustainability. A study conducted by the Journal of Sustainable Agriculture has shown that the introduction of organic farming methods improves soil health and mitigates the negative impact of traditional farming on the environment.

Innovation has also played a vital role in reducing post-harvest losses, which is another important aspect of agricultural sustainability. For example, the introduction of improved storage and transportation methods, such as cold storage and refrigerated trucks, has significantly reduced food spoilage. According to the United Nations, about a third of the food produced in the world is thrown into waste, and innovations can potentially save up to 250 million tons of food annually.

Although innovations in agriculture have undoubtedly brought numerous benefits, their negative consequences must be recognized. One of the main problems is dependence on genetically modified organisms (GMOs) [6]. Although GMOs have improved the resistance of crops to pests and diseases, some argue that their long-term effects on human health and the environment have not yet been fully studied. This requires an assessment of the potential risks associated with GMOs before their widespread adoption.

Another negative consequence of innovations in agriculture is the consolidation of power in the hands of large agribusinesses. The introduction of high-tech agricultural equipment and seed production technologies has led to increased costs for small farmers, who often find it difficult to afford these advances. As a result, small farmers are often forced to rely on larger companies, which leads to a loss of independence and the potential exploitation of their resources. This issue highlights the importance of promoting equitable access to innovative agricultural technologies.

Innovations in the agricultural sector have had a profound impact on sustainability, both positive and negative. Positive effects include increased crop yields, sustainable farming practices, and reduced post-harvest losses. These achievements have the potential to address the growing challenges of food security and environmental sustainability. However, the negative consequences should not be overlooked, especially with regard to GMOs and the consolidation of power. These challenges require a careful and balanced approach to ensure that agricultural innovation continues to foster positive change while avoiding any detrimental effects. By responsibly innovating, the agricultural sector can reach its full potential for a sustainable and secure future.

3 Conclusion

The impact of innovation on agricultural sustainability is an urgent and important topic in the modern world. The introduction of innovations in the agricultural sector can have both positive and negative effects, which must be taken into account when developing and applying new technologies.

One of the positive effects of introducing innovations in agriculture is to increase the yield and quality of agricultural products. Thanks to new technologies and methods of land cultivation, agriculture is becoming more efficient and productive. For example, the use of modern means of mechanization reduces the time and cost of tillage, and the use of genetically modified organisms increases the resistance of plants to pests and weather conditions [10].

The introduction of innovations also helps to optimize the use of resources. Modern irrigation, fertilization and crop storage systems can reduce losses and improve the efficiency of using water resources, fertilizers and energy. This is especially important in the context of climate change and the threat of depletion of natural resources.

However, the introduction of innovations can also have negative effects on agriculture. One of the problems is the dependence on new technologies and equipment. Agricultural enterprises that are unable to purchase new equipment or train their employees in new working methods may not be competitive and have to close down.

Also, the introduction of innovations can lead to an increase in the use of chemicals. Despite the fact that genetic modification can increase plant resistance, it can lead to an increase in the use of pesticides and herbicides, which in turn negatively affects the environment and human health.

Statistics confirm the positive impact of innovation on the sustainability of agriculture. For example, studies show that the use of modern technologies for cultivating land leads to an increase in yield by 2–3 times. Also, the use of new methods of storage and transportation of crops allows to reduce the level of product losses after harvesting.

Innovation has undoubtedly shaped the agricultural sector by increasing productivity, implementing sustainable practices and reducing food losses. However, we must also recognize and address negative impacts, such as the potential increase in dependence on agrochemicals and loss of biodiversity. In order to ensure a balanced and sustainable future for agriculture, it is essential to introduce and promote innovations, taking into account their environmental, social and economic consequences. Only with the help of responsible innovations can we achieve sustainable agriculture and solve the tasks of providing food to the growing population of the planet.

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Building and Developing the Entrepreneurial Potential of Rural Areas

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Abstract. The entrepreneurial potential of rural areas provides the necessary conditions for creating 'growth points' even in the most isolated rural settlements, which explains the urgency of this research. The research purpose is to study the entrepreneurial potential of ecovillages and develop the guidelines for generating the entrepreneurial potential in rural areas. In the course of research, the authors applied the monographic and logical methods, the methods of analysis, synthesis, analogy, survey, comparison, and content analysis. The scientific novelty of the work consists in 1) conducting a comparative analysis of the entrepreneurial potential of ecovillages, which has allowed identifying its specific features depending on the conditions of its formation and development, and 2) identifying the areas of entrepreneurial potential development taking into account personal advancement of entrepreneurs and state support measures for entrepreneurship. We found that the ecovillages under analysis are developing in the mainstream of trends typical for ecovillages. The rural residents are engaged in traditional activities, such as rural tourism, agriculture, arts and crafts, food processing, conservation and storage. The presence of creative entrepreneurs in ecovillages contributes to the formation of special zones for the entrepreneurial potential development in rural areas. Additionally, we defined the entrepreneurial potential and the interest of ecovillage residents in the entrepreneurial activity, which has helped to identify the areas for entrepreneurial potential development in rural settlements.

Keywords: entrepreneurial potential · rural areas · rural tourism · cultural heritage · rural infrastructure · agricultural business

1 Introduction

An ecological settlement (hereinafter referred to as an ecovillage) can be considered as an ideological community where residents are committed to nature sustainable development and conservation, as well as maintaining a healthy lifestyle. It is characteristic of such settlements to be built not only on the environmental ideas, but also on the ideas of personal development.

The origins of ecovillages in the West go back to the 1960s, while their emergence is closely connected with the establishment of alternative economic models based on the ideology of human personality development and an attitude of care towards nature. Having passed through a difficult formation stage, the survived communities changed

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their status to 'ecological settlements' (ecovillages). In the 1990s, ecovillages started integrating into international organizations and communities, which contributed to the establishment of the Global Ecovillage Network (GEN) (http://www.gen-europe.org/). Some examples of successful foreign ecovillages include the Findhorn community in Scotland (founded about 50 years ago, permanently inhabited by around 500 people), Twin Oaks in the USA (founded over 50 years ago), and The Farm in the USA (founded 53 years ago, with around 280 permanent residents).

The conducted analysis of scientific publications on the topic has allowed us to identify a number of research areas covering the issues of the establishment and development of the ecovillage settlement type.

The first research area includes publications on the impact of urbanization on the economic and environmental development of an economic space. Thus, O.A. Rastyapina and colleagues study the impact of urbanization on sustainable development of territories. In order to overcome the growing anthropogenic impact on the environment and people themselves and use land resources more efficiently, they propose developing ecological types of population resettlement based on rural communities. It has been found that this settlement type encourages the development of the economic base of a region, taking environmental factors into account [14; 042003].

It has been proved by P. Wang that self-organizing communities in China can be considered as an example of sustainability of social groups. Interactions in these communities are increasingly related to environmental issues and living space crisis in urban areas. The study has found that many social groups see self-organizing communities as an ideal alternative to the problems of rapid urbanization as they challenge unsustainable materialism and consumerism. The author applies ethnographic approaches to studying the life of a self-organizing community in South China (AnotherLand), which allows identifying how a self-organizing community maintains its sustainability by experimenting with a certain lifestyle (internal factors) and creating extensive social networks (external factors) [15].

Thus, an overview of research on the influence of urbanization on modern people's life and the issues of modern self-organizing ecological and ethnographic communities has revealed that the part of the population dissatisfied with the effects of urbanization prefers living in close communion with nature.

The second research area covers publications focusing on both ecovillages as a special type of population settlement and their residents' personal characteristics. For instance, using a grouped questionnaire, T. Kussaiynov and S. Tokenova conducted a large-scale study of rural communities which covered about 1,200 households [12; 18591866]. The authors attempted to characterize their sources of subsistence in terms of asset types and to identify opportunities and key constraints on productivity and resource management.

The work by D. Sopov and the team considers the evolution of the approach to organizing ecovillages in 1950–2020. [13; 020011]. Ecovillages have undergone a transformation from complete social isolation and primitive manual labour in the production of vital commodities to the creation of autonomous eco-cities operating on sustainable development principles and applying modern waste-free technologies for the production of energy, goods, and services in perfect harmony with the environment and people. It has been found that a defining feature of modern ecovillages is their multifunctionality.

The research results of D. Sopov and the team correlate with the study by Z. Yu, which analyses the peculiarities and advantages of the ecovillages Hanham Hall (Bristol) and Derwenthorpe (York), such as energy-saving technologies, ecological landscape, building combination and open space design, and architectural appearance and space design [16].

J. Farkas has found that many residents of Hungarian ecovillages consider traditional peasant culture to be an example of an ecological lifestyle, which results in a growing interest from ecovillage dwellers in peasant material culture [9; 383402]. The author presents the revival of the old tools of Hungarian peasant culture and the interpretation of traditional artifact-making activities in ecovillages.

D.K. Halim and E. Ervina analyse the development of tourist villages in Bali, which do not care about sustainability and are not as promoted as ecovillages, which leads to the deterioration of the natural environment [11; 012036]. Studying ecovillages and tourist villages has allowed identifying significant differences that affect the ecological burden and the perception of sustainable development in these settlements.

In his article, L.G.M.F. Duarte and colleagues study how the concepts of cultural complex influence the subjectivity of residents of two ecovillages in Switzerland and one in Brazil [8]. The authors found evidence that life in ecovillages develops collective complexes that mediate the relationships of individuals with their relevant groups regarding the aspects of individuality and collectivity and ways of relating to nature.

Thus, an overview of works on ecovillages shows that this type of settlement is aimed at reducing the anthropogenic load on nature and maintaining natural balance, which reflects in residents' worldview, the type of their economic activities, the architectural look of buildings, etc.

The third research area includes publications on human capital development in rural settlements, a type of which is ecovillages. B.A. Voronin and colleagues highlight that rural areas are a territory of labour and economic activity mainly for residents of rural settlements. Labor relations typically cover the areas of agriculture and forestry; in some regions – subsoil use and other types of economic activity [7; 05009].

S.G. Golovina and colleagues study the process of human capital development in rural areas analysing its key factors and opportunities for improvement (including the developments of entrepreneurial skills and creativity) [10; 83–102].

It is important to mention that the scientific works in the third group do not consider the development of entrepreneurial potential in relation to ecovillages; they are mainly devoted to human capital in rural areas.

Regarding Russian works on ecovillages, the research to stand out is the one conducted by the Zircon Research group in 2012 [1; 1–54]. It gives examples of successful ecovillages of its period of time, identifies the major issues faced by residents, and analyses various data on ecovillages available online.

E.V. Kuznetsova in her work examines the evolution of the ecovillage life cycle based on data collected in a sociological study [3; 170–179].

