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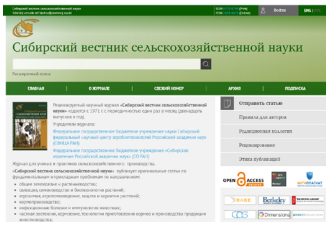


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# МЕТОДОЛОГИЯ ФОРМИРОВАНИЯ ЦИФРОВОЙ СИСТЕМЫ УПРАВЛЕНИЯ ЗЕМЛЕДЕЛИЕМ

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В работе изложены методологические подходы создания цифровой системы управления земледелием (ЦСУЗ). При выполнении исследований использован конвергентный подход, основанный на методах когнитивного (концептуального) анализа, применяемого к формированию адаптивно-ландшафтных систем земледелия. Основополагающими принципами организации ЦСУЗ выделены мониторинг посевов и окружающей среды (*in situ*, дистанционное зондирование), формирование архетипов систем земледелия на основе анализа результатов длительных полевых опытов, моделирование пространственных объектов и типизация земель с использованием ГИС, планирование и поддержка агротехнологий для адаптации к природным и хозяйственным условиям, моделирование экосистемных услуг и биоразнообразия, оценка воздействия на устойчивость и экономику производства растениеводческой продукции. Система реализуется при использовании геоинформационных моделей в конкретной географической координате. ЦСУЗ предусматривает осуществление «инвентаризации» природных и производственных ресурсов, а также выявление лимитов климатических, почвенных и агроландшафтных параметров при различных уровнях интенсивности землепользования. На каждом этапе организации блоков системы используются методы интеллектуального анализа данных и машинного обучения, а ядром работы системы выступает использование баз знаний и логических правил предметной области. Ключевым элементом системы является осуществление масштабирования результатов длительных полевых опытов и накопленных знаний в разных ареалах управления на основе параметризации многоуровневой вариативности систем земледелия и формирования их архетипов. Практическая реализации основных положений ЦСУЗ позволяет приблизиться к решению ключевых вопросов уменьшения уровня неопределенности и сопутствующих рисков в области земледелия за счет научно обоснованной организации рационального природопользования, повышения устойчивости производства растениеводческой продукции в различных условиях землепользования и информационного обеспечения сельских товаропроизводителей.

**Ключевые слова:** системы земледелия, концептуальная модель, цифровое управление, масштабирование, ГИС, машинное обучение

# METHODOLOGY FOR FORMING A DIGITAL FARMING MANAGEMENT SYSTEM

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The paper presents methodological approaches for the creation of a digital farming management system (DFMS). A convergent approach, based on cognitive (conceptual) analysis methods, is employed in the research and applied to the formation of adaptive landscape farming systems. The fun-

damental principles of organizing DFMS include crop and environmental monitoring (*in situ*, remote sensing); the formation of farming system archetypes based on the analysis of long-term field experiments; spatial object modeling and land typology using GIS; planning and support for agrotechnologies to adapt to natural and economic conditions; modeling ecosystem services and biodiversity; assessing the impact on the sustainability and economics of crop production. The system is implemented using geoinformation models in a specific geographic coordinate. DFMS involves conducting a "inventory" of natural and production resources, as well as identifying limits of climatic, soil, and agrolandscape parameters at different levels of land use intensity. At each stage of organizing system blocks, methods of intelligent data analysis and machine learning are used, with the core of the system relying on the use of knowledge bases and logical rules of the subject area. A key element of the system is the scaling of the results of long-term field experiments and accumulated knowledge in different management areas based on the parameterization of the multi-level variability of farming systems and the formation of their archetypes. The practical implementation of the main provisions of DFMS allows approaching the solution of key issues related to reducing the level of uncertainty and associated risks in agriculture. This is achieved through scientifically justified organization of rational land use, increasing the resilience of crop production in different land use conditions, and providing information support to rural producers.

**Keywords:** farming systems, conceptual model, digital control, scaling, GIS, machine learning

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## INTRODUCTION

Currently, it is accepted that digital agriculture provides a phased increase in efficiency, productivity, and resilience not only in the production of crops and livestock but also throughout the value creation chain [1]. Sensor systems and associated analytics can provide agricultural producers with higher quality information for making timely decisions with predictable outcomes, while the automation of decision-making using real-time sensor data and machine learning can enhance their reliability. The use of digital technologies can also provide innovative support for the successful implementation of agricultural systems and land use in their specific spatial conditions, fostering new learning in the process of decision-making [2, 3].

Knowledge sources in agriculture are based on general recommendations derived from inductive analysis of experiments conducted in experimental fields of scientific and educational institutions within limited geographical spaces. However, it is now widely recognized worldwide that results obtained in a specific spatial point (in experiments on "small plots") are not representative of heterogeneous production fields located in different natural conditions, even within the same soil-climatic region. The issue of scaling up these results to the full extent remains unresolved. Digital (intelligent) technologies offer the opportunity to transition from generalized agriculture management to individualized and optimized real-time management using sensors, the Internet of Things, and intelligent data analysis [4–8]. Additionally, digital technologies, including GIS and remote sensing of the Earth, can contribute to delineating and typifying management areas at the field, farm, regional, or soil-climatic zone

levels [9–12], thereby aiding in addressing the scaling issues of field experimental research results.

Digital support in agronomy is currently mainly focused on crop productivity management through the application of precision farming methods. It is considered to be high-end agritechnology; however, essentially, it implements specific agricultural cultivation practices but with the utilization of modern information systems (GLONASS/GPS, GIS, remote sensing, yield estimation technologies, variable rate application, Internet of Things). The actual agricultural systems and their connection with agritechnologies have been undeservedly forgotten, where the latter act as the final stage of agricultural system implementation and their linking element. For example, the cultivation of different types of crops in a specific land area and their spatial and temporal alternation (crop rotation) largely determine the nutritional level of crops and the phytosanitary situation in crops through the environmental influence of plant populations. Equally significant contributions to crop productivity management are made by soil tillage systems, regulating the agrophysical properties of the plow layer, water and air regimes, nutrient mobilization, and contributing to the control of the weed component of the phytocoenosis. The development of a fertilization system and its implementation in farming are also necessary, as they enable the calculation of nutrient removal by crops and their balance in soils (necessary for maintaining soil fertility), optimize the NPK ratio, and plan the acquisition of the required amount of fertilizer types and forms. The application of fertilizers in crops using Variable Rate Technology, applied in precision farming, should be considered as the final stage of fertilizer system implementation. The integrated plant protection system against harmful organisms functionally depends on the set of cultivated crops and their resistance to abiotic and biotic stressors of the environment, predecessors, soil tillage practices, and the level of fertilizer application. The application of pesticides in crops to control the development of harmful organisms is carried out only when the implemented blocks of the agricultural system have not optimized their abundance and harmfulness, and it should be interpreted as a forced measure rather than an end in itself. Therefore, in the paradigm of modern adaptive landscape agricultural systems, it is emphasized that the role of agritechnologies lies in supporting a unified management system within farm land use through crop rotations, soil tillage systems, fertilization, and plant protection[1] [13].

The research goal is to develop a methodology for forming a digital agriculture management system, including crop and natural object monitoring, scaling up field experiment results by agricultural system blocks, and utilizing modern information technologies and machine learning.

## MATERIAL AND METHODS

For the conceptualization of the Digital Agriculture Management System (DAMS), an analytical review of scientific publications was conducted. This review described both theoretical positions and functional capabilities, as well as the results of practical application of modern approaches that support decision-making in crop production. The analysis also included an examination of publicly available information on domestic tools in this subject area, presented on the Internet, and related to the general sphere of the DAMS application, i.e., based on general systems approaches that automatically collect and process information to support decision-making in agriculture.

Over 20 domestic software programs were analyzed, including Panorama AGRO (DB Panorama), Agrocomplex (AdeptIS), AgroHold-

[1]Agroecological assessment of lands, design of adaptive-landscape farming systems and agrotechnologies: Methodical guide / Edited by V.I. Kiryushin, A.L. Ivanov. Moscow: FSSI “Rosiformagroteh”, 2005, 784 p.

ing (CPS), ExactFarming (ITsfera), AgroMon (Agro Software), Assistagro, and the cloud service "Field History" (Geomir), among others. These programs primarily provide operational support for agritechnologies by offering agronomic information—a digital map of fields and their history, crop rotations, soil agrochemical analysis, a plan for crop production, various directories. The programs allow monitoring of crop conditions via mobile applications, perform biomass accumulation analysis via NDVI, use data from satellite monitoring of fields and UAV surveys (remote sensing), create maps for differential application of fertilizers and pesticides, take into account weather data, and control the adherence to agritechnologies using GLONASS/GPS, etc.

To formulate the methodology for the digital agriculture management system, a number of cognitive tasks were solved, including the conceptualization of the subject area and identification of cause-and-effect relationships between system elements. Diagrams were built based on the basic principles of creating UML architectural constructs, including classes and attributes. Other methods of working with information used included content analysis, abstract-logical reasoning, generalization, and conceptualization. Graphic constructions were made in the software package Draw.IO (app.diagrams.net).

## RESULTS AND DISCUSSION

DAMS is a rule- and knowledge-based decision support system (DSS) that integrates *in-situ* and remote sensing technologies for monitoring crops and natural objects, machine learning algorithms, and intelligent analysis of monitoring results and long-term field experiments. It involves forming archetypes of agricultural systems and their scaling, modeling spatial objects and land typing using GIS, web platforms with publicly available real-time databases, planning and support modules for agritechnologies, modeling ecosystem services (ES) and biodiversity, and assessing impacts on the sustainability and economy of crop production (see Fig. 1).

An important component of the DAMS is the monitoring of crops and the environment using *in-situ* and remote sensing technologies, performed based on the data from various sensors (invasive and portable) and digital images obtained from UAVs or satellites at regular intervals. Monitoring allows the systematization of information about the objects both in time (vegetative period, year, multi-year period) and space (management area, land use, agrolandscape, soil-climatic zone), reflecting the temporal and spatial dynamics of the observed objects (see Fig. 2).

Soil sensors and wearable devices for plants play a crucial role in intelligent agriculture, tracking real-time physical and chemical signals, such as temperature, humidity, gas exchange, leaf area, chlorophyll content, and others, providing key information for optimizing the growing conditions of agricultural crops, combating biotic and abiotic stresses, and increasing yield. Invasive (in-soil) sensors are used through a wireless sensor network based on the Internet of Things[2] [14–16]. Currently, Russia has a "roadmap"—"Development of Technologies in the Field of Internet of Things" (http://www.sovel.org/images/upload/ru/1259/Roadmap_FRII_IoT.pdf), which involves the development of infocommunication infrastructure and requirements for using Internet of Things technologies, including in agriculture, as one of its directions for state stimulation.

Remote sensing is a technology that can provide information about both biological objects (vegetation and its dynamics) and the physical conditions of land (changes in terrain, morphological and physical parameters). To analyze the characteristics of spatial objects, integration of remote sensing and GIS is carried out.

[2] *Tarkhanova O.Yu.* Application of wireless sensor networks in precision agriculture // Problems of Informmatics, 2017, N 4 (37), pp. 16-46.

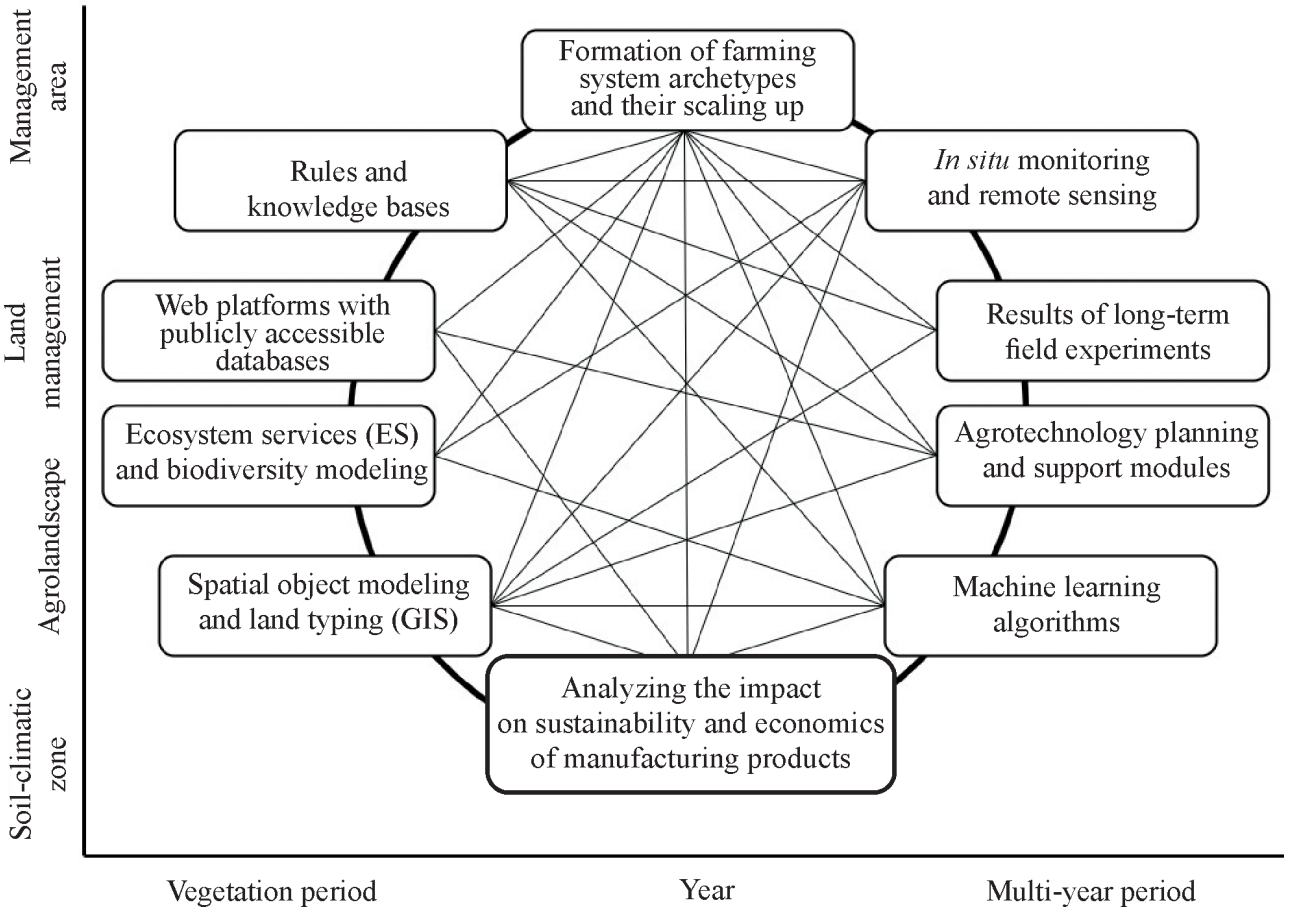


***Рис. 1.*** Схематическое представление концептуальной модели ЦСУЗ
***Fig. 1.*** Schematic representation of the conceptual DFMS model

For this purpose, segmentation and classification of digital image data are conducted using methods such as Geographic Object-Based Image Analysis (GEOBIA) with the application of machine learning algorithms[3] [17]. Various indices based on the reflectance of the Earth's surface and vegetation are calculated, serving as an information resource for the dynamics of natural and anthropogenic objects. One of the most promising achievements in this field is hyperspectral imaging (HSI), which combines spectroscopy and visualization [18].