Family settlements have been a research subject for Yu.O. Andreeva [2; 104–116], A.G. Seleznev [4; 933–939], I.A. Seleznev [5; 933–939], T.N. Temnokhud [6; 6775] and others. These works mainly tackle the issues of worldview and assess the impact of family estates on territory development.

Thus, a review of research works on ecovillages has shown that the issues under analysis mainly include ecovillage establishment and development, human influence on the natural environment, and residents' worldview. The works on entrepreneurship in ecovillages are particularly scarce, which emphasizes the relevance of research on the development of entrepreneurship among ecovillage dwellers.

The purpose of this research is to analyse the entrepreneurial potential of ecovillages in the Krasnodar Territory of the Russian Federation and identify the procedural guidelines for generating entrepreneurial potential.

In order to achieve this purpose, the following tasks have been set:

– to study the theoretical foundations for building the entrepreneurial potential in rural areas;
– to analyse the existing entrepreneurial potential in the ecovillages of the Krasnodar Territory;
– to formulate proposals for building and developing the entrepreneurial potential of the ecovillages in the Krasnodar Territory.

A unit of analysis is ecovillages operating in the rural areas of the Krasnodar Territory. The subject of this research is a set of economic and management relations arising in the development of the entrepreneurial potential of rural areas.

2 Materials and Methods

Let us elaborate on the logic of our research.

At the first stage of research, we collected information about ecovillages in Russia. According to the Global Ecovillage Network, there is only one ecovillage in Russia – Dobraya Zemlya (Kind Land), which does not give a true picture of ecovillages in the country.

Russian ecovillages are heterogeneous in terms of their mission or ideological component; the following ecovillage types can be distinguished:

– traditional eco-settlements that undertake an 'ecological' mission of nature restoration and conservation;
– family estate settlements whose creators focus on implementing the concept of self-sustainment by living off the land;
– social settlements whose main mission incorporates the environmental and social trends in order to deal with difficult life situations of disadvantaged social groups (orphans, physically impaired people, etc.);
– religious settlements whose mission includes a religious element in addition to the ecological and spiritual ones (as a rule, inhabited by the followers of traditional or 'new' religions).

Further in the article we shall apply the term 'ecovillage' as a general term to refer to all ecovillage types.

According to poselenia.ru – a website that provides information about Russian ecovillages, family settlements, and family estates – as of January 2024, there are 401 ecovillages of various types in Russia. 13,985 people, which amounts to 6,904 families, are currently building their family estates throughout the country (Fig. 1).

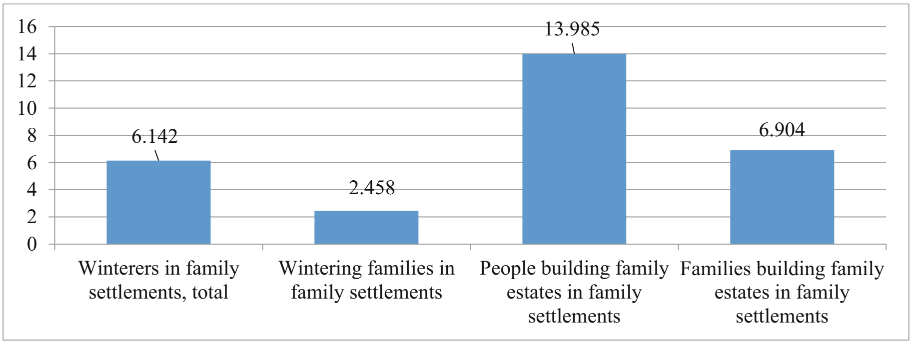

Fig. 1. Statistics on family estates in Russia according to poselenia.ru

The distribution of family estates by development status is as follows: 33% of estates are inhabited in winter; 25% are under construction (Fig. 2).

At the second stage of research, we drew a sample of ecovillages in the Krasnodar Territory according to the poselenia.ru website. The region houses 57 ecovillages, which makes it the leader in the Russian Federation in the number of ecovillages by territory. The Vladimir Oblast takes the second place with its 24 ecovillages. The region is known for its favourable climate and fertile soils, which creates optimum conditions for ecovillages. The performed analysis has revealed that the majority of ecovillages in the region can classify as traditional type and family estates.

At the third stage of research, in order to study the economic and entrepreneurial activities of ecovillage dwellers in the Krasnodar Territory, we developed and carried out a survey. The online questionnaire was distributed among ecovillage residents in the region.

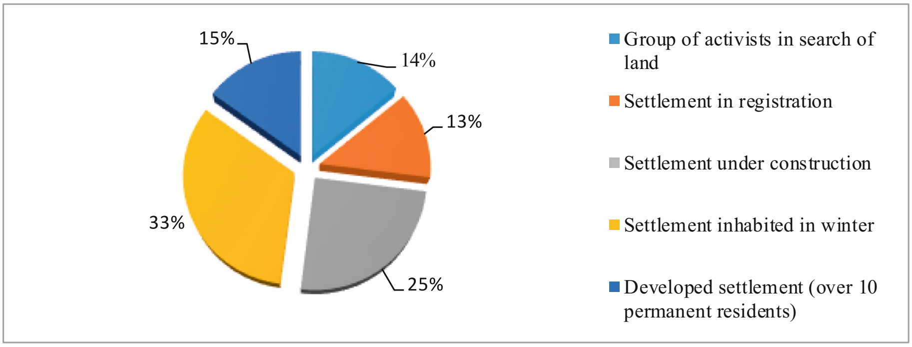

Fig. 2. Family estates in Russia by development status, according to poselenia.ru

The survey was conducted in the autumn of 2023. Sample size was 43 people. We should note that a number of potential respondents were somewhat reserved and refused to participate in the survey, which did not allow increasing the number of survey participants. 44.2% of respondents reside in the ecovillage Skazochnyy Krai, which is a family estate located in the Seversky district. 20.9% reside in the Novourupskoye rural settlement of the Uspensky district, 11.6% – in the Barakayevskoye rural settlement of the Mostovsky district, and 4.7% of respondents – in Balabushki (Fig. 3).

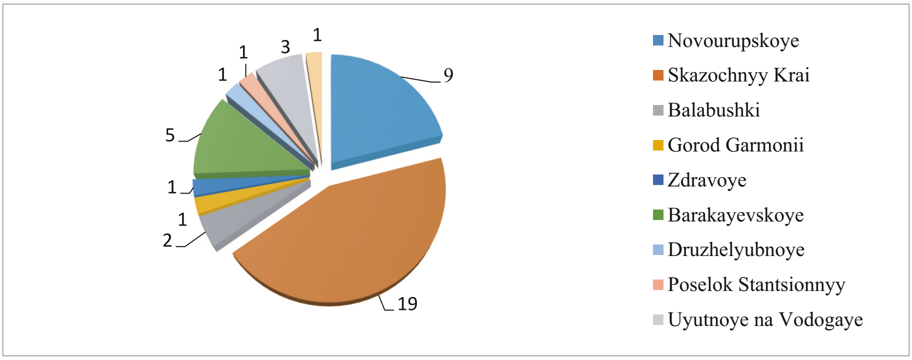

Fig. 3. Ecovillages and the number of respondents living in them

Ecovillages are mainly concentrated in the Seversky district of the region (55,8%), the Uspensky district (20,9%) and the Mostovsky district (16,3%).

According to the collected data, the majority of ecovillages (51,2%) have existed for 5 to 10 years, whereas 41,9% of ecovillages have existed for over 10 years. The obtained data related to the economic and entrepreneurial activities of ecovillages is presented in the Results section of the article.

At stage four of research, we developed proposals for building and developing the entrepreneurial potential of the ecovillages under consideration.

In the course of research, we applied the monographic and logical methods, the methods of analysis, synthesis, analogy, survey, comparison, and content analysis. The information base was formed by the data from the online survey of ecovillage residents in the Krasnodar Territory, as well as policy documents on business activities in three municipal districts of the region.

3 Results

As the survey data has shown, 48.8% of respondents are self-employed, 37,2% are owners of peasant farms, and 20,9% are retired. These figures allow making a conclusion that ecovillage residents are people who are used to fending for themselves and have a certain entrepreneurial spirit, which helps them survive in rural areas.

The main activities ecovillage dwellers are engaged in are traditional for this type of rural settlements and include rural tourism (34,9% of respondents), agriculture (32,5%

of respondents), arts and crafts, and food processing, conservation and storage (11.6% of respondents). 76,7% of respondents intend to continue working in tourism or start its development in their ecovillages. Among the most appealing types of tourism, they mention rural tourism (46,5% of respondents) and wellness tourism (11,6% of respondents).

Let us consider entrepreneurship development in three ecovillages of the Krasnodar Territory, namely the Novourupskoye rural settlement, the Barakayevskoye rural settlement, and the Skazochnyy Krai ecovillage.

The Barakayevskoye rural settlement is implementing the project «Craftsmen of Barakayevskoye». It was initiated by Natalya Izotova, who moved from city to village, decided to engage in rural tourism and received a grant to start her own tourism business. Having brought together talented craftsmen residing in Barakayevskoye, she launched the project. It aims to revive such crafts as hand reed weaving, lace tatting, making folk dolls, wood painting and carving, soap making, and baking (craftsmen bake homemade hop sourdough bread in a Russian wood-burning stove following traditional recipes). These folk crafts are the highlight of rural tourism in the Barakaevskoye rural settlement. Interestingly, what the residents are driven by is not only making profit but also preserving Russian traditions for future generations. Additionally, the fact that N. Izotova has been awarded a grant for entrepreneurs in the field of folk arts and crafts confirms the interest of local authorities in the development of this entrepreneurship activity. New residents coming to the ecovillage have resulted in positive changes leading to the revival of rural entrepreneurship and vigorous development of the rural settlement itself.

The dwellers of the Novourupskoye rural settlement are engaged in wood carving, weaving, carpentry, and pottery, but, unlike the residents of the Barakaevskoye rural settlement, they do not generate profit on crafts and consider them just as hobbies. Based on the existing village, the settlement has all the necessary infrastructure and facilities. According to Anastasia Yakovleva, a local resident, "none of the residents live solely from subsistence farming; we garden only for pleasure." The residents are mostly self-employed and engaged in business activities not related to agriculture or crafts.

Analysing the entrepreneurial activity in two ecovillages, we shall emphasize that the presence of a charismatic personality in a rural settlement, like N. Izotova, contributes not only to generating but also to developing its entrepreneurial potential, and allows creating special zones for the development of entrepreneurial potential in rural areas. The opportunities and resource potential of the two ecovillages under analysis can be considered equal.