In the concept of Digital Agriculture Management System (DAMS), integration of proximal (*in situ*) and remote sensing technologies is envisaged to select the most informative parameters of observed objects, standardize and normalize data obtained from different sources, and use them in creating machine learning models and GIS. DAMS is based on data intelligence approaches that extract useful information from large volumes of data. Data intelligence utilizes advanced algorithms to analyze and identify trends, distributions, and patterns that are difficult to discern with the naked eye. The acquired knowledge can help better understand data, observe how they change over time, and predict the future consequences of various management interventions.

As a result of crop and environmental monitoring, large datasets, commonly referred to as "big data," are generated, requiring storage, editing, analysis, and interpretation. The latter holds significant potential for decision-makers. Big data is typically characterized by volume, variety, velocity, veracity, and value [19]. Such

[3] *Blaschke T., Hay G.J., Kelly M., Lang S., Hofmann P., Addink E., Tiede D.* Geographic object-based image analysis – towards a new paradigm // ISPRS journal of photogrammetry and remote sensing, 2014, vol. 87, pp. 180–191. DOI: 10.1016/j.isprsjprs.2013.09.014.

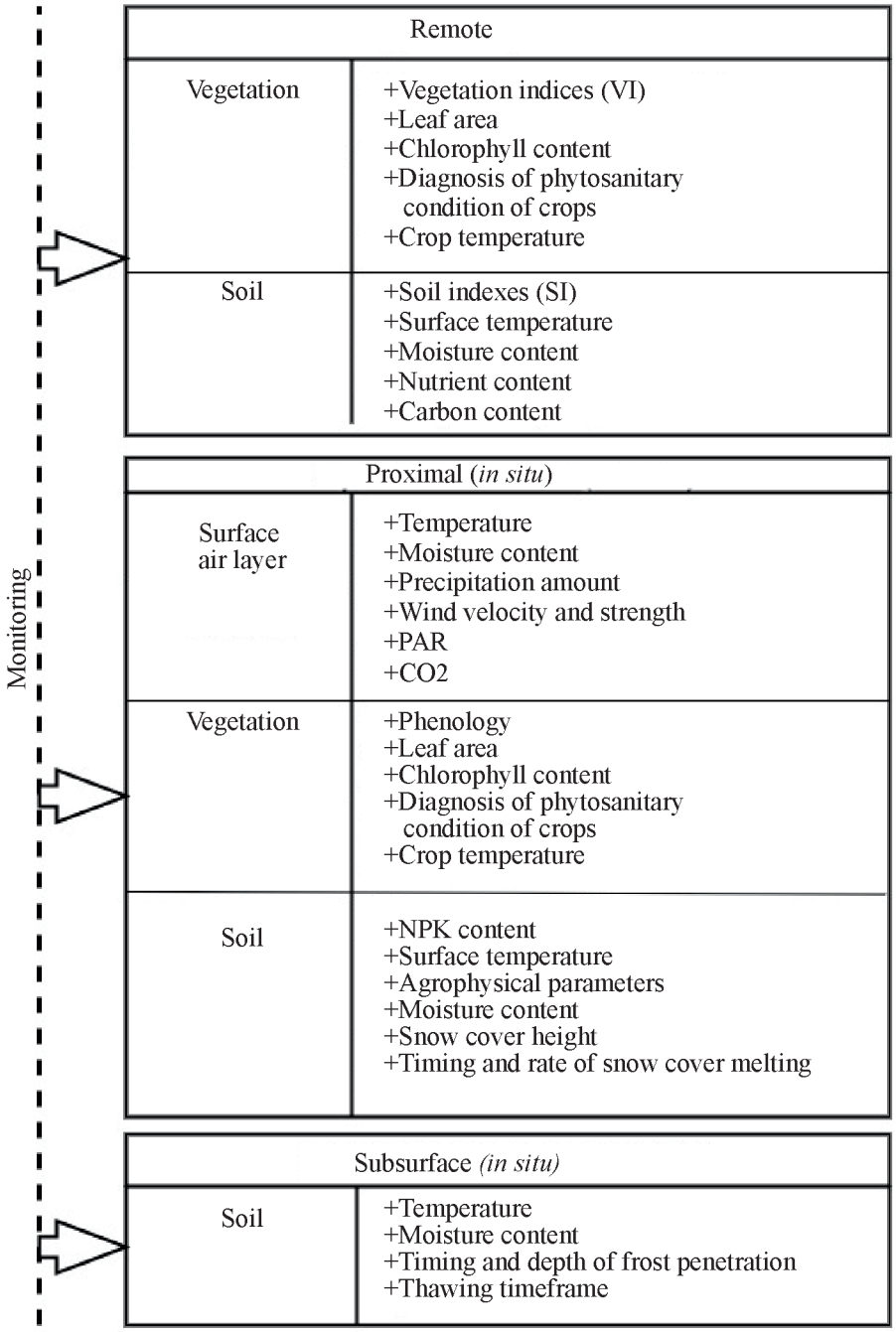


***Рис. 2.*** Графическое представление структурно-контекстного содержания мониторинга посевов и окружающей среды в рамках ЦСУЗ

***Fig. 2.*** Graphic representation of the structural and contextual content of monitoring crops and the environment within the framework of DFMS

data are conveniently stored and analyzed in the cloud. Cloud computing is a widely accessible paradigm offering advantages such as minimal management efforts, convenience, ease of maintenance, and centralized control [20]. Traditional data processing methods are inadequate to meet the constantly growing needs of intelligent agriculture, hindering the extraction of valuable information from field data. Machine learning (ML) is employed to address this issue, which is a subset of artificial intelligence [21] and leverages the exponential

growth of computer processing power.

The most common ML model used for data processing is artificial neural networks (ANNs). Among the popular ANNs are deep neural networks (DNNs), which incorporate multiple hidden layers between input and output levels. A common type of DNN is convolutional neural networks (CNNs), whose layers can adjust neurons in three dimensions, unlike traditional neural networks [22]. Recurrent neural networks (RNNs) are also widely used. They are called "recurrent" because they perform the same process for each element, with previous computations determining the current result [23]. In addition to ANNs for data processing and building predictive models, including the use of time series from long-term field experiments, the following ML algorithms can be utilized: K-nearest neighbors (KNN), Gaussian process regression (GPR), decision trees (DT), support vector machines (SVM), random forests (RF) [24], as well as the CART method [25], among others.

Data processing of monitoring and experimental results using ML is necessary because even scientists often find it challenging to interpret or utilize these data due to their volume and complexity, let alone production specialists, who typically do not require high-precision data for every decision and have limited capabilities for working with them.

For scaling up the results of long-term field experiments in agriculture, it is advisable to create archetypes of agricultural systems based on the data obtained from the SFSCA RAS experimental stations. An archetype of an agricultural system refers to a model of land use for a specific agroecological group of a natural-agricultural (soil-climatic, agrolandscape) region with an ecologically and economically determined set of cultivated crops and corresponding management practices (crop rotation, soil tillage, fertilization, plant protection).

When analyzing the results of long-term field experiments, particular importance lies in evaluating their multilevel variability along the gradient of management intervention and the temporal detailing of data. Developing general principles for the manifestation of agricultural system variability at the management area level across different agroecological zones (subtaiga, forest-steppe, steppe) allows for the development of more suitable adaptive land management strategies. In turn, the formation of agricultural system archetypes provides the opportunity to parameterize local land-use specifics, followed by the generation of the most characteristic class criteria. The following basic classes are identified: land group and type, crop, crop rotation, soil tillage system, plant protection system, and fertilization system. Each class forms an empirical basis for identifying and multidimensionally representing the complexity type of the agricultural system (see Fig. 3).

The structural-functional organization of agricultural system archetypes includes building a hierarchical structure of classes and their attributes, storing detailed data on the main biophysical variations of systems at the attribute level. The main principles of archetype development for further scaling can be considered as the allocation of valid field experiment data among different archetypes at the class level and the possibility of comparing their attribute characteristics[4]. Archetype formation should be accompanied by the creation of corresponding databases and knowledge, as well as logical rules.

Agricultural system archetypes are implemented in specific natural conditions (spatial objects), characterized by indicators that can be formalized and entered into databases. It is necessary to search for acceptable comparison algorithms (preferably in automated mode) for valid characteristics (there should not be many)

[4]*Mądry W., Roszkowska-Mądra B., Gozdowski D., Hryniewski R.* Some aspects of the concept, methodology and application of farming system typology // Electronic Journal of Polish Agricultural Universities, 2016, vol. 19, N 1, p. 12. http://www.ejpau.media. pl/volume19/issue1/art-12.html.

of agricultural system archetypes with the same characteristics of spatial land-use objects. Currently, the most probable technology for obtaining information about a spatial object for this purpose is remote sensing.

For scaling agricultural system archetypes in a geographical context, preliminary modeling of spatial objects and land typology using GIS of the territory planned for scaling of a particular agricultural system archetype are necessary. For these purposes, decision-making methods integrated with GIS can be used. ELECTRE TRI (ELimination Et Choix Traduisant la REalité) [26] is used as a tool. However, this approach does not allow evaluating land parameters in an extended context since it is limited by the number of attributes for analysis and is based on expert subjective opinion.

The most promising method is the creation of quantitative models of higher accuracy based on geospatial data on a continuous scale [27]. In global practice, such models are built on pub-

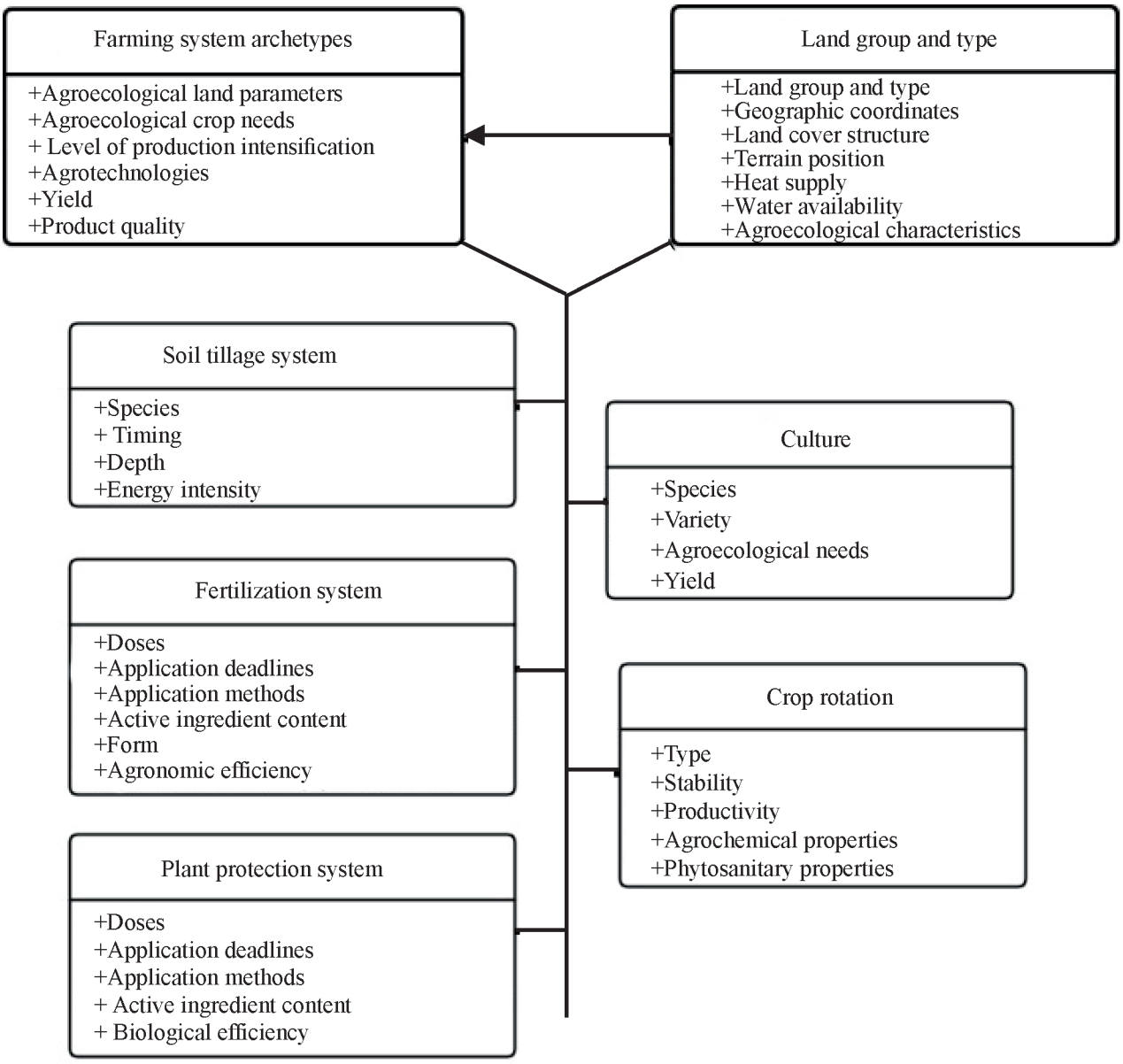


***Рис. 3.*** Диаграмма формирования архетипов систем земледелия в нотации UML
***Fig. 3.*** Diagram of the of archetypes o farming systems formation in UML notation

licly available data through the Google Earth Engine[5]. ML and remote sensing are also used for mapping land suitability at spatial-temporal scales. ML models can be trained based on datasets and easily integrate their various types [28]. For example, algorithms based on artificial neural networks, partial regression by least squares method, random forest, support vector machines, K-nearest neighbors, extreme gradient boosting, adaptive neuro-fuzzy inference system are used for land suitability mapping [29]. ML methods have demonstrated greater reliability and stability, making them popular and economically effective for assessing agricultural land features and potential [19].

Web platforms with publicly available real-time databases serve as the basis for data collection, processing, and display. They aggregate information with common characteristics and facilitate management. The advantage of some online databases is that they are free to install (a small fee is usually charged for use) and easy to use. The following databases belong to this category: Knack (https://www.knack.com) – allows creating various data views using filters, charts, dashboards, etc., Zoho Creator (https://www.zoho.com/de/creator/) – application and web application development without programming knowledge, ZenBase (https://getzenbase.com) – provides management functions, data import, and interactive reports, Back4App (https://www.back4app.com/) – application development, hosting, and management.

Digital global databases on meteorological parameters, soils, relief, and soil-vegetation cover allow improving the monitoring process and expanding the assessment of the suitability and productivity potential of agricultural lands. Examples of the most common open-access databases include: HWSD (http://www.fao.org) – global soil database, ERA Interim (https://www.ecmwf.int) and NCEP/NCAR (http://www.esrl.noaa.gov) – open global reanalysis databases, WorldClim (https://www.worldclim.org) – global climate database, ETOPO1 (https://ngdc.noaa.gov/mgg/global/relief/) or ASTER GDEM V3 (https://earthexplorer.usgs.gov) – global digital topographic models.

Domestic planning and support modules for agrotechnologies are based on a probabilistic, but essentially static approach, resulting in only partial adaptation to natural and production conditions (based on accounting for the average variability of resources)[6]. Additionally, these solutions fundamentally rely on regression models. Such models are built directly from observation and experimental data and help support decision-making through interpolation. Due to the complexity and uncertainty of the environment and management objects, interpolation has limited value. Therefore, the creation of a tool—simple in application and based on the achievements of information technology—is still relevant. In our opinion, such a tool (software) can be based on the method of controlling dynamic objects with the use of predictive models – Model Predictive Control (MPC)[7] method, which is currently the most advanced method for managing technological processes. MPC allows for high-precision control operations with moderate complexity and optimizes the process within a limited time frame, thus enhancing accuracy. Although MPC originated in industrial process control, it is also suitable for agriculture, as it can effectively manage nonlinear systems [30].