The Skazochnyy Krai ecovillage with its 17 estates located in the Seversky district bills itself as a family settlement for entrepreneurs 'with pure intent'. It is necessary to highlight the entrepreneurial focus of the residents' activity in Skazochnyy Krai. Not only do they carry out natural activities, but they also provide intellectual services, as can be seen in the list of 150 types of business activities the ecovillage residents can do for a living. The ecovillage dwellers receive support from local authorities and develop rural tourism, agriculture (there are numerous orchards in the ecovillage), beekeeping and other types of business. It is remarkable that the residents of Skazochnyy Krai support each other's entrepreneurial activities, which enables them to transform accumulated

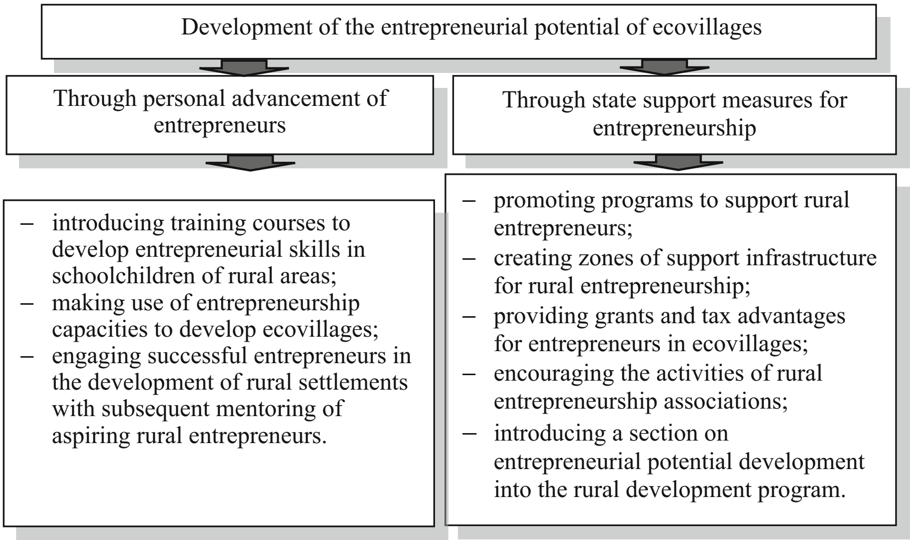

Fig. 4. Proposals for building and developing the entrepreneurial potential of ecovillages

knowledge and skills into entrepreneurial competencies. This contributes to building the entrepreneurial potential of rural areas.

The residents of three ecovillages under consideration have mentioned that they would appreciate additional support for their business activities. Thus, the research has defined the entrepreneurial potential and the interest of ecovillage residents in the entrepreneurial activity. We suggest that entrepreneurial potential should be developed in two directions: 1) through personal advancement of entrepreneurs and 2) through state support measures for entrepreneurship (Fig. 4). The implementation of these measures is expected to have a positive impact on building and developing the entrepreneurial potential in ecovillages, which will ensure its further reproduction.

4 Discussion

It should be emphasized that the results we obtained in the course of research correspond with the data from other studies on ecovillages. Similar trends have been found in the entrepreneurial and economic activities of ecovillage residents in the Krasnodar Territory, other regions of Russia, and other countries. Thus, ecovillage residents focus on generating profits on rural tourism or agriculture. This allows us to conclude that the three ecovillages under consideration are developing in the mainstream of trends typical for ecovillages. However, it is not conceivable to compare the development of the residents' entrepreneurial potential and state support for ecovillage entrepreneurship due to the fact that such studies have not been found.

5 Conclusion

In the course of research, we have studied the theoretical foundations for building the entrepreneurial potential of rural areas, which has enabled us to analyse the existing entrepreneurial potential of the ecovillages in the Krasnodar Territory and put forward the proposals for its formation and development. Therefore, the purpose and objectives of research have been achieved.

The practical significance of this research consists in the feasibility of applying the obtained results as guidance materials in government bodies with the purpose of building and developing the entrepreneurial potential of rural settlements. Subsequently, we plan to study the features of the entrepreneurial potential of ecovillages in more detail conducting special interviews and develop targeted support measures for residents engaged in entrepreneurial activity that strengthens the entrepreneurial potential of ecovillages.

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Directions of Ensuring Sustainable Development of Rural Areas (Case of the Omsk Region)

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Abstract. The article proposes a methodology for analyzing the level and dynamics of integrated development of territories and choosing mechanisms for ensuring sustainable development on its basis. The hypothesis of the integration of urban and rural areas as a mechanism for sustainable rural development is tested on the data of municipal statistics of one of the Russian regions. In addition, the authors identify other factors affecting the sustainable development of territories. Based on hierarchical cluster analysis, all municipalities in the region are divided into groups that reflect the level and dynamics of socio-economic development of the territories. The study revealed that the main factor influencing the level and dynamics of socio-economic development of territories is their close geographical location to cities, which confirms the hypothesis being tested. The relationship between the level of development and natural and climatic conditions is revealed. The results of clustering shows that traditional mechanisms for leveling the development of territories will not be able to solve the problems of territorial development. For the identified combinations of levels and dynamics of territorial development, the authors propose mechanisms that can be used to ensure sustainable development.

Keywords: Rural Territories · Municipalities · Sustainable Development · Rural Spatial Differentiation · Rural Development

1 Introduction

Today, the concept of sustainable development is one of the main ones in the development of territorial programs. The concept itself arose in response to the need to balance economic goals with the negative impact of development on the environment (1972, Limits of Economic Growth, Report of the Club of Rome [1]). Sustainable development is interpreted as a process of social and economic change that takes into account the needs of future generations for the place of residence and territory and ensures the preservation of the natural environment and resources. The UN identifies 17 Sustainable Development Goals, among which the fight against poverty, quality of education, decent work, reduction of inequality between urban and rural areas in quality of life, development of social and communal infrastructure are especially important for rural areas of the Russian Federation.

Each country has its own peculiarities of rural development. Despite active research on the theory and practice of sustainable development, the issue of finding mechanisms

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to ensure sustainable rural development, taking into account the characteristics of a particular region, remains relevant. It is the rural areas that have huge natural resources, ecological and historical potentials. At the same time, management of rural development is extremely difficult due to the lower standard of living compared to cities, limited employment opportunities, coverage and quality of social services, infrastructure development, etc. [2].

More often, studies on the problems of rural development use the term revitalization [3–5], which refers to the process of socio-economic revitalization of the territory, which implies the emergence of new types of economic activities, the development of the territory's infrastructure and the consolidation of residents. It should be noted that various revitalization mechanisms are used in the research, for example, the development of rural infrastructure and public spaces [4], improving financial mechanisms to support rural areas and strengthening targeting in the allocation of funds [6], investments in improving the quality of environment, and introduction of new technologies in the main sectors of the economy [5]. At the same time, the research of Chinese specialists focuses on changing the space and economy [3; 5], and European research focuses on the active position and participation of citizens in solving the rural areas problems, convenience and comfort of living (space development, not space exploration) [4]. The researchers also note the effectiveness of an integrated approach, when, taking into account the cultural characteristics of the area, all possible development tools are used and a multifactorial impact on the development process is ensured [7]. Another mechanism for sustainable development is the integration of urban and rural areas in order to ensure sustainability, when the task of urban development is to launch transformations in the associated countryside [3, 8]. Rural areas around cities with millions of inhabitants receive the greatest impetus for development.

Approaches based on public investments are used in world practice to solve the problem of unbalanced development and poverty in rural areas and increase the speed of development [9]. The issue of choosing a territory for financial support and the priority of support remains debatable. Several models of development support are presented in the literature: the alignment model and the growth point support model. Support for rural growth points is associated with the identification of territories that are drivers of development. The authors X. Cheng et al. note that the main revitalization strategy aimed at the overall development of strong agricultural industries, rural areas and wealthy farmers is effective in reducing the loss of talent, land, capital and other elements in rural areas [3, 10].

At the same time, another group of researchers emphasizes that the goal of sustainable development is social justice, which implies equal access to basic goods and services regardless of where a person lives, and therefore it is necessary to equalize territories in order to achieve the goals of social justice. Thus, the variation of factors such as population, land, industry, location, resources and the environment makes certain differences in the direction of rural and rural development [7].

For the Russian Federation, with its diverse territories, the issues of determining the factors and mechanisms of sustainable development of territories are of high relevance.

Russian researchers note the significant role of geographical factors in the formation and development of Russian rural areas [11] and the importance of their comprehensive assessment to determine key parameters of sustainable development in order to make further management decisions [12]. To solve this problem, the authors propose to use a methodology based on the grouping of territories using cluster analysis tools.

2 Materials and Methods

The purpose of the study is to group rural areas according to the level and dynamics of development in order to determine the typical characteristics of territories and the mechanisms of their sustainable development.

The study tests the following hypotheses:

- socio-economic development of rural areas is negatively related to the distance to the city and positively related to the size of the city.
- the socio-economic development of the territory is positively related to the availability of favorable conditions for agriculture.

To assess the development of rural settlements, we used data from municipal statistics of the Omsk region. The region is located in the south of Western Siberia. Omsk Region consists of 424 municipalities, including an urban district (Omsk is a million-plus city), 32 municipal districts, 365 rural settlements and 26 urban settlements (4 cities of regional significance, the rest are suburban settlements or urban-type settlements). Omsk region has an uneven density and settlement system, with a concentration of settlements in the southern part of the region. Thus, the average population density in the southern zone is 16 people, and in the northern zone – 2 people. Large fluctuations in density indicate a different degree of development of the territory, which depends on climatic conditions (the north is more unfavorable), infrastructural arrangement (the distance to the main market, the city of Omsk, is up to 500 km, the logistics of the region is limited to the Omsk market, there is no east-west connection in the north of the region). The south of the Omsk region is favorable for the development of agriculture. To assess the sustainability of rural development, the authors analyzed data from municipal districts, with the exception of indicators of socio-economic development of urban areas (Omsk, Nazyvaevsk, Tara, Isilkul, Kalachinsk). Data from municipal statistics were used to assess the sustainability of rural development.

The first block of municipal statistics is represented by indicators for evaluating the effectiveness of local government in rural municipalities in 2022. From this list, the authors selected indicators characterizing the economic and social development of rural municipalities.

The second set of indicators is development tables in the context of municipalities, containing indicators of infrastructure and social development (Table 1).

Some indicators of municipal statistics have been recalculated based on the population or the number of settlements in the municipality. A number of indicators for which there was no information for all municipalities (for example, the proportion of municipal preschool educational institutions whose buildings are in disrepair or require major repairs), as well as indicators that cannot be correctly calculated based on the population (for example, the number of medical and preventive organizations in a municipality, the number of sports facilities in settlements) were excluded from the analysis.

Table 1. Indicators of economic and social development of rural municipalities

Average values of indicators of economic development of rural municipalities	Average values of indicators of social development of rural municipalities
Name of indicator	Name of indicator
E1. The number of small and medium-sized businesses per 10,000 people, units (148.8)	S1. The total area of residential premises, on average per inhabitant - total, sq. m. (29.0)
E2. The share of the average number of employees (without external part-timers) of small and medium-sized enterprises in the average number of employees (without external part-timers) of all enterprises and organizations, % (16.1)	S2. The share of children aged 1-6 years receiving preschool general education services and (or) services for their maintenance in municipal general education institutions in the total number of children aged 1-6 years, % (54.9)
E3. The average monthly nominal accrued salary of employees, rubles (35090)	S3. The share of the total length of illuminated parts of streets, driveways of embankments at the end of the year, % (0.68)
E4. The full accounting value of fixed assets of all organizations of municipal ownership, thousand rubles per 1 person (70.6)	S4. The share of gasified settlements, % (24.5)
	S5. Percentage of settlements with water pipelines (separate water supply networks) (68.1)
	S6. Percentage of settlements with sewerage (separate sewerage networks) (5,6)

[authors' calculations]

The following indicators characterizing the dynamics of the municipalities' development were selected from the indicators of municipal statistics:

- the volume of investments in fixed assets per 1 person, rubles;
- the total area of residential premises put into operation for the year, accounting for an average per inhabitant, square meters;
- the share of heat and steam networks that were replaced and repaired during the reporting year;
- the share of a single stretch of the street sewer network that was replaced and repaired during the reporting year.

Given that the presented indicators have different dimensions and variability, the authors used data normalization for cluster analysis:

$$\widetilde{x_i} = (x_i - \underline{X})/\sigma_i,$$

where $\widetilde{x_i}$ – normalized value of the *i-th* indicator, x_i – original value of the *i-th* indicator, $\underline{X}$ – average value of *i-th* indicator, σ_i- standard deviation of *i-th* indicator.

3 Results

Using the method of hierarchical cluster analysis, we divided the entire set of rural municipalities into four groups. The results are presented in Fig. 1.

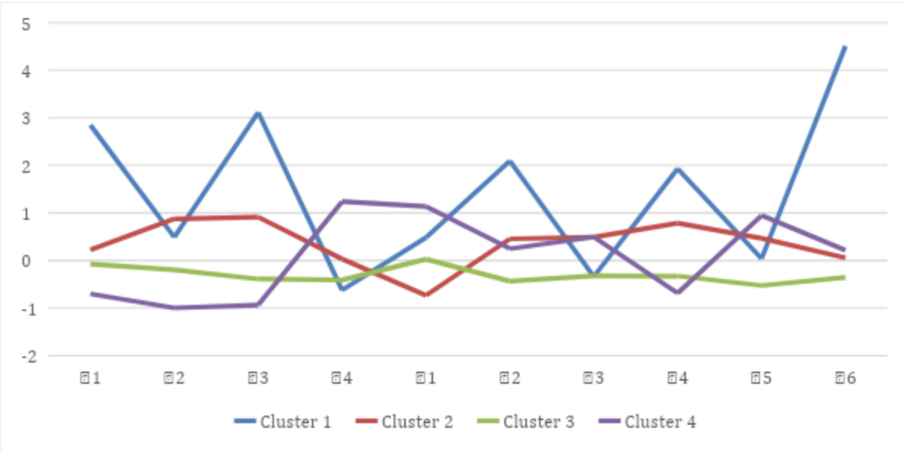

Fig. 1. Average values of indicators of sustainable development of rural municipalities in units of standard deviations.

The results indicate that there are differences in the level of development of municipal districts (the gap between leaders and laggards can reach up to 3 times in terms of indicators).

The leader of sustainable development (the group of medium and high level of development, cluster 1) is one municipal district. It is part of the Omsk urban agglomeration, which includes the city of Omsk (million-plus city) and the territory from the city borders at a distance of up to 100 km. A special feature of the cluster 1 municipal district is that the district encircles the city of Omsk. Thus, the hypothesis is confirmed that the most effective tool for sustainable rural development is the integration of urban and rural areas, when changes in the economy and urban space trigger transformations in rural areas.

The group of medium and above medium levels of development (cluster 2) includes rural areas located close to the city of Omsk (4 districts), or the territories of the south of the Omsk region (4 districts). It should be noted that the south of the Omsk region is a fairly developed territory with a high infrastructural arrangement with specialization in crop production, while 100 agricultural lands are used. This group also includes the northern Tarsky district (with the district center in the city of Tara, the second most populous city in the Omsk region). The entry of the Tarsky district into this cluster is also associated with the presence of a city on the territory of the district, as a potential point of growth of the territory. The economic specialization of Tara combines industrial machine-building enterprises and enterprises for processing agricultural products. The social sphere is characterized by the presence of personnel training centers for the north of the region and a drama theater, the only one in the north of the region.

The cluster of medium and below medium level of development (cluster 3) includes areas remote from Omsk at a distance of 150–250 km (rural areas of the south, center and north). Joining this group is associated with lower indicators of socio-economic development compared to group 1–2. The reasons for falling into this group are due to the initial lag behind other regions in infrastructure and economy, or to the loss of positions due to low activity in attracting funds from federal programs and national projects, aimed at the development of small and medium-sized enterprises and agriculture. This is the largest group, including the northern regions. It should be noted that there are no major failures in the provision of social infrastructure, despite the remoteness of the territory. That is, social funds have been created in this territory, but there are no economically attractive conditions for the population (lagging wages and the number of entrepreneurs). If growth points are identified for this group of territories, and special support programs are launched to revive the economic situation, it is possible to predict a decrease in asymmetry in terms of sustainability and an approximation to the average level of development. The presence of rural areas in this group, slightly remote from the million-plus city, indicates that the location next to large cities is not an absolute advantage for ensuring sustainable development. However, with an increase in investment, such territories can receive a significant agglomeration effect and can develop rapidly due to relatively small investments.

The last, fourth group (uneven development), also includes the northern regions (4 districts) and one of the southern regions of the region. These rural areas have significantly lower economic indicators compared to previous development clusters, but at the same time the cost of fixed assets of municipal ownership per capita is high. The northern regions of this group, due to the dispersion of settlements, require significant amounts of funds to ensure sustainability and they operate on previously created potential.

Further, the authors assessed the dynamics of rural development depending on the level of sustainability of development. As a result of the cluster analysis, all rural municipalities are divided into three groups according to the dynamics of development. Table 2 shows the relationship between the level and dynamics of the municipalities' development.

Table 2. Distribution of rural municipalities by level and dynamics of development

Clusters		Level of development			
		Cluster 1 Medium and high	Cluster 2 Medium and above medium	Cluster 3 Medium and below medium	Cluster 4 Uneven level
Dynamics of development	Cluster 1 Above average	1			
	Cluster 2 Average		5	2	
	Cluster 3 Below average		4	15	5

[authors' calculations]

Development leaders (rural areas from the group with high and above medium levels of development) also have high dynamics of development, which indicates opportunities to reach a stable trajectory. More than half of the rural areas that fall into the group of medium and above medium levels of development also have higher dynamics of development. 88% of rural territories belonging to the group of medium and below medium levels of development and 100% of the territories of the last cluster of uneven development are characterized by dynamics below average. The analysis of dynamics shows that if the current volume of investments is maintained at the expense of all sources, the asymmetry will remain. Traditional equalization mechanisms, including financial assistance, cannot solve the problems of lagging these territories. At the same time, it should be noted that a significant lag in economic indicators requires the development of special development tools. These could be special programs to support the development of the northern districts of the Omsk region at the expense of the regional budget.

Thus, it can be concluded that the impact on sustainable rural development is multifactorial and it is impossible to use a common approach in regional policy. When making decisions regarding the choice of territories for financial support, it is necessary to take into account the assessment and dynamics of rural development. In conditions of limited financial resources at the regional and municipal levels, it is possible to propose the main mechanisms for ensuring sustainable development in non-empty cells of the matrix (Table 3).

Table 3. Mechanisms of sustainable rural development

Clusters		Level of development			
		Cluster 1 Medium and high	Cluster 2 Medium and above medium	Cluster 3 Medium and below medium	Cluster 4 Uneven level
Dynamics of development	Cluster 1 Above average	Growth points support			
	Cluster 2 Average		Growth points support	Combination of alignment and growth points support	
	Cluster 3 Below average		Alignment	Alignment	Alignment

Growth points support is based on active participation in the state program "Integrated Rural Development" and the attraction of extra-budgetary funds to create infrastructure (under the terms of participation, a certain share of co-financing is provided by business entities). Alignment presupposes the priority of these rural territories for participation in regional and federal programs for the creation of water supply, gas supply, and social infrastructure (increasing targeting in the distribution of funds between territories and the allocation of subsidies for connecting to the engineering infrastructure of the population). Identifying economic niches for the development of small and medium-sized businesses and self-employment is a strategic task for any type of rural area.

4 Discussion

The conclusions obtained by the authors generally do not contradict the available Russian and foreign studies on the peculiarities of rural development [2] and the significant influence of geographical factors [11] and geographical proximity to a large city [3; 8] on it.

In general, the main factors influencing the sustainability of territorial development at the regional level are:

geographical location (southern regions with more favorable climatic conditions have great signs of sustainable development);

for rural areas, it is important to be relatively close to million-plus cities, the closer to a million-plus city, the higher the probability of sustainable development;

the size of the urban area adjacent to the rural area also affects sustainability (the larger the city in the area, the higher the probability of sustainable development);

districts in similar conditions may have different assessments of sustainable development, which is associated with the activity of municipal authorities in attracting funds from the regional and federal levels to increase the provision of social infrastructure;

Thus, a combination of factors can influence sustainable development. Therefore, an individual set of activities, projects and programs can be developed for a specific region. Understanding the factors of ensuring the sustainability of development in each specific case will allow regional authorities to develop effective mechanisms to increase the sustainability of development.

We found out that, in addition to the geographical location and the depth of integration with the regional center, other factors determining the inequality of municipalities are also significant. Territories located in relatively homogeneous geographical conditions have different characteristics of development. This conclusion is interesting from the point of view of further research on the influence of management teams and heads of municipalities on the development of territories, and also raises the question of the role of environmental transformation and human activity in sustainable development.

At the same time, it is important to note that the analysis of sustainable rural development is largely limited by the availability and quality of municipal statistics. Many indicators important for the analysis of sustainable development are currently evaluated only at the regional level. The importance of the problem under consideration requires updating the indicators of municipal statistics.