In the context of specific land use, the following informational support is necessary for choosing and adapting agrotechnologies: deter-

[5]*Gorelick N., Hancher M., Dixon M., Ilyushchenko S., Thau D., Moore R.* Google Earth Engine: Planetary-scale geospatial analysis for everyone // Remote sensing of Environment, 2017, vol. 202, pp. 18–27. DOI: 10.1016/j.rse.2017.06.031.

[6]*Stepnykh N.V., Zargaryan A.M., Zhukova O.A.* Computer program for designing technologies for growing crops // Agrarian Bulletin of the Urals. 2017, N 3 (157), pp. 54-58.

[7]*Mayne D.Q.* Model predictive control: Recent developments and future promise // Automatica, 2014, vol. 50, N 12, pp. 2967– 2986. DOI: 10.1016/j.automatica.2014.10.128.

mining the volumes of crop production and the structure of crop rotations, selecting appropriate crops and varieties; developing systems for soil treatment, fertilizers, and plant protection; designing agrotechnologies adapted to natural and economic conditions; and assessing their possible differentiation by levels of production intensification depending on the resource potential, including planning and implementing precision farming techniques (see Footnote 1) [31].

Ecosystem services (ES) are typically viewed in terms of "natural capital" or "a collection of natural assets" as a broad spectrum of potential benefits that humans receive from the use of nature. ES from agricultural lands can be divided according to their belonging to different components of the biogeocenosis: services related to soil (edaphotop), vegetation (phytocenosis), animals (zoocenosis), etc. [32]. The list of ES in farming systems reflects basic natural connections and includes bioproduction, bioresource, biotopic, gas exchange, water- and climate-forming, and soil-forming functions [33].

In the last two decades, many countries with intensive farming have seen an increased need for integrating a comprehensive evaluation and monitoring of ES into the practice of territorial planning and the organization of farming systems. For these purposes, various tools are developed, such as InVEST—a comprehensive assessment of ES and trade-offs, LUCI—a land use indicator and ES improvement opportunities, and ARIES—artificial intelligence for ES[8]. These tools help assess different land use management options and provide quantitative modeling results of ES, which can work with spatial objects. The choice of a particular instrument depends on the research objectives. Agent-based[9] and scenario [34] modeling is also used to assess ES.

Biodiversity provides a kind of buffer effect or "insurance" against irreversible environmental variability, through the adaptive response of the components of agrobiogeocenosis to these changes, collectively contributing to a more stable provision of ES in natural resource systems [35]. The concept of biodiversity is broadly interpreted and signifies not only species richness reflected in genetic, taxonomic, and functional diversity of various system components but also diversification of activities and managerial impacts, as well as a variety of approaches to planning and managing farming systems. The economic section allows for calculating potential damage from intensive natural resource use and subsequent long-term effects.

When planning and managing farming systems, it is important to assess the impact on the sustainability and economy of crop production. The basis of sustainability assessment involves determining risks and finding a balance between natural-climatic, socio-economic factors, and biological systems. A wide range of tools, consisting of groups of indexes or formalized models with a list of specific predictors, such as the Response Inducing Sustainability Evaluation (RISE), Farm Sustainability Indicators (IDEA), Sustainability Assessment of Food and Agriculture systems (SAFA), and Monitoring and Assessment of Sustainability (SMART), expert opinions combined with multi-criteria assessment (MCA) [10, 11] are developed to "measure" sustainability. These tools differ in their sustainability measurement purpose, spatial and temporal scales. It should be noted that a generally accepted methodology for creating a

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system of indicators and benchmarks for assessing sustainability has not yet been developed. The simplest tools for sustainability assessment could be multidimensional statistical methods, such as principal component analysis, which allows classifying indicator values depending on the driving force in agricultural production conditions.

The economic efficiency of farming systems, according to [36], is directly linked to land productivity and is based on the assessment of production costs, profitability, expenses on environmental protection measures, and other economic indicators.

In English-language literature, the advisability of digitizing agriculture and the potential consequences of its implementation are actively discussed. For instance, [37] indicates that it is still unclear what the future of digital agriculture will look like, who will benefit from digital farming, and how it will affect agricultural production and food systems overall, including the provision of ES. The authors of the publication conclude that identifying key existing and emerging issues, forming a more robust factual database, and increasing investment in research in this area are more than relevant for domestic agriculture, especially regarding research investment. In our opinion, the considerations made in [37] are more than relevant to domestic agriculture, especially regarding investment in research.

## CONCLUSION

Formation of a digital agricultural management system consists of the following main stages (blocks):

– monitoring of crops and the environment – provides crucial information for assessing the variability of natural conditions and their impact on crop yields, and aids in the development of predictive models for the yields of agricultural crops and the selection of management actions;

– formation of farming system archetypes based on the analysis of results from long-term field experiments, creation of databases and knowledge bases for scaling systems;

– modeling of spatial objects and typification of lands using the capabilities of integrating remote sensing and GIS to scale the archetypes of farming systems for their inclusion in the local decision support system;

– planning and support of agrotechnologies for adaptation to natural and economic conditions, their differentiation by levels of production intensification depending on the resource potential, including planning and implementation of precision farming techniques;

– modeling of ecosystem services (ES) and biodiversity with the aim of optimizing agricultural natural resource use, reducing environmental impact through reduced pesticide use, and diversifying cultivated agricultural crops;

– assessment of the impact on the sustainability and economy of crop production through forecasting risks of yield reduction and profitability due to possible adverse weather conditions, such as soil and air droughts.

The digital system for agricultural management (DSAM) is implemented with mandatory use of geoinformation models of spatial objects and cannot function without specific geographical localization (management areas). Each block of the DSAM involves data analysis using various machine learning algorithms, model building, and their integration into a unified system, forming knowledge bases and logical rules.

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# ДЕСИКАЦИЯ И СЕНИКАЦИЯ В ТЕХНОЛОГИИ ВОЗДЕЛЫВАНИЯ СОРТОВ ОЗИМОЙ ТРИТИКАЛЕ В СРЕДНЕМ ПРЕДУРАЛЬЕ

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Тритикале – искусственно созданная человеком культура, имеющая как положительные, так и отрицательные признаки и свойства. Одним из нежелательных признаков является низкая устойчивость зерна к прорастанию при созревании. В связи с этим поиск способа повышения устойчивости зерна становится достаточно актуальным вопросом. Решению данной проблемы может послужить осуществление предуборочной обработки посевов, а именно десикация и сеникация. Целью исследования, проведенного в условиях Удмуртской Республики, географически относящейся к Среднему Предуралью, было сравнительное изучение влияния десикации и сеникации посевов на урожайность и качество зерна озимой тритикале. В двухфакторном полевом эксперименте в течение вегетационных периодов 2021 и 2022 гг. изучали сорта Ижевская 2 (контроль) и Бета, посевы которых подвергались обработке десикантом Суховей и сеникантами – 20 и 30%-ми растворами аммиачной селитры и сульфата аммония. В годы исследования заключительные этапы онтогенеза у сортов тритикале проходили в жарких засушливых условиях. В итоге действие изучаемых веществ не отразилось на урожайности зерна. При сравнении заявленных сортов установлено преимущество по урожайности сорта Бета, обусловленное формированием более крупного зерна и большей продуктивностью соцветия. При этом большим накоплением сухого вещества на единице площади характеризовался более высокорослый сорт Ижевская 2. В ходе эксперимента выявлено повышение показателей натуры зерна озимой тритикале сорта Бета на 7–9 г/л в вариантах с применением сульфата аммония. Объемная масса зерна сорта Ижевская 2 под действием изучаемых приемов не изменялась.

**Ключевые слова:** десикация, сеникация, озимая тритикале, сорт, урожайность зерна, урожайность семян, натура

# DESICCATION AND SENIFICATION IN THE TECHNOLOGY OF CULTIVATION OF WINTER TRITICALE VARIETIES IN THE MIDDLE URALS

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Triticale is an artificially man-made culture that has both positive and negative signs and properties. One of such undesirable signs is the low resistance of the grain to germination during maturation. Therefore, the search for ways to reduce this phenomenon is an urgent issue. Pre-harvest treatment of crops, namely desiccation and senification, can be a solution to this problem. The purpose of the study, conducted in the conditions of the Udmurt Republic, geographically belonging to the Middle Urals, was a comparative study of the effect of desiccation and senification of crops on yield and grain quality of winter triticale. In a two-factor field experiment during the growing seasons 2021 and 2022, the varieties Izhevskaya 2 (control) and Beta, whose crops were treated with desiccant Sukhovey and senicants – 20 and 30% solutions of ammonium nitrate and ammonium sulfate, were studied. In the years

of the study, the final stages of ontogenesis in triticale varieties took place in hot dry conditions. As a result, the effect of the studied substances did not affect the grain yield. When comparing the declared varieties, the yield advantage of the Beta variety was established due to the formation of larger grains and higher inflorescence productivity. At the same time, a greater accumulation of dry matter per unit area was characterized by a higher-growing variety Izhevskaya 2. In the course of the experiment the increase of the natural weight indices of winter triticale variety Beta by 7–9 g/l in the variants with the use of ammonium sulfate was revealed. Grain volume weight of the Izhevskaya 2 variety did not change under the influence of the studied methods.

**Keywords:** desiccation, senification, winter triticale, variety, grain yield, seed yield, natural weight

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## INTRODUCTION

Yield is the result of the complex and intensive life activity of the entire plant. There is a close interrelationship between the seeds and vegetative parts of the plant, which determines the yield level of the cultivated crop. The synthesis of vital compounds in the vegetative parts and their transfer to the forming seeds largely depend on the conditions of the external environment. The natural course of seed maturation is conditioned by the polymerization of high-molecular substances, which is accompanied by the release of moisture into the atmosphere. When there is increased humidity in the atmosphere, moisture release decreases, leading to slower seed maturation.

In the second half of the last century, scientists searched for substances that enhance the "pumping" of vital compounds from leaves and stems to the reproductive organs of the plant. We know them as desiccants and senicants. In Latin, *desiccare* means "drying out," and senium means "aging"[1,2]. Desiccation involves the inhibition of physiological processes in plant cells, while senescence optimizes the ratio of free to bound water within them. Moisture loss during desiccation is associated with the breakdown of cell walls, and during senescence, with the optimization of phloem flow and an increase in dry matter content in the cell. Under such pre-harvest treatments, stems lose moisture more significantly, leaves less so, and seeds the least. However, the action of desiccation in this case is more aggressive, accompanied by damage to chloroplasts and an increase in ethylene concentration. Senescence represents a non-pesticide way to improve grain quality[3]. The choice between these practices is linked to the specific conditions of the ripening and harvesting period [1].

One of the lesser-known but valuable crops is winter triticale. In the Middle Urals, which includes the Udmurt Republic, breeding work with this crop is conducted, and technological practices for cultivating it for grain, seeds, and fodder are developed[4] [2, 3]. Considering the re-

[1]*Altergot V., Makhotkina G., Sezenov A.* Senication. What does it give? // Zemledelie, 1972, N 7, pp. 42-45.

[2]*Batueva I.V., Eliseev S.L., Yarkova N.N.* Harvesting time and desiccation of winter grain crops in the Middle Urals // Agrarian Bulletin of the Urals, 2014, N 10 (128), pp. 10-13.

[3]URL: https: // agroinfo.kz (accessed on: 10.02.2023).

[4]*Babaytseva T.A., Lentochkin A.M., Ovsyanikova I.A.* Influence of sowing techniques on seed productivity of winter triticale varieties in the Middle Urals // Achievements of science and technology of AIC, 2014, N 8, pp. 14-16.

gional conditions and based on the description, study of morphobiological characteristics, and formation of productive elements, a model of an adapted variety of winter triticale for grain and fodder purposes has been created[5] [4, 5]. It is known that triticale is characterized by grain instability to sprouting of grain in standing crop (in the ear), inherited as a recessive trait from rye, which also varies by variety [6].

Due to the limited study of harvesting practices in the region aimed at preserving the quantity and quality of the harvested winter triticale crop, the purpose of our study was to comparatively investigate the influence of desiccation and senescence of crops on the yield and quality of grain of winter triticale varieties. The objectives of the research are:

1) to identify the influence of desiccation and senescence of crops on the yield of grain of winter triticale varieties;

2) to substantiate the yield of grain obtained under different abiotic conditions by its structure, particularly by the accumulation of dry matter;

3) to determine the influence of desiccation and senescence of crops on the specific weight of grain of winter triticale varieties.

## MATERIAL AND METHODS

A two-factor field experiment was conducted in 2020 and 2021 on the territory of the "Agrotechnopark" Educational Scientific and Production Complex (56°51'09" N, 53°12'24" E; Udmurt Republic, Votkinsk district, Iyulskoye village). Two varieties of winter triticale were studied: Izhevskaya 2 (control) and Beta. During the experiment, the crops were treated with 20% and 30% solutions of ammonium nitrate ($NH_4NO_3$) and ammonium sulfate ($(NH_4)_2SO_4$) (at a grain moisture content of 45%), and with the desiccant Sukhovey (at a grain moisture content of 30%). For the preparation of the working solution, 27 and 40 kg of ammonium nitrate, 30 and 45 kg of ammonium sulfate, and 1.5 liters of Sukhovey desiccant were used respectively. The rate of the working solution application was 300 l/ha in all cases.