5 Conclusion

The conducted research made it possible to better understand the causes of uneven development of rural municipalities. The hierarchical cluster analysis formed groups of regions that differ in the level and dynamics of socio-economic development. The analysis of the selected clusters confirmed the hypothesis that the socio-economic development of a municipality is related to the distance to the city and its size. The area surrounding the regional center has the best indicators of the level and dynamics. Another point of growth is the geographical proximity to Tara, the second largest city in the region. On the contrary, districts located further from the regional center are more likely to fall into a cluster with relatively low indicators of the level and dynamics of development. The second hypothesis about the positive relationship between the development of the territory and the availability of conditions for agriculture has also been confirmed. Southern forest-steppe and steppe regions were more often included in clusters uniting territories with a relatively high level of development, in contrast to the taiga northern regions, which were more often concentrated in clusters with lower indicators of development.

In conditions of rather severe budget constraints, support for such different territories requires the use of different mechanisms – from growth point support to implementation of an alignment policy.

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Limit Allowable Value of the Bank of Russia Key Rate: Based on the Example of Agricultural Holdings

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Abstract. The purpose of the work is to substantiate the maximum value of the Bank of Russia key rate using the example of the activities of holdings in agricultural system. The results of the study are partially hypothetical and allow us to answer the question regarding the maximum permissible value of the key rate of the Bank of Russia, subject to the refusal of subsidizing bank lending and the use of bank loans by organizations in the agricultural system on market conditions. The average statistical values of profitability indicators for a sample of agricultural holdings were determined for the period 2009–2022, the values of which were: return on assets - 7%, return on current assets - 14.5%, return on equity - 19.5%. Provided that agricultural holdings use bank loans on market conditions, we determined that in the long term the key rate for such entities should not be higher than 4–5% per annum; in the medium term it is acceptable - no higher than 11.5–12.5% per annum; in the long term it is critical if the key rate is higher than 16.5–17.5% per annum.

Keywords: Agricultural Holding · Large-Scale Agricultural Producer · Return On Equity · Return On Assets · Agricultural System · Key Rate of the Bank of Russia · Inflation · Bank Loan

1 Introduction

The key rate of the Central Bank in the country, and in the case of Russia - the Bank of Russia, is a widely known and frequently used tool for reducing inflation in the country. Such an instrument of macroeconomic regulation can be compared to a kind of medicine for the country's economy, which is "bitter", but is considered useful when the inflation rate increases significantly. However, in medicine, the practice of using drugs requires strict adherence to dosages. Whatever medicine is good, there should not be too much of it. By analogy with medicine, the question arises about the limits of using the key rate as an anti-inflationary tool. The minimum limit for such a rate assumes a zero value,

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although in rare cases it can be negative. But the upper limit raises questions. In addition, an increase in this rate is a reducing factor in curbing inflation.

In 2023, the key rate of the Bank of Russia rose to 16%, but in the history of the country there were cases when such a rate reached the level of 20%. At the same time, the Central Bank of Turkey raised the corresponding rate in September 2023 to 30%. If in this country it has reached such limits, why not raise it in Russia to a similar level in order to finally neutralize inflation.

For the Central Banks of most countries, this is practically the only tool that they can counter with price increases. At the same time, many expect any decisive actions from regulators to reduce prices and strengthen the national currency, and this issue often develops from an economic one into a political one. Few people like rising prices and falling national currency. As soon as consumer prices rise in a country and the exchange rate of the national currency falls, many political forces and economic participants in the country demand decisive action from the regulator. Therefore, the key rate has until now been and is a popular means of combating inflation, widely used in practice.

On the other hand, the corresponding decisive actions of the regulator are associated with an increase in the key rate. But in addition to the impact on reducing inflation and the growth of the national currency, such a measure negatively affects other factors of economic processes in the country's economy. As they say in medicine: "we treat one thing and cripple another." Raising the key rate increases the price of credit money in the financial market, which is a significant obstacle to business scaling, further increasing the costs of enterprises. An excessively high value of the key rate can make the use of borrowed funds completely inappropriate. In conditions when a number of sectors of the economy are dependent on such a resource, a high key rate in the long term may stop the existence of enterprises in such sectors. Thus, "the drug used kills the patient due to excess dosage."

Taking into account the advantages and disadvantages of the regulatory instrument under consideration, there must be a limit value that cannot be exceeded in the long term, no matter what the inflation and the rate of devaluation of the national currency. The definition and justification of such a value is relevant in the context of its increasing trend.

Ideally, the appropriate value should be determined based on a study of the maximum capabilities to withstand an increase in the key rate of key sectors of the country's economy. In most countries, there are different industries that are basic to the national economy, but at the same time have varying degrees of ability to withstand high key rates in the long term. A low value favours absolutely everyone equally.

In our study, the emphasis is on Russian agricultural holdings, as the most technologically advanced representatives of the agro-industrial system, which are also large-scale agricultural producers, which, in the context of sanctions and the urgency of implementing the country's food security programs, puts these entities in the rank of key enterprises, the liquidation of which on a significant scale is unacceptable for the national economy.

It can be noted that there is a significant number of works devoted to the key rate of the financial market regulator, as well as the impact of inflation on business entities [1–6]. The issues raised are directly related to the issue of the maximum value of the key rate of the regulator, however, the research results in the presented works do not provide a final answer regarding this value for Russian agricultural holdings.

The vast majority of other works on the problems of the activities of the agricultural system [7–11] allow us to state the high importance of this industry for the country's economy, when its liquidation or significant reduction in the volume of activity is unacceptable. Unfortunately, in the presented works and others that are devoted to the agricultural systems, one can notice a significant disregard for the influence of the key rate on the activities of such organizations.

It is possible that the large number of works devoted to the study of the application and influence of the key rate of the regulator in the financial market does not allow us to identify studies that would justify its maximum permissible value in relation to the economy as a whole or to a particular industry. The small number of such studies makes a more in-depth development of this area urgent.

The purpose of the work is to substantiate the maximum value of the Bank of Russia key rate using the example of the activities of agricultural holdings.

2 Materials and Methods

We proceed from the fact that theoretically in the national economy a number of basic industries are of fundamental importance for the country's economy and cannot cease to exist completely or on a significant scale. Let us assume that such industries include the agricultural systems and agricultural holdings in particular.

In this case, the key rate should ensure and not impede the processes of business scaling for the average industry entity.

It is known that a fundamental condition for scaling a business is the ability to use credit resources when:

$$\mathrm{ROA} > \mathrm{PBC}, \tag{1}$$

where ROA is the return on assets of an average business entity in an industry necessary for the economy, %;

PBC is the market value of bank loans or the price of using borrowed capital, % per annum.

Wherein:

$$\mathrm{PBC} = \mathrm{KR} + \mathrm{MB}, \tag{2}$$

where KR is the key rate of the Bank of Russia (regulator), % per annum;

MB - commercial bank margin, which is 2 - 3%, sometimes 5%. Depending on the magnitude of the risk and other factors.

If the parameters of formula (1) are observed, ideal conditions are met for the average subject of industry to be able to use bank loans on market conditions. In this case, the regulator's key rate should be 2–3% less than the return on assets of such an entity.

In the long term, the value of the regulator's key rate should not exceed the level of return on assets of the average business entity in an industry important for the country's economy.

But this is in the long term, when the situation in the economy develops according to a scenario that is favourable for the national economy with a minimum level of inflation. In practice, such conditions are not always met, and the regulator has to significantly increase the key rate to counter inflation. Given the relatively low values of return on assets in many industries, the question of the final upper limit for increasing this rate arises.

Taking into account the basic provisions of financial management, it can be assumed that in the short term, business entities take bank loans mainly to form current assets. It should also be assumed that the crisis increase in the regulator's key rate should not be long-term in nature: a crisis with high inflation, in principle, should not be eternal and long-term. Therefore, as a compromise solution, a condition can be accepted when:

$$\text{RCA} > \text{PBC}, \tag{3}$$

where RCA is the return on current assets of the average industry entity, %.

Considering that the total value of assets of most business entities is always greater than the value of current assets, then:

$$\text{RCA} > \text{ROA}, \tag{4}$$

But is the achievement of the regulator's key rate of return on current assets the limit of a business's ability to withstand a further increase in such a rate?

When the price of borrowed capital (PBC) reaches the value of the return on current assets of the average industry entity, then the conditions for scaling a business through the use of bank loans are less favourable than when ROA > PBC. However, in some cases, such loans can be used to form current assets, and the business as a whole develops, but mainly at the expense of equity capital.

That is, for such a business, the value of the regulator's key rate in the amount of its profitability of current assets is not critical.

In the medium term, the value of the regulator's key rate should not exceed the level of profitability of the current assets of the average business entity in an industry important for the country's economy.

What then is the value of the regulator's key rate in the long term that will completely eliminate the business of an average business entity?

If the key rate of the Bank of Russia rises and in the long term remains at a level where the return on equity (ROE) is less than the price of borrowed capital (PBC), the corresponding business becomes inappropriate:

$$\text{ROE} > \text{PBC}, \tag{5}$$

Therefore, raising the key rate to the level (RSK) of the average business entity in an industry important for the economy is possible only in the short term. In such conditions, it is not economically feasible to use bank loans on market conditions, and it also makes sense to sell the business and transfer capital to other areas.

In the long term, the value of the regulator's key rate should not exceed the level of return on equity of an average business entity in an industry important for the country's economy.

Considering the agricultural system and agricultural holdings as such entities, the task of the study is to determine the values of their corresponding indicators: return on assets, current assets and equity capital. The average statistical values of such indicators serve as conditional boundaries of the zones of permissibility of raising the key rate of the Bank of Russia.

Acceptable risk zone: the value of the key rate (KR) from 0 to ROA - MB, that is, KR < ROA - MB.

High-risk zone: ROA - MB < KR < RCA - MB.
Critical risk zone: RCA - MB < KR < ROE - MB.

Without the ability to quantify the average statistical indicators (ROA, RCA, ROE) of all agricultural holdings in the country using official statistics, one can resort to the method of selective observation. Based on the ratings of the country's leading agricultural holdings, we identified 50 entities that are directly related to them, which are presented in Table 1 and are predominantly management companies in such holdings. The sampling principle is the inclusion of lists of relevant ratings.

Table 1. The first sample of entities (mainly management companies) related to the country's leading agricultural holdings

№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject
1	5003077160	11	6025024237	21	1303067817	31	3403014273	41	7113502396
2	7718560636	12	2356040994	22	7708813052	32	3602007714	42	6162015019
3	7816430057	13	7735004043	23	7721242760	33	1203005214	43	7708632345
4	2315014748	14	6167054653	24	3614005528	34	7017012254	44	7708525142
5	3913009739	15	2328000083	25	5024126971	35	7453268150	45	2901170107
6	7017094419	16	3116002683	26	3662104737	36	7714937659	46	3328458132
7	3122504272	17	1831089218	27	6163070862	37	2631805988	47	7715034360
8	7704669440	18	3123100360	28	1207007950	38	7716128854	48	7721147115
9	3123160948	19	1604010557	29	1657049075	39	5948025679	49	3116003662
10	7730202605	20	0411137185	30	7424030241	40	7816455333	50	6163072316

Naturally, the selective observation method has objective disadvantages, which will also affect our study. To neutralize such shortcomings, we expanded the sample to 110 entities (Table 2), where, based on the same ratings, we included entities from other agricultural holdings, and also included entities that are not management companies in the structure of these holdings.

Using the source of information [12], we determined the average statistical values of the required indicators for both samples. Since the source [12] presents data for the period 2009 - 2022, this period became possible for the corresponding study.

Table 2. The second sample of entities related to the country's leading agricultural holdings

№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject	№	Individual tax number of the subject
1	5003077160	23	7721242760	45	2901170107	67	5528001851	89	6829076796
2	7718560636	24	3614005528	46	3328458132	68	5528028116	90	7718972679
3	7816430057	25	5024126971	47	7715034360	69	4004001997	91	7718548798
4	2315014748	26	3662104737	48	7721147115	70	7810152029	92	6829052210
5	3913009739	27	6163070862	49	3116003662	71	1658029057	93	4812042756
6	7017094419	28	1207007950	50	6163072316	72	7721235763	94	3664078874
7	3122504272	29	1657049075	51	4100000530	73	7714626332	95	5032000235
8	7704669440	30	7424030241	52	7438015885	74	5836650508	96	4703108044
9	3123160948	31	3403014273	53	3811185573	75	3906072585	97	5809022198
10	7730202605	32	3602007714	54	3128052689	76	4623004836	98	4246006730
11	6025024237	33	1203005214	55	4706002688	77	6330050963	99	7017302796
12	2356040994	34	7017012254	56	7703011680	78	6453110490	100	7017166840
13	7735004043	35	7453268150	57	3923004320	79	4628005230	101	2310105350
14	6167054653	35	7714937659	58	5722033117	80	5717001991	102	1624004583
15	2328000083	37	2631805988	59	4823037028	81	5817003417	103	7705274941
16	3116002683	38	7716128854	60	7704702640	82	7728307368	104	3122509834
17	1831089218	39	5948025679	61	7701174512	83	4621001614	105	4619004640
18	3123100360	40	7816455333	62	5528001523	84	7460002000	106	3109003598
19	1604010557	41	7113502396	63	5500000061	85	2540203376	107	3250519281
20	0411137185	42	6162015019	64	5020002260	86	6804008674	108	3115006100
21	1303067817	43	7708632345	65	7224005872	87	6803120472	109	3252005997
22	7708813052	44	7708525142	66	0273010086	88	7722607816	110	5720020715

3 Results

The dynamics of the studied indicators for a sample of 50 subjects are presented in Table 3.

The dynamics of the studied indicators for a sample of 110 subjects are presented in Table 4.

Table 3. Dynamics of profitability indicators of a sample of 50 entities related to the country's leading agricultural holdings

Indi-cator	Years														Average
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
ROA	5,04	4,57	4,30	6,10	6,23	7,95	12,78	3,42	4,49	8,23	9,17	10,91	9,45	7,91	7,18
RCA	9,58	8,06	7,88	10,99	12,23	15,57	23,88	6,86	9,78	18,17	21,95	24,64	20,81	15,82	14,73
ROE	19,86	14,67	14,11	17,50	19,48	24,46	32,52	8,92	12,04	21,85	21,00	24,67	21,33	20,18	19,47

Note: the value of profitability indicators was calculated based on profit before tax

Table 4. Dynamics of profitability indicators for a sample of 110 entities related to the country's leading agricultural holdings

Indi-cator	Years														Average
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	
ROA	6,24	5,30	4,93	5,66	5,24	7,19	9,07	4,43	4,88	7,99	8,18	9,93	9,34	7,33	6,83
RCA	12,17	10,08	9,53	10,85	10,52	14,77	17,57	9,12	10,78	17,58	18,98	21,75	20,83	14,80	14,24
ROE	19,16	15,12	14,55	16,09	15,20	21,86	27,30	13,32	14,76	24,26	21,77	26,15	24,77	20,76	19,65

Note: the value of profitability indicators was calculated based on profit before tax

A comparison of the average statistical results for two samples (Table 2 and Table 3) showed a slight discrepancy between them, which allows them to be used as representative ones.

By averaging the results obtained, we can summarize the following values of indicators of Russian agricultural holdings in the long term:

– return on assets: ROA = 7%;
– return on current assets: RCA = 14.5%;
– return on equity: ROE = 19.5%.

The permissible zones for raising the key rate of the Bank of Russia for agricultural holdings are as follows.

Acceptable risk zone: KR < 7% – 3% = 4%.
High-risk zone: 7% - 3% < KR < 14.5% - 3%.
Critical risk zone: 14.5% - 3%. < KR < 19.5% - 3%.

In the long term, it is desirable for Russian agricultural holdings that the key rate should not be higher than 4–5% per annum.

In the medium term, it is acceptable for these entities that the key rate should not be higher than 11.5–12.5% per annum.

In the long term, it is critical for Russian agricultural holdings if the key rate is higher than 16.5–17.5% per annum.

Otherwise, in order to preserve and develop the agro-industrial system, it is necessary to provide government subsidies to the interest rate on bank loans.

The presented limits of risk zone boundaries for Russian agricultural holdings, depending on the value of the Bank of Russia key rate, are important for lending on market conditions. In the case of state subsidization of interest rates on bank loans or preferential use of equity capital for business activities, only a comparison of the key rate with the return on equity of the subjects under study is important.

4 Discussion

A debatable issue in this study is the sufficiency of the sample to obtain reliable results. However, the authors specifically present the results of different samples. The minimum deviation of the corresponding results allows us to state the possibility of using a sample of 50 subjects.

The selective observation method has objective disadvantages. But this research method is often used in cases where it is impossible to use continuous observation. In modern realities, it is impossible to apply the method of continuous observation regarding agricultural holdings in Russia, so the authors are forced to use a sample.

5 Conclusion

At the present stage of development of the agricultural system in Russia, organizations in the sector, like agricultural holdings, often use government subsidies of bank lending in the amount of the regulator's key rate. Therefore, the results of the study are partially hypothetical and allow us to answer the question regarding the maximum permissible value of the key rate of the Bank of Russia, subject to the refusal of such subsidies and the use of bank loans by organizations in the agro-industrial system on market conditions. At the same time, not all agricultural holdings benefit from state subsidies of bank loan rates.

The average statistical values of profitability indicators for a sample of agricultural holdings were determined for the period 2009–2022, the values of which were: return on assets - 7%, return on current assets - 14.5%, return on equity - 19.5%. These values are determined based on profit before tax.

It is reasonable to consider these indicators and their values as the maximum permissibility limits for raising the key rate of the Bank of Russia, provided that agricultural holdings are essential for the country's economy and cannot cease to exist completely or on a significant scale.

Provided that agricultural holdings use bank loans on market conditions, it has been determined that in the long term it is desirable for such entities that the key rate should not be higher than 4–5% per annum; in the medium term, it is acceptable - no higher than 11.5–12.5% per annum; in the long term it is critical if the key rate is higher than 16.5–17.5% per annum.

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The Balanced Scorecard: Integration into the non-financial Reporting System

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Abstract. In modern conditions of transformation of economic relations, non-financial reporting, including reporting in the field of sustainable development, must present a balanced and reasonable picture of the organization's performance in relation to sustainable development. Such a reporting system is an important source of information for making management decisions. The article shows that the use of a balanced scorecard in the practical activities of companies can significantly improve the system of intra-company non-financial reporting without increasing its volume. Based on the results of the study, we concluded that the integration of a balanced scorecard into corporate non-financial reporting makes it possible to formulate more effectively the strategic goals of the organization and timely plan activities to achieve these goals. This process helps to improve the quality of the organization's management system.

Keywords: sustainable development · gas distribution organization (GDO) · balanced scorecard (BSC) · strategic diagnostics · non-financial reporting · organizational environment · confirmation of non-financial information

1 Introduction

As a result of the economic crisis and economic instability in Europe, Russian manufacturing organizations face many challenges, the most important of which is the restructuring of the management system and its orientation towards sustainable development. The activities of modern companies are increasingly influenced by the attitudes towards companies of various groups of stakeholders. These groups often have very conflicting needs and interests. At the same time, the involvement of an organization in solving a large variety of social problems forms social, environmental and corporate management (ESG factors) in its structure [14]. One of the tools for implementing the concept of socially responsible business and the concept of sustainable development is non-financial reporting of companies. When preparing these reports, a balanced system of financial and non-financial indicators is actively used, taking into account their industry adaptation.

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Russia ranks second in Europe in terms of the availability of natural gas to the population (according to the rating agency RIA Rating LLC) [18]. The overall level of gasification in Russia reached 73% by the beginning of last year [16, 19]. At the same time, despite such optimistic indicators, there are significant problems in the territorial context of the implementation of the gasification program. For example, an important problem in the activities of gas distribution organizations remains the sectoral, territorial, and inter-seasonal imbalance of economic subsystems [5].

The problems of sustainable development of the regions in the long term remain relevant. The influence of antimonopoly legislation on the activities of gas distribution organizations is significant. It is also necessary to highlight the special role of these organizations in the formation of regional fuel and energy balances and the implementation of regional gasification programs [16].

The methods currently proposed in Russia to ensure the development of the gas distribution business do not allow comprehensive management of this business in the current economic environment, taking into account the paradigm of sustainable development. Thus, the theoretical relevance and practical significance of this study is determined by the objective need to solve the problems of ensuring the strategic development of gas distribution organizations. Including through the formation of high-quality reporting on sustainable development. These reports, in terms of content, are non-financial statements.

2 Materials and Methods

The issues of ensuring balanced and sustainable development of companies are reflected in the works of G.B. Kleiner, J. Kornai, R. Kaplan, D. Norton, M.A. Rybachuka, O.V. Soboleva and other scientists [5, 9, 14, 15, 22–25, 27, 29]. In turn, economic scientists, for example, K.A. Alekseeva, E.V. Arsenova, M.L. Pyatov, T.N. Solovey, A.S. Sorokina, J. M. Korzovatykh, A.V. Kozharinov, V.S. Levin, A.D. Sheremet, consider in detail the importance of non–financial reporting in the modern economy and its impact on solving the problems of sustainable development [6, 7, 10–13, 20, 21, 26, 28]. Existing scientific views, ideas, assessments and approaches are a valuable scientific heritage. They are the basis for studying and modeling the processes of interaction between the external and internal environment of gas distribution organizations in order to achieve sustainable development goals in a post-industrial society [30–32].