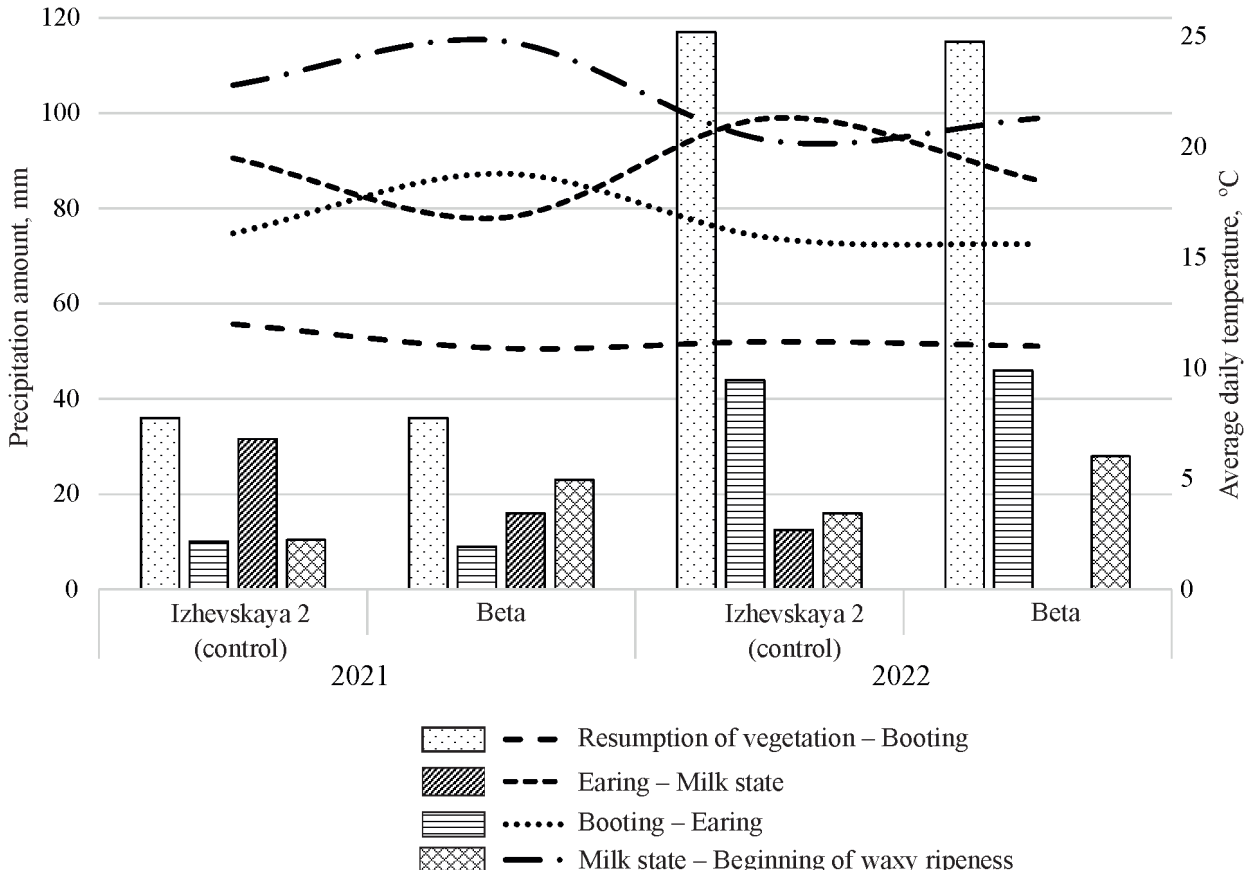
Field studies were conducted according to the commonly accepted agronomic methodology. The registration plot per "variety" factor was 150 $m^2$, and per "treatment" factor was 25 $m^2$, with each factor being repeated four times. The experiment was conducted on a typical regional sod-podzolic medium loam soil of medium cultivation level. The cultivation technology followed regional recommendations. The forecrop was spring rapeseed, harvested for green fodder a month before sowing. After the harvest of the forecrop, discing was performed, followed by cultivation with harrowing after two weeks, and then pre-sowing cultivation. Sowing was done using the Alfa CC-11 selection seeder in the usual row method with a seeding rate of 5 million germinable seeds/ha. In the spring, after the start of regrowth, top-dressing with ammonium nitrate was applied at a rate of 1 c/ha in physical weight. The plots were harvested at the end of the wax ripeness phase of the grain using a Terrion SR-2010 combine in a single-phase method. After harvesting, the grain yield was adjusted to a standard moisture content of 14%.

## RESULTS AND DISCUSSION

The growth and development of winter triticale plants during the spring-summer period of 2021 occurred under relatively high average daily air temperatures (deviation up to +9.7 °C) accompanied by a small amount of precipitation (see Fig. 1).

The ratio between the sum of precipitation and the air temperature above 10 ºC (HTC) from the phase of stem elongation to grain maturity and harvesting ranged from 0.50 to 1.10 for Izhevskaya 2 and from 0.29 to 0.77 for Beta. The combine harvesting of winter triticale treated with senicants in the form of ammonium nitrate and ammonium sulfate solutions was conducted 20 days after treatment for Beta and

[5] *Vafina E.F.* Programming of winter triticale grain yield in the conditions of the Udmurt Republic // Modern achievements of plant breeding - production: Proceedings of the National Scientific and Practical Conference, Izhevsk, 2021, pp. 54-59.




***Puc. 1.*** Метеорологические условия в весенне-летний период развития сортов озимой тритикале
***Fig. 1.*** Meteorological conditions in the spring-summer periods of the development of winter triticale varieties

18 days for Izhevskaya 2. The grain moisture content at harvest in the senification treatment variants was 12%. Plots of both varieties in the variant using the desiccant Sukhovey were harvested 3 days later at a grain moisture content of 10%.

In these abiotic conditions, winter triticale had a relatively low grain yield – from 1.91 to 2.47 t/ha, with a 0.44 t/ha advantage for the Beta variety ($LSD_{05}$ = 0.13 t/ha) (see Fig. 2).

In May, June, and the first five days of July 2022, the conditions were cool (the deviation of the average daily air temperature from the long-term average was –2.6…–1.1 ºC) with sufficient precipitation (96 and 174% of the norm). In July and August, however, growth and development of plants occurred under hot (temperature exceeded the norm by 1.5…4.5 ºC) and dry conditions (precipitation was 42 and 2% respectively). Desiccation with Sukhovey reduced the grain moisture of both varieties to optimal within 7 days. After treatment with nitrogen fertilizer solutions, the harvest of Beta crops was conducted 23 days later, and Izhevskaya 2 – 15 days later. In terms of grain yield, the Beta variety outperformed the control by 0.69 t/ha ($LSD_{05}$ = 0.32 tons/ha). The elevated temperature regime and insufficient moisture during the grain filling and ripening period neutralized the effect of the treatments, and the yield differences between the variants in the years of the study were insignificant. Harvesting of the control plots and those treated with desiccant and senicants was carried out at the same calendar time (differences between the variants with different treatments were insignificant).

The studied varieties did not differ in plant winter survival. However, by harvest time, the Izhevskaya 2 variety showed a higher tillering coefficient, and the Beta variety had greater inflorescence productivity. In the abiotic conditions of 2021, the Izhevskaya 2 had 407–412

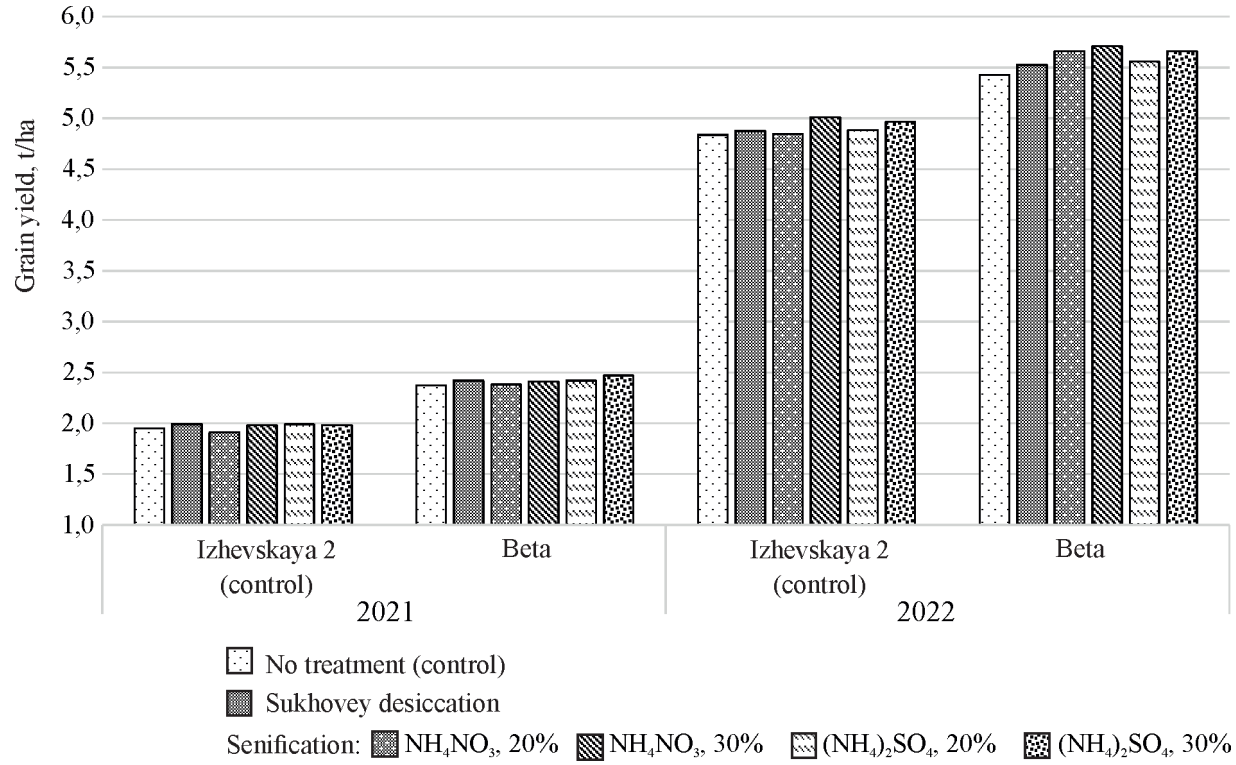



***Рис. 2.*** Урожайность сортов озимой тритикале при проведении десикации и сеникации посевов

***Fig. 2.*** Yield of winter triticale varieties during desiccation and senification of crops

productive stems/m$^2$, and the ear productivity was 0.69–0.72 g, while for the Beta, these figures were 356–367 stems/m$^2$ and 1.11–1.13 g respectively ($LSD_{05}$ by the "variety" factor – 12 stems/m$^2$ and 0.03 g respectively) (see Fig. 3). In the relatively more favorable conditions of the 2022 vegetation period, the winter triticale varieties differed in the density of productive tillering (441-457 stems/m$^2$ for Izhevskaya 2 and 439–453 stems/m$^2$ for Beta) and the grain mass per ear (1.60–1.64 g and 1.67–1.79 g respectively). The varieties also differed in height: Izhevskaya 2 formed taller plants in both years of the study (2021: $LSD_{05}$ = 15 cm; 2022: $LSD_{05}$ = 10 cm).

The Izhevskaya 2 and Beta varieties had different dry matter accumulation characteristics during various phases of vegetation. In the less favorable abiotic conditions of the 2021 vegetation period, dry matter accumulation by the varieties was on the same level (see Fig. 4). Some advantage was noted for the Beta variety from the phase of stem elongation to the beginning of wax ripeness, with a difference from the similar indicator of Izhevskaya 2 ranging from 14 to 110 g/m$^2$ ($LSD_{05}$ by phases of vegetation – 17, 10, 20, 15, 30 g/m$^2$). In 2022, during the stem elongation phase, both varieties formed dry matter equal in quantity to the dry matter formed by the varieties in 2021 only during earing. The Izhevskaya 2, being more morphologically taller, had an advantage in dry matter accumulation per unit area from the earing phase in the conditions of the 2022 vegetation period. The difference in dry matter was minimal during earing (18 g/m$^2$; $LSD_{05}$ = 10 g/m$^2$), and maximum at the start of the wax ripeness of the grain (395 g/m$^2$; $LSD_{05}$ = 30 g/m$^2$).

Triticale grain can have various intended uses. Currently, it is primarily used for feed purposes. In our country, a standard for feed triticale grain has been established and is in effect, and regulatory documents have been developed for triticale grain in general and for triticale flour. The biochemical composition of the grain and flour is of practical interest to the

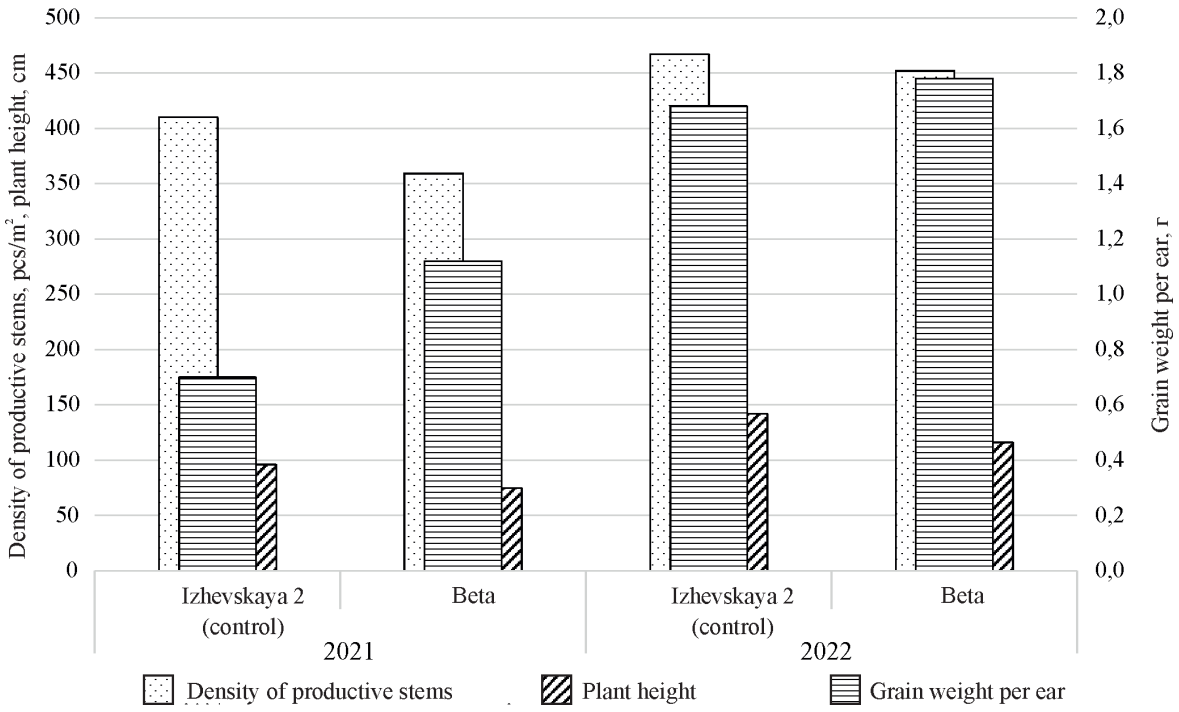



***Рис. 3.*** Показатели структуры урожайности зерна сортов озимой тритикале
***Fig. 3.*** Indicators of grain yield structure of winter triticale varieties

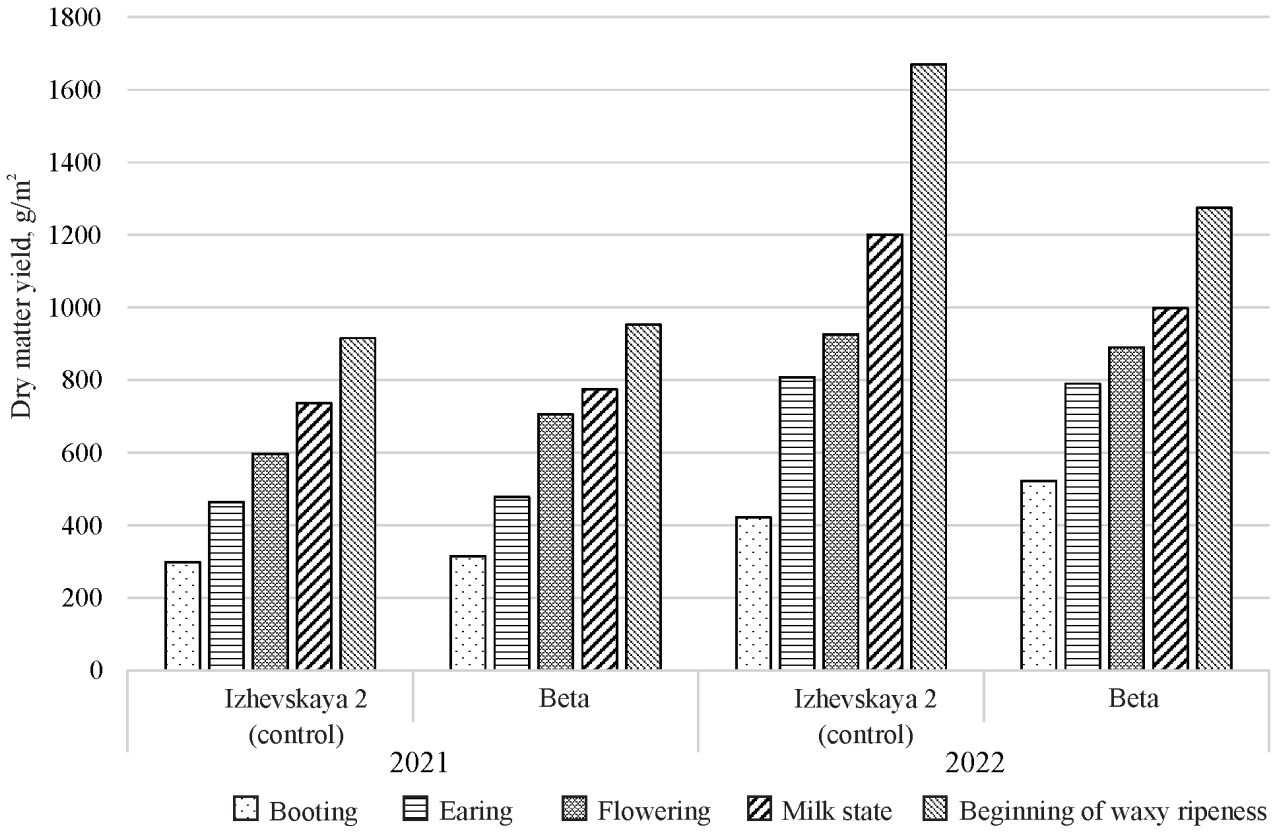



***Рис. 4.*** Динамика сбора сухого вещества сортами озимой тритикале
***Fig. 4.*** Dynamics of dry matter collection by winter triticale varieties

bakery and confectionery industries[6] [7, 8]. According to GOST 34023–2016, a range of indicators is regulated, one of which is the specific weight of the grain (bulk density). Thus, for the 1st class, the minimum specific weight of the grain must be 700 g/l, for the 2nd class – 680 g/l, and for the 3rd class, it is not limited. The higher the specific weight, the greater the grain's completeness, providing higher nutritional value. In grains with a higher specific weight, there is more endosperm, meaning more storage nutrients from different groups are present[7]. Research has shown that meteorological conditions, technological practices, and varietal characteristics significantly influence the bulk density of the grain [9–11].

In the less favorable moisture conditions of 2021, the winter triticale variety Izhevskaya 2 formed grain with a bulk density of 660–669 g/l, while the Beta variety was 639–647 g/l (see the table). In 2022, which was more humid, the specific weight of the grain increased. Thus, for the Izhevskaya 2 variety, it varied within the range of 698–703 g/l, and for the Beta variety, it was 689–708 g/l.

Depending on the pre-harvest treatment of the crops, the specific weight of the grain for the Izhevskaya 2 variety did not significantly change in both years of the study. The Beta variety reacted differently to the treatments: in 2021, no changes in specific weight were observed across the experimental variants, while in 2022, an increase of 7–9 g/l was recorded with senification treatments of 20 and 30% ammonium sulfate solutions.

## CONCLUSIONS

1. Increased air temperatures and low amounts of precipitation during the second half of the vegetation period neutralized the effects of desiccation and senification treatments included in the cultivation technology of winter

Натура зерна сортов озимой тритикале в зависимости от десикации и сеникации посевов, г/л
Natural weight of winter triticale varieties depending on desiccation and senification of crops, g/l

| Option | 2021 | | 2022 | |
|---|---|---|---|---|
| | Izhevskaya 2 (control) | Beta | Izhevskaya 2 (control) | Beta |
| Without treatment (control) | 660 | 640 | 703 | 689 |
| Desiccant Sukhovey | 661 | 641 | 698 | 692 |
| Senicants: | | | | |
| $NH_4NO_3$, 20% solution | 665 | 639 | 700 | 693 |
| $NH_4NO_3$, 30% solution | 665 | 645 | 700 | 694 |
| $(NH_4)_2SO_4$, 20% solution | 669 | 647 | 701 | 708 |
| $(NH_4)_2SO_4$, 30% solution | 668 | 644 | 700 | 706 |
| Average (A) | 666 | 654 | 700 | 697 |
| $LSD_{05}$ | For 1st order plots | For 2nd order plots | For 1st order plots | For 2nd order plots |
| Factor “variety” | $F_ф < F_{05}$ | | 1 | 3 |
| Factor “treatment” | $F_ф < F_{05}$ | | 4 | 6 |

[6] *Alasheeva A.Yu., Milchakova A.V., Mazunina N.I.* Comparative evaluation of the cookies “Minutka” with the addition of triticale flour // Contribution of young scientists in the implementation of priority directions of development of agrarian science: Proceedings of the National Scientific and Practical Conference of Young Scientists, Izhevsk, 2021, pp. 190-193.

[7] *Gunkin V., Karpilenko G., Sorokin A.* Influence of wheat grain shape on its natural weight // Khleboprodukty, 2009, N 9, pp. 56-57.

triticale varieties. The grain yield across the experimental variants did not show significant differences.

2. The grain yield of the winter triticale variety Beta exceeded that of the Izhevskaya 2 variety by 0.45–0.69 t/ha. The Izhevskaya 2 variety was distinguished by forming a denser productive tillering, while the Beta variety had higher ear productivity.

3. The genetically determined tall stature of the Izhevskaya 2 variety (plant height 21–26 cm taller than the Beta variety) allowed for the accumulation of a greater amount of dry matter per unit area.

4. The grain of the Izhevskaya 2 variety had a higher specific weight (666–700 g/l) compared to the Beta variety (654–697 g/l). The filling of the grain of the earlier maturing Beta variety was influenced by senescence treatments with ammonium sulfate solutions, increasing its value by 7–9 g/l. For the Izhevskaya 2 variety, no changes in grain specific weight due to desiccation and senification treatments were detected.

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# ПОЛУЧЕНИЕ СТАНДАРТНЫХ КЛОНОВЫХ ПОДВОЕВ ВИШНИ МААКА ПУТЕМ ЗЕЛЕНОГО ЧЕРЕНКОВАНИЯ

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Изучена вишня Маака (*Cerasus maackii* (Rupr.)) для применения в качестве подвоя в питомниководстве. Культура обладает такими хозяйственно ценными признаками, как устойчивость к болезням и вредителям, зимостойкость, быстрая восстановительная способность, высокая укореняемость зеленых черенков. В статье рассмотрены особенности выращивания вишни Маака путем зеленого черенкования в условиях Челябинской области. Задачей исследования являлось оценить вишню Маака на укореняемость и возможность получить стандартный клоновый подвой. Установлено, что при использовании зеленых приростов вишни Маака длиной 20, 30 и 40 см укореняемость возрастает соответственно на 2,5; 12,5 и 19,1% по сравнению с контрольным вариантом (15 см). Выход стандартных подвоев увеличивается при использовании более длинных черенков (30–40 см) по сравнению с контролем (15 см), или в 2,5–3,4 раза соответственно. Изменения произошли и в увеличении диаметра условной корневой шейки, она увеличилась на 9,3; 28,0 и 50,0% больше, чем на контроле (3,2 мм). Поставленным опытом доказано, что при длине нарезки зеленых черенков вишни Маака длиной 40 см можно за один вегетационный период получить с 1 м$^2$ защищенного грунта более 150 шт. клоновых подвоев, пригодных для зимней прививки. При зеленом черенковании вишни Маака в теплице, оборудованной туманообразующей установкой, длина зеленого черенка, высаженного на укоренение, оказывает существенное влияние на укореняемость и выход однородных клоновых подвоев. При использовании однолетних побегов длиной 30–40 см, нарезанных в активный период роста, укореняемость вишни Маака возрастала в 1,3 раза, диаметр условной корневой шейки – в 1,5 раза, общий выход пригодных для прививки подвоев – в 3,4 раза по сравнению с контрольным вариантом (15 см).

**Ключевые слова**: вишня, Маака, зеленое черенкование, подвой

# OBTAINING STANDARD CLONAL ROOTSTOCKS OF THE MAAK CHERRY BY GREEN CUTTINGS

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The Maak cherry (*Cerasus maackii* Rupr.) has been studied for use as a scion in nursery production. The culture has such economically valuable features as resistance to diseases and pests, winter hardiness, fast regenerative ability, high rooting capacity of green cuttings. The article deals with the peculiarities of cultivation of the Maak cherry by green cuttings in the conditions of the Chelyabinsk region. The objective of the study was to evaluate the Maak cherry for the rooting ability and the possibility of obtaining a standard clonal scion. It has been found that using green shoots of the Maak cherry, 20, 30 and 40 cm long, the rooting capacity of cherry increases by 2.5; 12.5 and 19.1%, respectively, compared to the control variant (15 cm). The yield of standard rootstocks increases, when using longer cuttings 30–40 cm, when compared to the control (15 cm), or 2.5–3.4 times, respectively. Changes also occurred in the increase in the diameter of the conditional root neck, it increased by 9.3; 28.0 and 50.0% more than the control (3.2 mm). It has been proved by the experiment that at cutting length of green cuttings of the Maak cherry with the length of 40 cm, it is possible to get more than

150 pieces of clonal rootstocks suitable for winter grafting from 1m$^2$ of the protected ground during one vegetation period. In green cuttings of the Maak cherry in a greenhouse equipped with a fogging unit, the length of green cuttings planted for rooting has a significant effect on rooting and yield of the uniform clonal rootstocks. When using 30–40 cm long annual shoots cut during the active growth period, rooting ability of the Maak cherry increased 1.3 times, the diameter of the conditional root neck – 1.5 times, the total yield of the suitable for grafting rootstocks – 3.4 times compared to the control variant (15 cm).

**Keywords:** cherry, Maak, green cuttings, rootstock

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## INTRODUCTION

Maak Cherry (*Cerasus maackii* (Rupr.)) is named after Richard Karlovich Maak (1825–1886), a member of the Russian Geographical Society, who participated in three major scientific expeditions exploring Siberia and the Far East[1].

This variety of cherry is distinguished by its high winter hardiness and resistance to coccomycosis and rotting, making it widely used for producing clonal rootstocks. One of the most common methods of propagating Maak Cherry is green cutting [1–3]. The factors that significantly affect the yield of standard clonal rootstocks include the length of the green cutting planted in a greenhouse with automatic watering [4–6].

Cherry varieties are typically propagated by grafting a selected scion onto a grown rootstock [7]. Mass production of genetically uniform rootstocks for cherry propagation is facilitated by green cutting in covered greenhouses, which allow control over growing conditions. The use of rooting stimulants increases the yield of planting material [8–11].

Grafting stone fruit cultures onto clonal rootstocks allows for the implementation of several significant practices that facilitate the technological maintenance of planted orchards from the planting of seedlings to the harvest [12, 13].

Clonal rootstocks of Maak Cherry are intended for propagating a collection of cherry and sweet cherry varieties that have a weak rooting ability when propagated by green cuttings. Local cherry varieties such as Troitskaya, Kurchatovskaya, and Vishnevaya Gorka (elite and selected forms) are propagated using winter grafting from December to March, a period when the intensity of agricultural work is reduced. In our region, the cost-effectiveness is achieved when the planting of winter grafts begins in mid-April, with the seedlings (planted in containers) reaching the market in the first ten-day period of June.

The purpose of the research is to determine the optimal length of green cuttings of Maak Cherry to produce rootstocks within one vegetation period.

## MATERIAL AND METHODS

From 2015 to 2018, studies were conducted on one-year growths of Maak Cherry at the Department of Horticulture of the South Ural Research Institute of Horticulture and Potato Farming as part of the creation and improvement of technologies.

During the study period, green cuttings were made at the Maak Cherry mother plot, and the timing of harvesting (second ten-day period of

[1] *Evmenova L.N., Gryanova O.V.* Maak Richard Karlovich researcher of Siberia in the middle of the XIX century // In the world of science and art: issues of philology, art history and cultural studies, 2016, N 1 (56), pp. 79-86.

June) coincided with the active growth of one-year shoots. Figure 1 shows that the one-year growth was cut to different lengths (15, 20, 30, and 40 cm). The obtained green cuttings were tied in bundles of 50 and placed in a water solution of the rooting stimulator Kornevin (1 g/l). In the solution, the cuttings were immersed with their bottom ends, which were covered by a 1 cm layer of water. The cuttings remained in the water solution of the agent for 15–18 hours. Figure 2 shows the mother trees of the Maak Cherry, where green cuttings for the experiment were made. After soaking in the solution, the green cuttings were planted in soil consisting of a middle loamy leached chernozem (layer 18 cm) and a top layer (5 cm) of washed sand. The green cherry cuttings were planted according to a 10 × 5 cm scheme with a planting depth of 3 cm. The plots were randomized, with 50 green cuttings planted in each variant in threefold replication. The greenhouse with polycarbonate covering, where the planted cuttings were located, was equipped with an automatic watering system. The planted green cuttings were sprinkled with fine irrigation.

The irrigation was automatic at regular intervals. The first watering was at 7 a.m., followed by every 2 hours. Each watering lasted 1 minute. The last watering was at 9 p.m. local time. In rainy weather, the interval between the waterings was extended to 4 hours. After the beginning of rooting, the watering frequency was reduced to 6 times a day. The emergence of a root system in green cuttings was noted at the beginning of the second decade of July. The digging up of the rooted clonal rootstocks, as well as the taking of records and measurements, began on September 15. The obtained data were entered into a computer for statistical processing[2]. The research was conducted according to classical methods according to the guide and instructions for the production of planting material[3,4].

***Рис. 1.*** Зеленые черенки вишни Маака, подготовленные для высадки в теплицу

***Fig. 1.*** Green cuttings of the Maak cherries prepared for planting in the greenhouse

***Рис. 2.*** Маточные деревья вишни Маака, где нарезали зеленые черенки для опытов

***Fig. 2.*** Mother trees of the Maak cherry where green cuttings were cut for the experiments

[2]*Dospekhov B.A.* Methodology of field experiment. Moscow: Agropromizdat, 1985, 351 p.

[3]Program and methodology of varietal study of fruit, berry and nut crops. Orel: VNIISPK Publishing House, 1999, 668 p.

[4]*Polikarpova F.Ya.* Methodical instructions for production of rootstock of stone fruit crops (cherry and plum) by green cuttings. Moscow: VASKhNIL, 1978, 21 p.

The rootstocks obtained as a result of green cutting belong to the second category according to the GOST R 53135–2008[5].

## RESULTS AND DISCUSSION

The propagation of difficult-to-root stone fruit cultures by grafting them onto a rootstock grown within one vegetation period is promising and relevant[6] [14].

A film greenhouse equipped with automatic watering allows for the production of rootstocks in one season from the Maak Cherry green cuttings.

The research showed that increasing the length of the green cutting used for planting improves the rooting of the Maak Cherry. It was noted that green cuttings with a length of 20 cm increased rooting by 2.5%, 30 cm by 12.5%, and 40 cm by 19.1% compared to the control variant (15 cm) (see Table 1).

In 2016, high rooting was observed in the variant with a cutting length of 40 cm (86.3%), which was 29.0% higher than the control.

As the length of the green cutting increases, so does the diameter of the conditional root neck. In the control variant with a green cutting length of 15 cm, over four years it was 3.2 mm, while in the variants with cutting lengths of 20, 30, and 40 cm, the diameter of the conditional root neck of the grown rootstocks increased by 0.3, 0.9, and 1.6 mm, respectively.