The purpose of the study is to substantiate theoretical provisions and develop methodological and practical recommendations that ensure the sustainable development of gas distribution organizations based on the use of a model and organizational and economic tools for the formation of high-quality non-financial reporting as one of the basic tools for implementing the paradigm of sustainable development.

In order to achieve this goal, the research process provides for the consistent solution of a number of interrelated tasks:

- to clarify the conceptual framework for the sustainable development of gas distribution business entities;
- to propose an adapted balanced scorecard for gas distribution organizations;

– to develop an algorithm for evaluating internal non-financial reporting in a group of companies, which can be used in planning and conducting analytical procedures for the purpose of evaluating and confirming non-financial information by internal and external auditors.

The article uses general scientific principles of a systematic approach, methods of situational and comparative analysis, methods of a balanced scorecard, methods of financial, economic, and statistical analysis.

The hypothesis of the study suggests that in conditions of fierce competition and external challenges, the need for managing the activities of production organizations using a system of balanced indicators for the purpose of forming high-quality non-financial reporting increases.

The result of these actions will be an increase in the efficiency of the organizations and the group as a whole. As the level of their innovation and business activity increases, the resource intensity of production processes will decrease, competitiveness will increase, and the social and economic effectiveness of organizations will increase. The scientific novelty of the research consists in compiling a system of adapted balanced scorecard to assess the sustainable development of a gas distribution organization for the purpose of forming high-quality and useful non-financial reporting of an individual company and the group as a whole.

3 Results

The sustainable development of industrial organizations is one of the factors of Russia's economic security. In relation to an individual company, sustainable development is the alignment of the interests and short-term goals of its stakeholders with long-term strategic goals determined by the development of the company and its interaction with the organizational environment (internal and external).

In order to solve the problems of sustainable development and offset the negative consequences of the influence of organizational factors on gas distribution organizations, it is necessary to develop and apply effective management tools, which requires the construction of an adequate methodological framework. Therefore, the balanced scorecard of the company should be considered as "an instrument of the organization's management mechanism based on diagnostics, assessment, analysis and monitoring of its activities on a set of optimally selected target financial and non-financial indicators reflecting the basic aspects of the organization's business activity, ensuring proportionality, proportionality, close interaction of its structural subsystems in order to increase the degree of systemic balance and sustainable functioning and development" [5]. This period of development of corporate reporting in Russia is associated with the emergence of the concept of integrated reporting, which includes both financial and non-financial indicators. These indicators are subject to classification into economic, social, managerial and environmental.

According to the Concept of Development of public non-financial reporting, "non-financial reporting is a set of information and indicators reflecting the goals, approaches and results of organizations' activities on all significant issues of social responsibility and sustainable development, including a minimum list of mandatory disclosed indicators" [3]. Along with this, "non-financial reporting discloses information about the organization's activities in the context of social responsibility and sustainable development, reflects interaction with stakeholders, as well as the results achieved, including economic, environmental and social aspects considered in their interrelationship" [3].

Based on their research, Robert Kaplan and David Norton found that "a balanced scorecard is not just a collection of financial and non-financial indicators. It should transform the company's strategy into an interconnected set of indicators that define both long-term goals and mechanisms for achieving them" [15]. R. Kaplan and D. Norton developed a "strategy map" in which scientists identify four "predictable prospects: financial prospects of the organization; prospects for relationships with consumers; prospects for the development of internal business processes at the enterprise (key processes that largely determine the effectiveness of the company's activities); prospects for the level of professional training and experience of personnel" [15]. Projections of the strategic aspects of the production organization's activities are shown in Fig. 1.

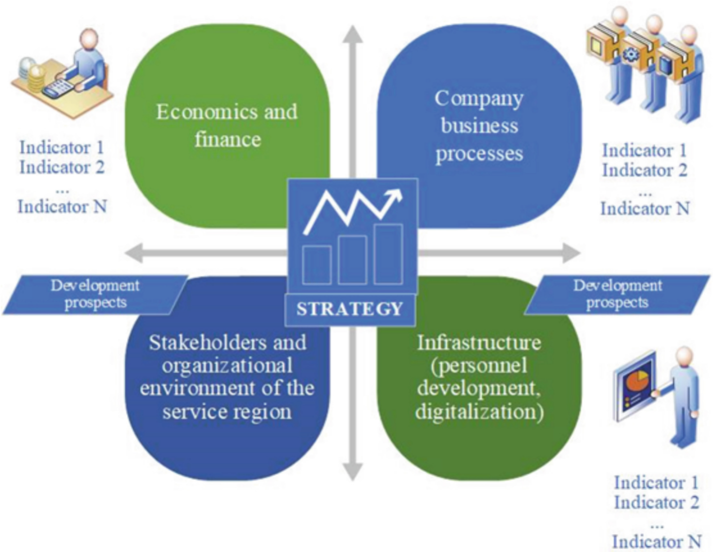

Fig. 1. Projections of the strategic aspects of the production organization's activities. Source: developed by the authors based on [5, 15].

A strategic survey of the company in order to assess the processes of formation of non-financial reporting, we believe, should be considered as "a set of methods and principles for recognizing dysfunctions and diagnosing the object under study in order to increase the efficiency of its functioning, competitiveness in an organizational environment, designed to identify the condition and signs of dysfunctions of the management object" [8]. The proposed procedure involves a detailed formalization of each area of analysis, the subsequent choice of a development strategy and the formation of an adapted balanced scorecard for the chosen strategy.

The regulations for conducting a strategic survey is a document defining the general principles and objectives of this system, the distribution of functions and responsibilities of participants in the process, the order of their interaction, the schedule for conducting the survey as such, the algorithm for forming and structuring the strategy, its implementation plan and budgets for the development of the organization, as well as the procedure for monitoring their implementation. The ISO 9001:2015 standard [2] regulates the understanding of the organization's environment and obliges the organization to systematically analyze and formalize the environment in which it operates. To understand the environment in which an organization operates, it is necessary to correctly classify and take into account all external and internal environmental factors that affect the organization. A feature of the domestic gas distribution system is the affiliation of the vast majority of gas distribution organizations either to the Gazprom holding company, or to the subjects of the Russian Federation or local authorities [5]. At the same time, gas distribution organizations are usually socially responsible organizations.In 1999, Russia signed and in 2004 ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change on Commitments to Reduce Greenhouse Gas Emissions into the Atmosphere [1]. According to the holding's official website, "compliance with environmental standards for the construction, operation of gas pipelines and gas equipment, and minimization of environmental risks are among the main priorities of Gazprom Group's activities" [16].

Strategic partnership with stakeholders plays an important role in the implementation of the sustainable development goals of this business. In the process of forming a partnership, it is necessary to develop methods and protocols for interaction with stakeholders, including in the field of public assurance of non-financial statements of companies. Such public assurance, in accordance with the norms of the Concept of Development of Public non-financial Reporting [2], can be implemented by establishing interaction with representatives of the main groups of stakeholders through the formation of a special "permanent body of interested parties". A specially convened group of representatives of interested parties may also be formed [2].

The actual data that was obtained during the systematic analysis of the external and internal environment should be analyzed and automatically entered into the digital budget management information system, which independently updates, verifies and step-by-step systematizes the information received. Such procedures are relevant for making effective management decisions. Taking into account these circumstances, it seems relevant to improve the methodological aspects of assessing the level of efficiency of an organization, including a separate review of internal business units and processes for further stratification of analytical procedures. Under the level of efficiency of the gas distribution organization, we will determine the degree of achievement of the target (or planned) metrics of a balanced scorecard.

According to the results of the study, it was found that in organizations there is practically no unified approach to quantitative and qualitative assessment of the fulfillment of the target metrics of a balanced scorecard. Therefore, the development and implementation of a diagnostic system and, based on it, a subsystem for monitoring the activities of subsidiaries based on an internal corporate non-financial reporting system seems reasonable and relevant. Such a system allows you to timely assess the degree of completion of tasks; identify redundant operations, time delays in performing operations or overloading individual structural elements; compare the performance of subsidiaries among themselves; plan measures to improve activities and select priority areas of development, strengthen the trust of stakeholders and increase their interest [5]. An algorithm for evaluating internal non-financial reporting in a group of companies has been developed for gas distribution organizations (Fig. 2).

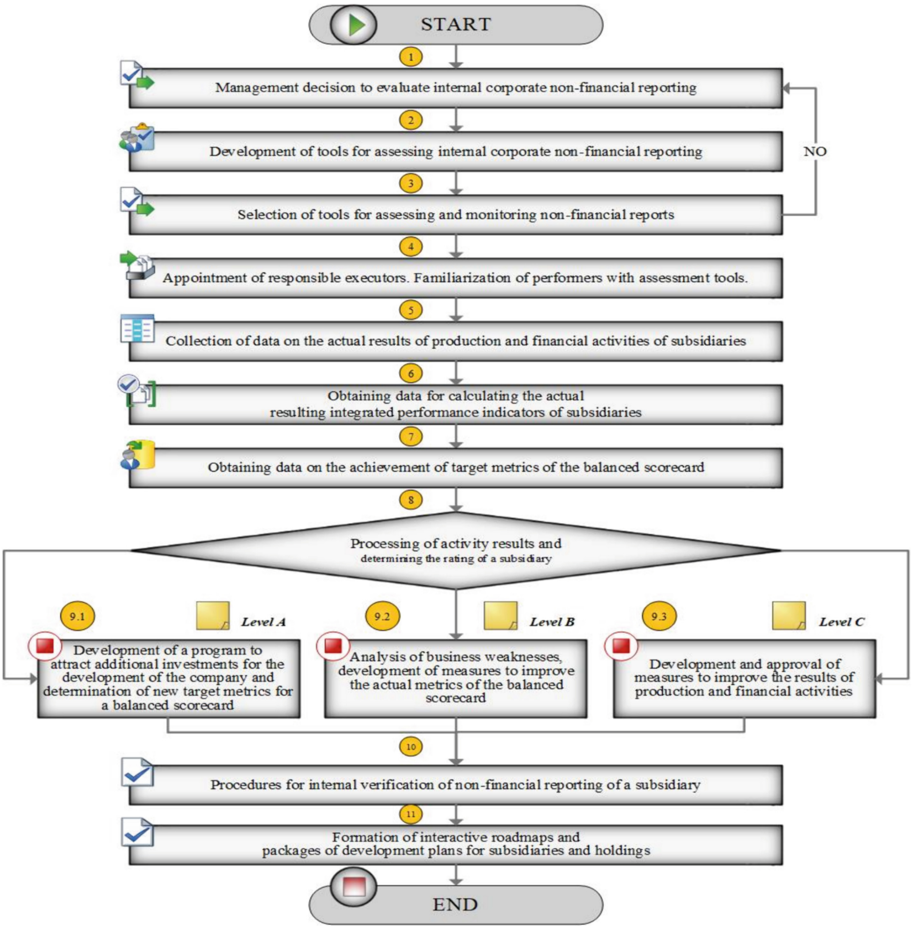

Fig. 2. Algorithm for evaluating internal non-financial reporting in a group of companies. Source: developed by the authors on the basis of [5].