The rooting obtained in 2015 in the control variant (78.3%) allows us to conclude that the Maak Cherry has a high level of rootability, which should be studied in further experiments. The diameter of the conditional root neck of the rootstocks, which were planted with a green cutting length of 40 cm, increased by 1.5 times (from 3.2 to 4.8 mm), making them suitable as

**Табл. 1.** Влияние длины зеленого черенка на укореняемость вишни Маака
**Table 1.** Effect of green cuttings length on the rooting performance of the Maak cherry trees

| Stem length, cm | Rooting capacity by years, % | | | | Average for 4 years |
|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | |
| 15 (control) | 78,3 | 57,3 | 61,6 | 60,3 | 64,4 |
| 20 | 62,6 | 73,3 | 63,7 | 68,3 | 66,9 |
| 30 | 68,3 | 83,6 | 78,3 | 77,6 | 76,9 |
| 40 | 82,3 | 86,3 | 84,3 | 81,3 | 83,5 |
| $LSD_{05}$ | 2,1 | 1,9 | 3,7 | 1,9 | 11,3 |

**Табл. 2.** Влияние длины зеленого черенка вишни Маака на диаметр условной корневой шейки выращенных подвоев
**Table 2.** Effect of the Maak cherry green cuttings length on the diameter of the conditional root neck of the grown rootstocks

| Stem length, cm | Conditional root neck diameter, mm | | | | Average for 4 years |
|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | |
| 15 (control) | 3,4 | 3,7 | 2,6 | 3,1 | 3,2 |
| 20 | 3,4 | 3,8 | 3,2 | 3,5 | 3,5 |
| 30 | 3,9 | 4,5 | 3,7 | 4,1 | 4,1 |
| 40 | 4,7 | 5,1 | 4,6 | 4,7 | 4,8 |
| $LSD_{05}$ | 0,3 | 0,3 | 0,2 | 0,3 | 0,2 |

[5]GOST R 53135-2008. Planting material of fruit, berry, subtropical, nut, citrus crops and tea. Technical conditions. Moscow: Standardinform, 2008, 42 p.

[6]*Bezukh E.P.* Progressive technological elements in nursery farming in the North-West of Russia // Horticulture and viticulture, 2012, N 3, pp. 36-39.

rootstocks for stone fruit cultures without the need for further growth in the following year (see Table 2).

Figure 3 shows the clonal rootstocks of the Maak Cherry that were grown in one vegetation season in a greenhouse with automatic watering.

When assessing the impact of the length of the green cherry cuttings on the output of the clonal rootstocks suitable for spring and winter grafting, it was found that the output per square meter increased. On average, over four years of research compared to the control variant (15 cm), a length of 20 cm of cuttings planted for rooting produced 73.7 pcs/m$^2$ of clonal rootstocks, at 30 cm cuttings length – 114.4 pcs/m$^2$, at 40 cm length – 152.4 pcs/m$^2$.

The data obtained convincingly demonstrate the advantage of using longer cuttings to obtain standard clonal rootstocks (see Table 3).

The harvested clonal rootstocks of cherry are stored in a facility where a constant temperature of minus 2 °C is maintained. The clonal rootstocks obtained are subsequently used for grafting selections, varieties, and collections of cherry during the winter period.

***Рис. 3.*** Клоновые подвои вишни Маака
***Fig. 3.*** Clone rootstocks of the Maak cherry

**Табл. 3.** Влияние длины зеленого черенка вишни Маака на выход клоновых подвоев, шт./м$^2$

**Table 3.** Effect of the Maak cherry green cuttings length on the yield of clonal rootstocks, pcs/m$^2$

| Stem length, cm | 2015 | 2016 | 2017 | 2018 | Average |
|---|---|---|---|---|---|
| 15 (control) | 40,3 | 48,3 | 44,6 | 45,6 | 44,7 |
| 20 | 67,6 | 93,6 | 68,6 | 65,3 | 73,7 |
| 30 | 124,3 | 105,3 | 112,3 | 115,6 | 114,4 |
| 40 | 162,3 | 149,3 | 147,6 | 150,3 | 152,4 |
| $LSD_{05}$ | 2,5 | 2,1 | 2,0 | 2,4 | 14,9 |

## CONCLUSION

The scientific research conducted on obtaining standard clonal rootstocks showed that the Maak Cherry is capable of achieving a high percentage of rooting under favorable (greenhouse) conditions. By increasing the length of the green cutting from 15 to 30–40 cm, rooting increased by 1.3 times, and the diameter of the conditional root neck increased by 1.5 times. The number of standard clonal rootstocks also increased from 44.7 per m² in the control variant to 152.4 per m² in the variant with a green cutting length of 40 cm. The use of green cuttings with a length of 30–40 cm, cut and planted in the greenhouse during the period of active growth, allows for the production of high-quality standard clonal rootstocks suitable for propagating sweet cherry and cherry within one vegetation period without the need for further growth.

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# БИОХИМИЧЕСКИЕ ПОКАЗАТЕЛИ БЕЛКОВОГО ОБМЕНА КРОВИ КАК КРИТЕРИИ ПОЛНОЦЕННОСТИ КОРМЛЕНИЯ БРОЙЛЕРОВ

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Опыты проведены на цыплятах-бройлерах кросса «Смена-9» в условиях вивария Селекционно-генетического центра «Загорское экспериментальное племенное хозяйство», г. Сергиев Посад. Результаты биохимических исследований плазмы крови показали волнообразные изменения активности трипсина во всех исследуемых возрастных периодах. Повышение концентрации общего белка в 7-суточном возрасте во всех группах по сравнению с суточным могло быть спровоцировано переходом с эндогенной формы кормления при поступлении экзогенного корма, содержащего большее количество протеина по сравнению с желточным мешком. Возрастная динамика активности щелочной фосфатазы имела резкие колебания на протяжении всего периода выращивания. В возрастной период с 1–7 сут наблюдалось повышение фосфатазной активности с последующим снижением до 35-суточного возраста относительно контроля во всех группах. Пик высокой активности данного фермента приходился на 7-е сутки (31 030 ед./л) в контрольной группе и на 14-е сутки – во 2-й опытной группе. Далее происходило постепенное снижение активности данного фермента. Резкое увеличение уровня щелочной фосфатазы в крови цыплят-бройлеров в 7–21-суточном возрасте свидетельствует об интенсивном росте и становлении организма, однако резкий скачок активности в 7-суточном возрасте также мог быть вызван переходом на новый рацион, что является фактором стресса. Понижение активности данного энзима в 28–35-суточном возрасте свидетельствует о замедлении процесса роста. Следовательно, целью данного исследования являлось изучение биохимического состава крови в разных периодах постэмбриогенеза цыплят-бройлеров кросса «Смена-9» при изменении уровня протеина в рационе, что в данном случае остается актуальным и информативным источником информации о влиянии изменения ингредиентного состава корма на организм птицы в целом.

**Ключевые слова**: цыплята-бройлеры, сырой протеин, трипсин, щелочная фосфатаза, общий белок, мочевая кислота

# BIOCHEMICAL INDICES OF BLOOD PROTEIN METABOLISM AS CRITERIA OF BROILER NUTRITION ADEQUACY

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The experiments were conducted on the broiler chickens of the cross "Smena-9" in the vivarium of the Selective Genetic Centre "Zagorskoe Experimental Breeding Farm" in Sergiev Posad. The results of the blood plasma biochemical tests showed wavelike changes in the trypsin activity at all ages studied. The increased concentration of total protein at 7 days of age in all groups could have been induced by switching from endogenous feed when receiving exogenous feed containing more pro-

tein than the yolk sac. The age dynamics of the alkaline phosphatase activity had sharp fluctuations throughout the whole rearing period. At 1–7 days of age, there was an increase in the phosphatase activity with a subsequent decrease until 35 days of age relative to the control in all groups. The peak of high activity of this enzyme occurs on the 7th day – 31030 units/l in the control group and on the 14th day in the experimental group 2. Thereafter, there is a gradual decrease in the activity of this enzyme. A sharp increase in the level of alkaline phosphatase in the blood of broiler chickens at 7–21 days of age indicates intensive growth and formation of the organism, but a sharp surge in activity at 7 days of age could also be caused by the transition to a new diet, which in itself is a stress factor. A decrease in the activity of this enzyme at 28–35 days of age indicates a slowdown in the growth process. Consequently, the purpose of this study was to investigate the biochemical composition of blood in different periods of post-embryogenesis of broiler chickens of the cross "Smena-9" at changing the level of protein in the diet, which in this case remains a relevant and informative source of information on the effect of changes in the ingredient composition of feed on the bird organism as a whole.

**Keywords:** broiler chickens, crude protein, trypsin, alkaline phosphatase, total protein, uric acid

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## INTRODUCTION

Poultry farming is the most advanced sector of livestock agriculture globally. Thanks to improved farming methods, automated equipment, comprehensive and balanced feeding, and other new technologies, chicken meat is one of the most popular options in meat production [1, 2]. This type of meat also contains a large amount of digestible protein, low cholesterol, low fat, and a high proportion of unsaturated fatty acids, enhancing its quality and accessibility [3]. The taste, which can be influenced by many components of the diet, is crucial for meat quality [4]. It is well-known that altering the composition of animal feed can modify the fatty acid and protein profile of the products [4, 5].

Modern feed, which is manufactured for the intensive fattening of poultry, ensures maximum utilization of its nutrients by rule. Special attention needs to be paid to the peculiarities of digestion, absorption, and metabolism [6] because the concentration of glucose, amino acids, fatty acids, and other substances in body fluids is a factor of homeostasis[1]. Some authors have shown that under various nutritional conditions, broiler chickens exhibit specific and significant shifts in blood parameters, as blood serves as an effective indicator reflecting various aspects of metabolism in the body [7]. In this case, blood parameters in birds can be used as a biochemical criterion of the adequacy of their diet, which are reliable indicators of the well-being of birds and reflect the processes of nutrition, physiolog-

[1]*Gietzen D.W.* Neural mechanisms in the responses to amino acid deficiency // The Journal of nutrition. 1993. N 123 (4). P. 610–625.

ical and pathological state of the organism as a whole [8].

Literature[2] suggests that insufficient protein levels decrease growth rate and metabolism, slow development, and deteriorate the quality and nutritional value of carcasses, which subsequently prevents the realization of the high genetic potential for meat productivity of the fattened young stock. Both excess and deficiency of protein in poultry diets lead to fat deposition in internal organs and subcutaneous tissue, cause digestive system disorders, and decrease productivity[3]. Since modern poultry farming is entirely based on industrial technology, the norms for feeding poultry with regard to the quantity and quality of the feeds used should be constantly improved.

The purpose of the study is to investigate some basic biochemical indicators of protein metabolism in the blood of "Smena-9" broiler chickens cross during the post-embryonic period of ontogeny at different protein levels in the diet.

## MATERIAL AND METHODS

Experiments to study biochemical indicators were conducted on 105 "Smena-9" broiler chickens. The poultry were reared from day-old to 35-day-old in the vivarium of the breeding and genetic center “Zagorskoye Experimental Breeding Farm” (SGC “Zagorskoye EBF” – a branch of FSC “VNITIP”) under the condition of feeding and housing in accordance with the requirements for these age groups and cross of poultry [9].

The experiments were conducted in accordance with the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes[4]. At one day old, three groups of 35 individuals each were formed. The experimental scheme is presented in Table 1.

The feeding of the chickens had three periods: a starter period (0–14 days), a growth period (15–21 days), and a finishing period—from day 22 until slaughter. The variation in crude protein in the diet was achieved by changing the proportion of soybean meal and synthetic amino acids used.

Blood for analysis was collected weekly from 5 individuals from each group. At day-old and 7-day-old, it was collected at slaughter. At other age periods, it was taken from the axillary vein. For plasma studies, sterile vacuum tubes with lithium heparin anticoagulant were used. To separate plasma from blood cells, samples were centrifuged at 5000 rpm for 5 minutes using an EVA-200 centrifuge (China).

Biochemical analyses of blood were performed on a SINNOWA BS-3000P semi-automatic biochemistry analyzer (China) using appropriate reagent kits for determining total protein, alkaline phosphatase, and uric acid. Trypsin activity was determined using benzoyl DL-arginine nitroanilide (BAPNA, "ACROS ORGANICS", Switzerland) as a substrate.

**Табл. 1.** Схема опыта
**Table 1.** Experiment scheme

| Group | Number of heads | Feeding features |
|---|---|---|
| Control | 35 | Basic Diet (BD) with crude protein content in starter 23.0% |
| Experimental: | | |
| 1st | 35 | BD with crude protein content in starter 21.5% |
| 2nd | 35 | BD with crude protein content in starter 24.5% |

[2]*Konoblei T.V.* Indicators of morphological and biochemical composition of blood of broiler chickens grown on mixed fodder with a different ratio of protein of vegetable and animal origin / T.V. Konoblei, M.V. Tolstopiatov // Integration processes in science, education and agricultural production - a guarantee of successful development of agroindustrial complex: proceedings of the International Scientific and Practical Conference: in 4 volumes, Volgograd, January 25-27, 2011, vol. 2, Volgograd: Volgograd State Agrarian University, 2011, pp. 146-149.

[3]*Pogosyan D.G., Rybalko M.N.* Effect of different levels of protein in diets on metabolism in the body of broiler ducklings / D.G. Pogosyan // Theoretical and practical aspects of innovative achievements in zootechnics and veterinary medicine: a collection of scientific articles of the All-Russian scientific and practical conference, Kursk, November 30, 2022 / Kursk State Agricultural Academy named after I.I. Ivanov, 2022, pp. 180-183.

[4]European Convention for the Protection of Vertebrate Animals Used for Experimental or Other Scientific Purposes (ETS No. 123) (Strasbourg 18.03.1986). URL: http://www.conventions.ru/view_base.php?id=19432).

For statistical analysis of the results, Microsoft Office Excel was used, which performed calculations of the mean value (*M*) and standard deviation (± *m*). The significance of differences was determined using the Student's *t*-test, with differences considered statistically significant at $p < 0.05$.

## RESULTS AND DISCUSSION

Analyzing the data in Table 2, one can observe wave-like changes in trypsin activity throughout all growth periods. There are both declines and increases in enzyme activity.

The trypsin activity at one day of age was at the same level across all groups, averaging 1253 ± 109.1 units/l. By the 7th day of age, the activity of this enzyme had significantly decreased by 76.9% ($p \geq 0.05$) in the control group, 75.7% in the first experimental group ($p \geq 0.05$), and 79.3% in the second experimental group ($p \geq 0.05$) compared to the activity at one day of age. By the 14th day of age, enzyme activity had significantly increased by 1.9 times in the control group and 2.1 times in both experimental groups compared to the 7th day of age. At 21 days of age, there was a decrease in enzyme activity compared to the 14th day of age, amounting to 360.0 ± 33.4 units/l in the control group, 455.0 ± 37.1 units/l in the first experimental group, and 404.0 ± 55.3 units/l in the second experimental group. By the 35th day of age, trypsin activity had almost returned to the levels seen at 7 days of age. Apparently, changes in enzyme activity are related to the physiological maturation of the pancreas.

It should also be noted that there is experimental evidence that digestive enzymes can be absorbed into the bloodstream, then carried by the blood to the pancreas and secreted back into the intestine [10]. Apparently, the increase in this enzyme with a reduction in protein in the diet at all growth periods compared to the control group supports this hypothesis. This is also evident from the decrease in enzyme activity in the blood in the second experimental group compared to the first experimental group, where the enzyme is likely being returned to the pancreas for activation to further break down dietary protein.

**Табл. 2.** Активность трипсина в плазме крови цыплят-бройлеров кросса «Смена-9» при разном уровне протеина в рационе, ед./л

**Table 2.** Trypsin activity, units/l in blood plasma of broiler chickens of the cross «Smena-9» at different levels of protein in the diet

| Age, days | Group | | |
|---|---|---|---|
| | control | experimental | |
| | | 1st | 2nd |
| 1 | 1253 ± 109,1 | | |
| 7 | 289 ± 34,4* | 304 ± 26,2* | 259 ±24,4* |
| 14 | 557 ± 47,2* | 650 ± 39,0* | 547 ± 40,8* |
| 21 | 360 ± 33,4* | 455 ± 37,1* | 404 ± 55,3* |
| 28 | 490 ± 56,6* | 684 ± 46,1* | 489 ± 57,9* |
| 35 | 352 ± 31,6* | 289 ± 28,7* | 266 ± 16,3* |

*$p \geq 0,05$ compared to the daily age.

The biochemical data analysis of the total protein level is presented in Table 3. The content of total protein in the serum of broiler chickens in all groups during the entire observation period was within the physiological norm. However, analyzing the age dynamics of total protein content, a significant ($p \geq 0.05$) increase in its level from 7 days of age compared to one day of age in all groups at all growth periods can be noted.

Considering that the intensity of protein metabolism in poultry and the level of meat productivity are closely related and that the protein level in the bird's body is regulated by the central nervous system and hormones, it can be assumed that the increase in total protein content in all groups starting from 7 days of age is related to the enhancement of protein synthesis under the influence of the protein metabolism nerve center located in the hypothalamus of the intermediate brain[5].

[5]*Tsyurik A.V., Bezborodov N.V.* Effect of vitamin-mineral complex Mixodil on the hormonal background and protein content in the blood of laying hens // Vestnik of OSU, 2015, N 6 (181).

**Табл. 3.** Содержание общего белка в плазме крови цыплят-бройлеров кросса «Смена-9» при разном уровне протеина в рационе, г/л

**Table 3.** Total protein content in the blood plasma of broiler chickens of the Smena-9 cross at different levels of protein in the diet, g/l

| Age, days | Group | | |
|---|---|---|---|
| | control | experimental | |
| | | 1st | 2nd |
| 1 | 28,3 ± 0,54 | | |
| 7 | 35,9 ± 1,27* | 34,8 ± 1,68* | 35,0 ±1,79* |
| 14 | 33,7 ± 0,98* | 37,1 ± 1,28* | 31,5 ± 1,02 |
| 21 | 32,5 ± 1,03 | 35,2 ± 0,99* | 37,8 ± 0,73* |
| 28 | 33,4 ± 0,95* | 33,1 ± 0,60* | 35,4 ±0,72* |
| 35 | 33,8 ± 1,37* | 37,4 ± 0,70* | 37,8 ± 1,11* |

*$p \geq 0,05$ compared to the daily age.

The protein minimum (the amount of protein necessary to maintain nitrogen balance) depends on the type of poultry, its physiological state, and the level of productivity (intensity of growth or egg production). For example, the amino acid requirements of broiler chickens and turkey poults[6] are noted to be higher compared to adult poultry. An imbalance of amino acids disrupts normal growth and development, decreases poultry resistance to diseases. Excess protein in the diet overloads the body with protein degradation products. In this case, during deamination, urea, sulfuric, and other acids[7] are produced in increased amounts as end products.

Uric acid is the primary product of nitrogen-containing compound metabolism in birds.

The amount of uric acid in the blood depends not only on many factors but also largely on the amount of protein consumed or the rate of its breakdown in the body [11].

As seen in Figure 1, at one day and 7 days of age, the level of uric acid in all studied groups is approximately at the same level. Starting from 14 days of age until slaughter, a lack of protein in the diet leads to a decrease in the concentration of uric acid in the serum. An increase in the concentration of this indicator in the blood plasma of broiler chickens in the second experimental group compared to the first experimental group is likely due to an excess of nitrogen, which the broilers attempted to remove via uric acid, thereby increasing its content [12].

Alkaline phosphatase is a cellular enzyme, and the biochemical composition of blood plasma reflects the metabolic situation in tissues, allowing for the assessment of changes in organ functions and the animal's adaptation to dietary and physiological challenges [13]. An increased activity of this enzyme in the blood is universally recognized as a marker of skeletal or hepatobiliary diseases [14].

According to our studies, a peak in high activity of alkaline phosphatase in the control group (see Fig. 2) occurs on the 7th day, but there is a gradual decrease afterward. A sharp increase in phosphatase activity in the blood of broiler chickens at 14 days of age in all groups indicates intensive growth and development of the organism. By 21 days of age, there is a decrease of 40.7% in the first experimental group, while in the second experimental group, there is an increase of 7.4% compared to the control group. Apparently, a decrease in the activity of this enzyme at 28–35 days of age indicates a slowing of growth processes.

## CONCLUSION

In the blood of broiler chickens during the post-embryonic period, certain dynamics of biochemical indicators were observed. Changes in all studied blood parameters indicate the intensity of growth of broiler chickens in the

[6] *Tarasov N.V.* Lysine and methionine in mixed fodder for broilers // Poultry farming, 2009, N 5, pp. 12-15.

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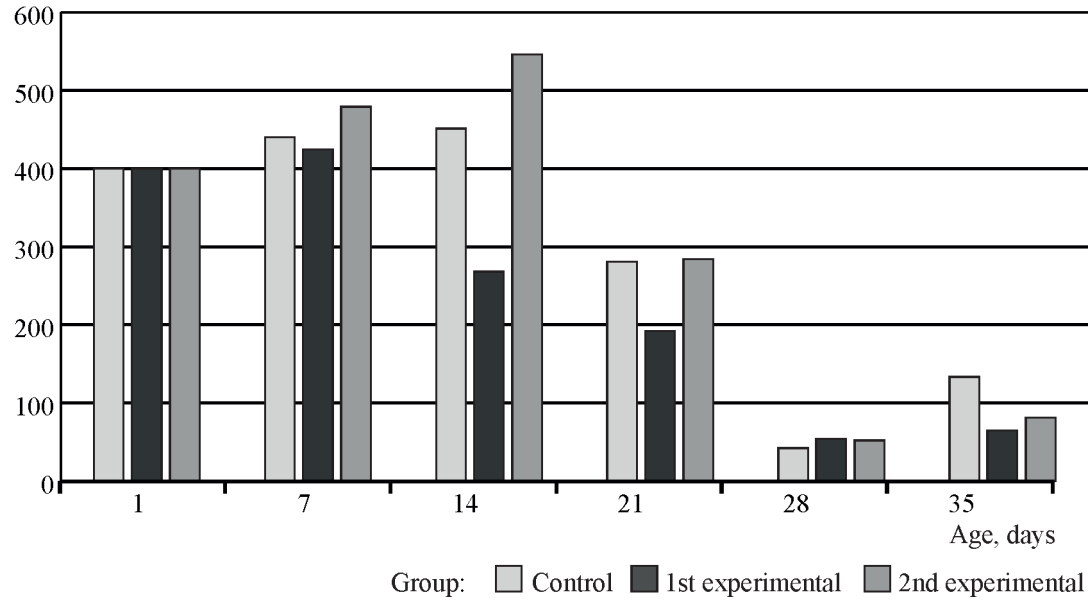


***Рис. 1***. Содержание мочевой кислоты в плазме крови цыплят-бройлеров кросса «Смена-9» при разном уровне протеина в рационе, мкмоль/л

***Fig. 1.*** Uric acid content in the blood plasma of broiler chickens of the Smena-9 cross at different levels of protein in the diet, μmol/l

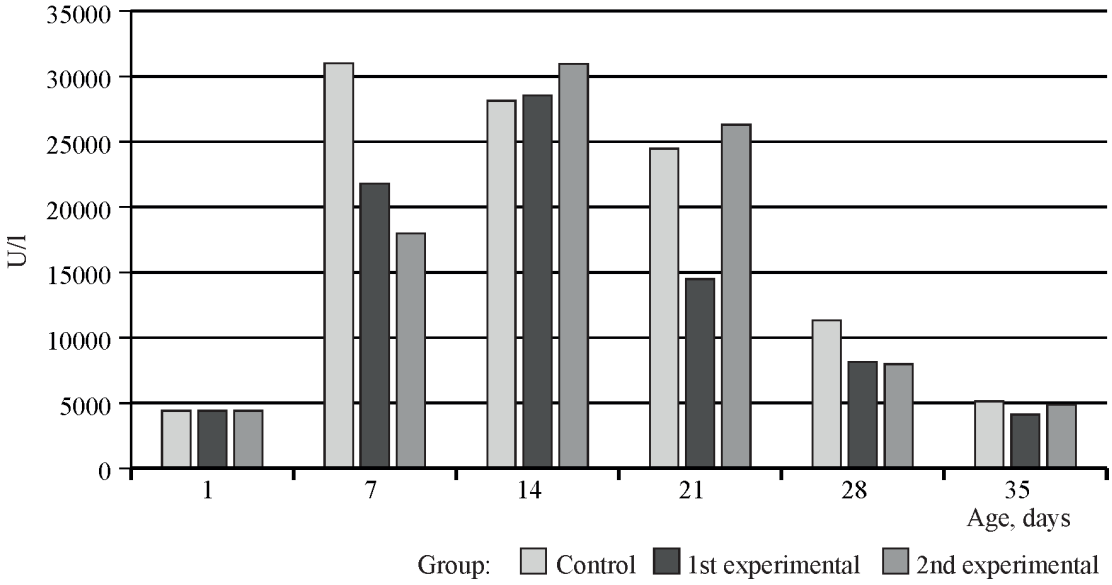


***Рис. 2.*** Активность щелочной фосфатазы в плазме крови цыплят-бройлеров кросса «Смена-9» при разном уровне протеина в рационе, ед./л

***Fig. 2.*** Alkaline phosphatase activity in the blood plasma of broiler chickens of the Smena-9 cross at different levels of protein in the diet, units/l

post-embryonic period of ontogeny and the establishment of their digestive system, which is fundamental to the growth and development of the bird.

Reducing the protein level in the diet leads to an increase in trypsin activity, a decrease in alkaline phosphatase activity, and a reduction in uric acid content compared to the control group at all growth periods.

Increasing the protein level in the diet leads to an increase in alkaline phosphatase activity at 14 and 21 days of age, a wave-like change in

trypsin activity at all periods, and an increase in uric acid content compared to the control group.

Therefore, our experimental data show that changes in crude protein in the feed for broiler chickens of the cross "Smena-9" affect the biochemical composition of the blood. The data indicate that reducing crude protein in the feed through soybean meal has a more beneficial effect on the overall condition of the bird than increasing it. It is essential to ensure that there are no changes in the metabolic energy and nutritional value of the diet due to other components of the feed. It can be suggested that in the future, blood parameters in poultry could be used as a biochemical criterion of feeding adequacy and as markers of the physiological state of high-producing birds.

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# ГЕМАТОЛОГИЧЕСКИЕ ПОКАЗАТЕЛИ КРОВИ ТЕЛОК РАЗЛИЧНЫХ ЛИНИЙ КАЗАХСКОЙ БЕЛОГОЛОВОЙ ПОРОДЫ

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Опыт завоза импортных высокопродуктивных производителей показал недостатки данной практики, обусловленные низкой адаптацией завезенных животных и трудностями их полноценной акклиматизации к новым условиям содержания и кормления. В результате в лучшем случае это не позволяет реализовать их потенциал, в худшем – способствует тому, что они быстро выбывают из процесса воспроизводства. Отечественные породы приспособлены к условиям России, однако нуждаются в совершенствовании продуктивных качеств. Поэтому селекционно-племенная работа имеет ключевое значение в технологическом развитии отрасли мясного скотоводства нашей страны. Нами были проведены исследования на телках казахской белоголовой породы линий Донгуза 7139, Короля 13682НВ-6 и Золотого 3423 в условиях СПК (колхоз) «Аниховский» Адамовского района Оренбургской области. Отбор проб крови у телок проводили в 15-месячном возрасте утром до кормления из яремной вены ($n$ = 18). Кровь, предназначенную для морфологических исследований, помещали в вакуумные пробирки с антикоагулянтом, для биохимических – в пробирки с активатором коагуляции. Установлено, что телки линии Золотого 3423 превосходили животных других линий. Например, представительницы данной линии превосходили телок линии Донгуза 7139 по содержанию в крови общего белка (79,9 г/л) на 5,6%, альбуминов (36,8 г/л) – на 6,35%, АСТ (27,8 Ед/л) – на 4,27%, АЛТ (105 Ед/л) – на 14,2%, эритроцитов (5,67 · $10^{12}$ кл/л) – на 15,24%, гемоглобина (79,6 г/л) – на 12,42%, что свидетельствует о высокой скорости метаболизма и окислительно-восстановительных процессов в их организме и исключает скрытые риски по устойчивости, адаптированности генофонда новой селекционной формы. Учитывая приведенные в нашей предыдущей статье показатели продуктивности, а также полученные в процессе данного исследования результаты, перспективными в селекционно-племенной работе со стадом казахского белоголового скота в условиях СПК являются создание и увеличение численности животных линии Золотого 3423.

**Ключевые слова:** крупный рогатый скот, казахская белоголовая порода, линия, телки, гематологические показатели, селекция, адаптивность

# HEMATOLOGICAL PARAMETERS OF BLOOD OF THE HEIFERS OF DIFFERENT LINES OF THE KAZAKH WHITE-HEADED BREED

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The experience of importing high-yielding foreign producers has shown the disadvantages of this practice due to low adaptation of the imported animals and difficulties in their full acclimatization to new conditions of housing and feeding. As a result, at best it prevents them from realizing their potential, at worst it contributes to their rapid drop out of the reproduction process. Domestic breeds are adapted to Russian conditions, but need to improve their productive qualities. Therefore, selection and breeding work is of key importance in the technological development of the beef cattle breeding industry of our country. We conducted studies on the heifers of the Kazakh white-headed breed of the Donguz 7139, Korol 13682NV-6 and Zolotoi 3423 lines in the conditions of the APC (collective farm) "Anikhovsky" of the Adamovsky district of the Orenburg region. Blood sampling of the heifers at 15 months of age ($n$ = 18) was carried out in the morning before feeding from the jugular vein, for mor-

phological studies – in vacuum tubes with an anticoagulant, for biochemical – with a coagulation activator. It was found that the heifers of the Zolotoi 3423 line surpassed the animals of the Donguz 7139 line in blood content of total protein (79,9 g/l) by 5.6%, albumins (36,8 g/l) by 6.35%, AST (27,8 Un/l) by 4.27%, ALT (105,0 Un/l) by 14.2%, erythrocytes (5,67 · $10^{12}$ cells/l) by 15.24% and hemoglobin (79,6 g/l) by 12.42%, that indicates a high rate of metabolism and redox processes in their body and eliminates the hidden risks of stability, adaptability of the gene pool of a new breeding form. Taking into account the productivity indicators given in the previous article, as well as the results obtained in the course of the present study, the creation and increase in the number of animals of the Zolotoi 3423 line is promising in breeding and breeding work with a herd of the Kazakh white-headed cattle in the APC (collective farm).