The analysis results were processed using such an algorithm using the example of a regional group of companies.

Based on the results of the study, an adapted balanced system of performance indicators of a gas distribution organization is presented for conducting a “point-rating system” assessment, which is shown in Table 1 [5].

Table 1. A point - rating system for evaluating the activities of a gas distribution organization based on a balanced scorecard

Code	Name of indicator group (name of indicator)	Target indicator	Actual indicator
I	Infrastructure (staff development, digitalization)		
A	Assessment of the level of digitalization		
1	An integral indicator of the level of digitalization	IILDt	IILDf
2	Index of system balance in terms of digitalization level	ISDt	ISDf
B	Development of the personnel management system		
1	Employee turnover rate	PMS1t	PMS1f
2	Indicator of change in average training time	PMS2t	PMS2f
3	Share of non-productive breaks	PMS3t	PMS3f
4	Share of training costs per employee	PMS4t	PMS4f
5	Employee satisfaction rate	PMS5t	PMS5f
II	Business processes of the company		
A	Safety, Uninterrupted, Trouble-Free		
1	Ratio of the volume of losses to the volume of gas transportation	SUT1t	SUT1f
2	Accident Reduction Rate at Facilities	SUT2t	SUT2f
3	Costs of emergency and unscheduled repairs per unit length of gas distribution networks	SUT3t	SUT3f
4	Share of scheduled maintenance costs in operating costs	SUT4t	SUT4f
B	Environmental Performance		
1	Share of Gas Process Losses in Gas Transportation Volume	EP1t	EP1f
2	The decrease in the share of waste sent for disposal	EP2t	EP2f
3	Reduction of costs in the form of payments for negative impact on the environment	EP3t	EP3f
4	Reduction of specific consumption of fuel and energy resources for own needs	EP4t	EP4f
5	Execution of the environmental expenditure plan	EP5t	EP5f
C	Balancing the internal structure of the company		
1	Index of internal structure balance by non-financial indicators	ISIt	ISIf

(*continued*)

Table 1. (*continued*)

Code	Name of indicator group (name of indicator)	Target indicator	Actual indicator
III	Stakeholders and organizational environment of the service region		
A	Development of Gas Distribution Assets		
1	Indicator of the increase in the length of serviced gas pipelines	GDA1t	GDA1f
2	Indicator of increase in the length of gas pipelines owned by the company	GDA2t	GDA2f
3	The company's share of participation in controlled companies	GDA3t	GDA3f
4	Average percentage of depreciation of core business assets	GDA4t	GDA4f
5	Degree of implementation of the investment program	GDA5t	GDA5f
B	Customer loyalty rate	CLRt	CLRf
C	Stakeholder group satisfaction rate	SSRt	SSRf
D	Indicator "Responsibility and openness"	ROt	ROf
IV	Economics and finance		
1	Return on sales	E1t	E1f
2	Return on assets	E2t	E2f
3	Invested capital turnover ratio	E3t	E3f
4	Index of internal structure balance by financial indicators	E4t	E4f
5	Debt-to-equity ratio	E5t	E5f
6	Labor productivity change index (by employee income)	E6t	E6f

Source: developed by the authors based on [5].

The introduction of planned (target) indicators and actual performance results into the automated information system is carried out by representatives of subsidiaries. To determine the level of effectiveness of the organization's activities, a scale of value intervals is proposed that the resulting integral indicator (RII) can take (Fig. 3). Target metrics can be assigned to this indicator.

Data processing and scoring points are performed for each indicator of the organization's activity in accordance with the proposed methodological solutions. The calculation of the resulting integral indicator for the gas distribution organization was carried out

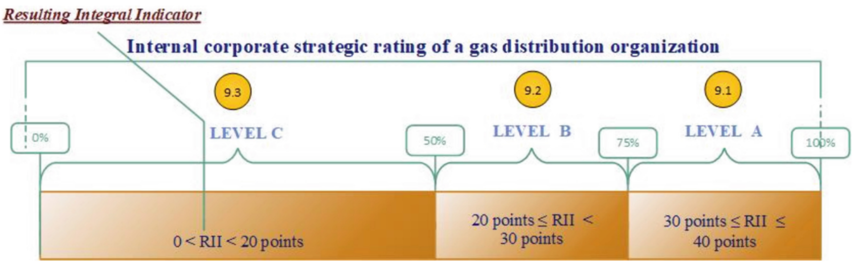

Fig. 3. Scale for determining the effectiveness of an organization in a group. Source: developed by the authors based on [5].

according to the calculated additive formula (1) [5]

$$RII_n = \sum\nolimits_{i=1}^{I} \sum\nolimits_{j=1}^{J} \left(\frac{\sum_{k=1}^{k} \varphi\left(\frac{P_{f_{ijk}}}{P_{t_{ijk}}}\right) \cdot r_{ijk}}{\sum_{k=1}^{K} r_{ijk}} \right) \cdot Rn, \tag{1}$$

where n = 1,…,N – the number of organizations under study; Rn is a regional correction factor determined by the service area for each of the N organizations;

i = 1,…,I – number of groups of indicators in the balanced scorecard; j = 1,…,J – number of subgroups in the group of BSC indicators; k = 1,…,K – number of indicators in a subgroup of the balanced scorecard group; r_{ijk}– weight of the k-th indicator in the j-th subgroup of the i-th group of the balanced scorecard (takes on a value from 0 to 1);

$P_{f_{ijk}}$ – actual value of the k-th indicator in the j-th subgroup, i-th group of the balanced scorecard; $P_{t_{ijk}}$ – target value of the k-th indicator in the j-th subgroup of the i-th group of the balanced scorecard;

$\varphi\left(\frac{P_{f_{ijk}}}{P_{t_{ijk}}}\right)$ – a function of comparing the actual indicator with the target indicator for the reporting period and assigning points depending on the share of the target indicator. Accepts values from 0 to 5 points [3].

According to the presented methodology of internal corporate analysis, calculations for 2022 were carried out for thirty subsidiaries and dependent companies that are under the management of Gazprom Gazoraspredelenie Stavropol JSC [17]. The criteria for evaluating the implementation of the target are shown in Table. 2.

Table 2. Criteria for evaluating the implementation of the target indicator

from 0.00 to 0.10	from 0.10 to 0.20	from 0.20 to 0.50	from 0.50 to 0.65	from 0.65 to 0.80	from 0.80 to 1.00	range of values
0	1	2	3	4	5	points

Source: developed by the authors based on [5]

According to the diagnostic results, eight organizations correspond to level A (a good level), twenty companies correspond to level B (medium level), the indicators of two organizations are located in the zone of level C (lower level). This result is better than similar indicators of the previous year.

Thus, according to the results of 2022, the gas distribution organizations in the region with the best result, among others, are: JSC Novoalexandrovskraigaz, JSC Pyatigorskgorgaz, JSC Nevinnomysskgorgaz, JSC Kislovodsk Gorgaz, JSC ZheleznovodskGorgaz, JSC Essentukigorgaz. As a result, a stable average level of performance was determined for the regional group. Based on the results of the analysis, a plan and a program of measures to ensure the sustainable development of the organization are formed, respectively, the plans of the regional group are adjusted.

The following factors can be identified as having a negative impact on the level of the resulting integral indicator [5]: peculiarities of state and regional tariff policy; untimely non-payments by certain consumer groups; social orientation of organizations; unauthorized connections to gas distribution networks; imperfection of the regulatory framework regarding the recognition of ownership rights to gas pipelines and other factors.

4 Discussion

The transition to sustainable development should ensure for the future a balanced solution to the problems of socio-economic development and the preservation of a favorable environment and natural resource potential, meeting the needs of present and future generations of the country's population. Obstacles and limitations to the formation and implementation of sustainable development indicators in Russia in the practical activities of organizations are largely due to the lack of necessary economic, social and environmental information. In this regard, it is necessary to develop the institution of compiling and presenting non-financial reports to interested users [20, 21]. In turn, the system of balanced indicators of sustainable development is not only a source of information for the formation of non-financial reports. This system allows you to ensure control over the achievement of established indicators; to link the budget process with the plans and results of the development of companies, industries and regions of Russia. For example, energy intensity indicators are the most important economic indicators in all international and country systems. Such indicators also reflect the environmental burden, environmental pollution and the efficiency of using energy resources. The use of accumulated experience should be preceded by a thorough analysis of the specifics of the company's region of activity, which is due to many circumstances, among which it should be noted the transformational nature of the Russian economy, its non-stationary nature, the huge sanctions burden, as well as the social and natural uniqueness of many areas. Along with regional issues, it is necessary to investigate the time factor, which can have a significant impact on changing conditions for the development of the region. Therefore, the list of indicators of sustainable development is not a static system and should be adjusted when trends and issues change.

Since the planetary ecosystem is a single system, the transition to sustainable development of the entire world community can be carried out only in conditions of effective international cooperation. Russia's role in solving planetary environmental problems is determined by the possession of large territories that are practically untouched by economic activity and are a reserve for the stability of the entire biosphere as a whole.

In this regard, an urgent national task is the need to raise awareness in the state and society on issues of social responsibility, sustainable development and environmental safety, as well as to expand the practice of non-financial reporting. Non-financial reporting is an important element of the management system, including risks, and the development of communications with stakeholders, a prerequisite for improving the efficiency and strengthening the competitiveness of organizations. The current stage in the development of public reporting practice is associated with the emergence of the concept of integrated reporting, including financial and non-financial indicators, including social, managerial and environmental [12, 13].

5 Conclusion

The proposed tool for evaluating the process of forming internal non-financial reporting allows, in the context of automated solutions, to timely assess the activities of subsidiaries (dependent) companies and make decisions on the implementation of the necessary set of measures for the sustainable development of management facilities.

The presented methodology can be used in planning and performing analytical procedures by the holding's internal audit units, as well as by external auditors, in order to perform tasks that provide reasonable (limited) confidence in non-financial information [4].

Thus, it can be reasonably assumed that the integration of a balanced scorecard into corporate non-financial reporting allows for a more optimal formulation of the strategic goals of the organization's activities, timely planning of activities necessary to achieve the goals, contributes to their successful implementation, improving, as a result, the quality of the management system.

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