**Keywords:** cattle, Kazakh white-headed breed, line, heifers, hematological parameters, breeding, adaptability

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## INTRODUCTION

It is crucial that in Russian beef cattle farming, breeding animals that are adapted to the climatic conditions of our country and distinguished by high productivity predominate. This can be achieved not merely by importing livestock from abroad, but through scientifically grounded use of genetics from foreign breeds and the improvement of domestic ones. Significant importance in creating high-quality breeding herds and improving the breed quality of agricultural animals is given to breeding methods[1] [1–3].

Domestic and international practices have shown that the primary method in breeding livestock should be purebred breeding by lines. Purebred animals can stably transmit their qualities and produce highly productive offspring when crossbred. Enhancement of breeding and productive qualities is achieved through systematic selection and matching, as well as improving feeding and maintenance of the livestock [4–8].

In selecting new forms (lines, types, etc.), breeders focus on the characteristics they wish to obtain and develop in the animals. These traits are concentrated in parental forms carrying a specific genotype. Creating a related group with the necessary characteristics and further breeding such animals promote the consolidation of heredity, determining the expression of these traits in the given population, which is precisely what breeders need. At the same time, in the case of linebred animals, heredity characterized by high indicators of external trait expression might suggest the possibility of a different response to external stimuli (climate, housing conditions, feeding, etc.), hidden in the internal indicators. Therefore, the best criteria for the successful development of the obtained genotype in specific

[1] *Tyulebaev S.D., Kanatpayev S.M., Nurpisov I.B., Karsakbaev A.B.* "Bredinsky meat" type of the Simmental breed – a new direction in beef cattle breeding in Russia // Herald of Beef Cattle Breeding, 2009, vol. 4, N 62, pp. 109-112.

local conditions are the harmony of the internal environment of the animal's body and the stability of internal indicators. Thus, blood is a vital medium for all cells, tissues, and organs of animals. Through it, the most important property of matter—metabolism—is realized. Blood delivers nutrients and oxygen to body cells, removes metabolic products and carbon dioxide. Furthermore, it participates in maintaining the balance of the body's hormonal function and regulating the immune system.

Blood, while maintaining a certain consistency of composition, is a highly labile system that reflects oxidative-reductive processes occurring in the body, as well as the metabolism of substances depending on the variability of external conditions. In this context, there are values beyond which hematological indicators cross in cases of reduced immunity or the presence of disease[2] [9]. This quality of blood is utilized in biology, medicine, and veterinary science, providing the ability to monitor organism development and regulate the processes of forming animal productivity indicators.

The purpose of the study is to investigate the hematological indicators of heifers of the Kazakh white-headed breed from various forming lines.

## MATERIAL AND METHODS

The subjects of the study were heifers of the Kazakh white-headed breed from the Donguz 7139, Korol 13682HB-6, and the newly created Zolotoi 3423 lines.

Animal procedures were carried out in accordance with the instructions and recommendations contained in the USSR Ministry of Health Order "On Measures to Further Improve Organizational Forms of Work with Experimental Animals" No. 755 dated August 12, 1977, and the "Guide for the Care and Use of Laboratory Animals" (1996). In doing the research efforts were made to minimize animal suffering, and the minimum possible number of samples was used.

During the experiment, 54 clinically healthy Kazakh white-headed heifers were divided into three groups (18 each): 1st – Donguz 7139 line, 2nd – Korol 13682HB-6, 3rd – Zolotoi 3423. The study was conducted at the APC (collective farm) "Anikhovsky" in the Adamovsky district of the Orenburg region. The duration of the experiment was 212 days (from 8 to 15 months of age). Blood samples were taken from 15-month-old heifers (6 from each group). Sampling was done once in the morning before feeding and watering from the jugular vein. Blood used for morphological studies was placed in vacuum tubes with anticoagulant (EDTA), and for biochemical studies, in tubes with coagulation activator (silica dioxide – $SiO_2$).

For the selection-genetic evaluation of lines, primary documentation on zootechnical and breeding records adopted on the farm was used. Animal groups were formed according to the pair-analogs method and were maintained according to specialized meat livestock technology. The line testing was carried out based on the methodologies and instructions of the State Variety Commission of the Russian Federation.

The study of animal biosubstrates ($n$ = 18) was conducted using equipment at the Testing Center of the CUC of Biological Systems and Agrotechnologies of the Russian Academy of Sciences (accreditation certificate № RA.RU.21PF59 dated October 12, 2015)[3]. The physiological health status of the animals was monitored throughout the experiment. Morphological blood parameters were determined using an automatic hematological analyzer URIT-2900 Vet Plus (URIT Medical Electronic Co., Ltd., China). Biochemical analysis of the blood serum was conducted on an automatic biochemical analyzer DIRUI CS-T240 (Dirui Industrial Co., Ltd., China) using commercial veterinary biochemical kits from DiaVetTest (Russia). Biochemical parameters of blood included determination of total protein, albumin, creatinine, urea, direct bilirubin, cholesterol, lactate dehydrogenase (LDH), glucose, aspartate aminotransferase

[2] *Ayadi O., Gharbi M., Benchikh-Elfegoun M.C.* Haematological and biochemical indicators of tropical the ileriosis diseased cattle in wilaya of Sétif (North East Algeria) // Journal Parasitic Diseases, 2017, N 41 (2), pp. 538–542.

[3] URL: www.цкп-бст.рф.

(AST), alanine aminotransferase (ALT), and etc.

Statistical processing was performed using IBM SPSS Statistics 20 software. The level of significance was considered statistically significant at $p \leq 0.05$.

## RESULTS AND DISCUSSION

Due to the possibility of presenting some indicators in a diagram form, we have changed the usual sequence of material presentation. Considering the key properties of blood, we studied its morphological and biochemical indicators, which for all presented parameters did not exceed the reference intervals for cattle [10]. Heifers of the Korol 13682HB-6 and Zolotoi 3423 lines surpassed their peers from the Donguz 7139 line in the accumulation of transaminase enzymes (AST and ALT), which characterize the rapidity of lipid metabolism in the body (see the table).

The young stock of the Donguz 7139 line was inferior in AST content to the heifers of the Korol 13682HB-6 line by 0.49%, and to the Zolotoi 3423 line by 4.27%; in ALT by 3.29% and 14.40% respectively ($p \leq 0.05$). The highest amount of direct bilirubin was recorded in the heifers of the Donguz 7139 line – 2.10 μmol/l, they surpassed animals of the Korol 13682HB-6 and Zolotoi 3423 lines by 9.5% and 21.9% respectively ($p \leq 0.01$).

One of the most important properties of blood is the supply of oxygen to the body tissues. Analyzing the blood parameters of heifers across the three lines, it is evident that the number of erythrocytes in animals of the Korol 13682HB-6 and Zolotoi 3423 lines is higher by 16.05% ($p \leq 0.01$) and 15.24% ($p \leq 0.01$) respectively,

Гематологические показатели 15-месячных телок казахской белоголовой породы
Hematological parameters of 15-month-old heifers of the Kazakh white-headed breed

| Indicator | Line | | |
|---|---|---|---|
| | Donguz 7139 | Korol 13682HB-6 | Zolotoi 3423 |
| ALT, units/l | 24,30 ± 0,79 | 25,10 ± 2,01 | 27,80 ± 1,11[a] |
| AST, units/l | 100,70 ± 0,99 | 101,20 ± 1,29 | 105,00 ± 1,31[a] |
| Direct bilirubin, μmol/l | 2,10 ± 0,132 | 1,90 ± 0,159 | 1,64 ± 0,114[a, b] |
| Creatinine, μmol/l | 144,20 ± 6,12 | 140,90 ± 8,98 | 160,50 ± 4,28 |
| Leukocytes, $10^9$ kl/l | 6,42 ± 0,51 | 7,50 ± 0,76 | 7,10 ± 0,63 |
| Lymphocytes, % | 60,80 ± 8,83 | 44,70 ± 6,76 | 37,90 ± 8,20 |
| Monocytes, % | 18,98 ± 0,98 | 15,44 ± 0,95 | 17,40 ± 1,05 |
| Granulocytes, % | 20,22 ± 7,56 | 39,86 ± 8,84 | 44,62 ± 12,78 |
| Erythrocytes, $10^{12}$ kl/l | 4,92 ± 0,17 | 5,71 ± 0,31[a] | 5,67 ± 0,21[a] |
| Hematocrit, % | 21,30 ± 0,88 | 22,80 ± 0,97 | 23,38 ± 1,21 |
| Average erythrocyte volume, fl | 43,30 ± 0,98 | 40,20 ± 1,41 | 41,40 ± 1,02 |
| Average hemoglobin content in the cell, pg | 14,32 ± 0,41 | 13,40 ± 0,32 | 14,02 ± 0,29 |
| Red blood cell distribution accuracy, % | 20,00 ± 0,31 | 19,50 ± 0,37 | 20,16 ± 0,35 |
| Red blood cell distribution width, fl | 30,10 ± 1,02 | 27,00 ± 1,43 | 28,0 ± 0,93 |
| Thrombocytes, $10^9$ kl/l | 245,40 ± 11,3 | 213,80 ± 15,6 | 225,20 ± 13,9 |
| Average thrombocyte volume, fl | 9,40 ± 0,32 | 9,30 ± 0,29 | 10,10 ± 0,34 |

[a] $p < 0,05$ (to the 1st group).
[b] $p < 0,05$ (to the 2nd group).

compared to representatives of the Donguz 7139 line.

Animals of the Donguz 7139 line outperformed heifers of the Zolotoi 3423 and Korol 13682HV-6 lines by 0.3 and 0.92 pg (2.1 and 6.9%) in average cellular hemoglobin concentration, respectively (with a non-significant difference).

In terms of platelet content, the animals of the Donguz 7139 line had superiority over the representatives of the Zolotoi 3423 and Korol 13682HV 6 lines by 31.6 · 109 kl/l (12.8%) and 20.2 · 109 kl/l (8.2%), respectively (with an unreliable difference).

The highest percentage of lymphocytes was found in the blood of heifers of the line Donguz 7139 – 60.8%, while this average indicator varied within 37.9 –44.7% in animals of the line Korol 13682HV-6 and Zolotoi 3423. Due to the high variability of the trait, the reliability of differences was not revealed.

The mean platelet volume was within the normal range and ranged from 9.3 to 10.1 fl. The relative volume of platelets by lines differed insignificantly.

The ability of animals to convert feed protein into body proteins is evidenced by the amount of total protein in blood serum. Thus, the highest concentration of total protein in blood serum was found in the animals of the lines Korol 13682HV-6 and Zolotoi 3423 – by 6.7 ($p \leq 0.05$) and 5.6% ($p \leq 0.05$) more relative to the animals of the line Donguz 7139 (see Fig. 1). Moreover, the increase in the content of total protein was at the expense of an almost uniform increase in albumin.

In the course of the study, it was found that a greater amount of albumin was in the blood serum of heifers of the Korol 13682HV-6 and Zolotoi 3423 lines. According to this indicator, the animals of Donguz 7139 line lagged behind them respectively by 4,04 ($p > 0,05$) and 6,35% ($p \leq 0,05$).

The highest hemoglobin content was observed in the blood of the representatives of the line Zolotoi 3423 – by 3.10 ($p > 0.05$) and 12.42% ($p < 0.05$) more than in the lines of Korol 13682HV-6 and Donguz 7139.

The lowest amount of urea was recorded in the blood of heifers of the Donguz line 7139 – by 9.4 ($p > 0.01$) and 16.9% ($p > 0.01$) less than the indicators for the lines of Korol and Zolotoi (with unreliability of the difference) (see Fig. 2).

The highest concentration of cholesterol was observed in the heifers of the Korol 13682HB-6 lines: by this indicator they surpassed the compared lines by 7.36 and 10.76%. Glucose content in blood serum of the heifers varied from 1.61 to

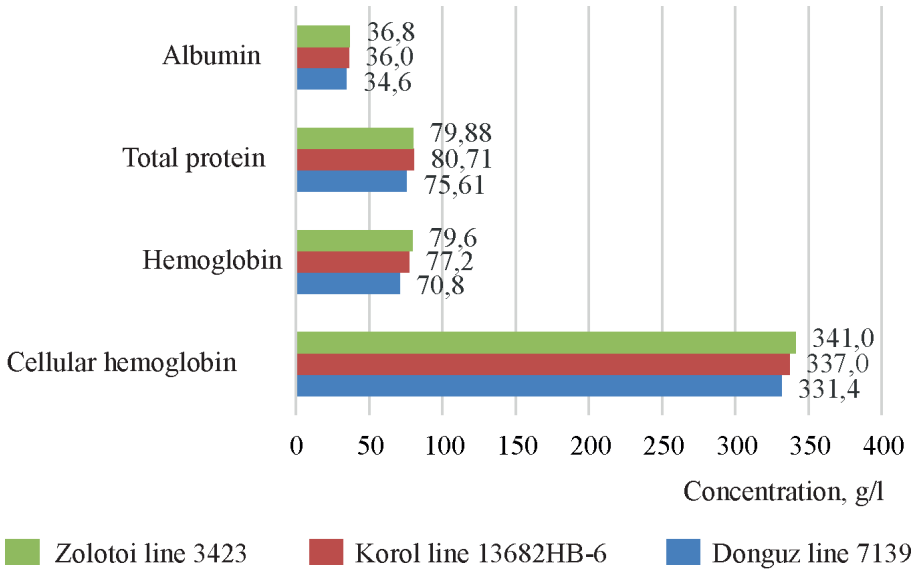


***Рис. 1.*** Концентрация белков и гемоглобина в крови телок разных линий
***Fig. 1.*** Protein and hemoglobin concentration in the blood of heifers of different lines

1.76 mmol/l depending on the lines. However, the difference was not significant for these indicators as well.

The practice of breeding cattle of foreign selection in Russia shows some vulnerability of such animals in terms of resistance to climatic conditions of our country.

It is possible to indirectly judge the resistance of the organism, immune system to unfavorable factors on the basis of the analysis of blood parameters and stability of its composition. Currently, it is more appropriate to breed beef cattle of domestic selection as more adapted to our conditions in the conditions of farms [11, 12]. One of such breeds of domestic selection is the Kazakh white-headed cattle.

Creation of breeder lines on the basis of related groups of high-class stud bulls is of great importance for the improvement of the whole breed. In order to consolidate the features of the line at the first stage of its creation it is important to study hematological parameters of progeny, to exclude hidden risks on stability, adaptability of the gene pool of the new breeding form. In addition, the content of total protein, albumin, erythrocytes and hemoglobin in the blood can be judged on the intensity of metabolic processes in the body and average daily live weight gain [13].

In our experiment heifers of the line Zolotoi 3423 had superiority over their peers of the line Donguz 7139 bred in the farm in the following parameters: total protein – by 5.60%, albumin – by 5.97, erythrocytes – by 15.24, hemoglobin – by 12.42%. The number of erythrocytes and hemoglobin concentration in the blood of the animals of the Korol 13682HV-6 line were higher by 16.05 and 9.03%, respectively ($p \leq 0.05$) compared to the heifers of the Donguz 7139 line. The increase in the content of total protein and albumin fractions in the animals of the line Zolotoi 3423 is a biochemical confirmation of high average daily gains. And it agrees with the data of our previous studies [14].

V.G. Oguy and T.V. Kureninova also found that a higher level of hemoglobin and erythrocytes ensures high productivity of cattle [15].

## CONCLUSIONS

1. Blood parameters of the animals of different lines did not exceed the reference intervals and corresponded to the values typical for the animals bred under comfortable environmental conditions.

2. There were small differences between the indicators of the heifers of different groups. In particular, it was found that the representatives of the line Zolotoi 3423 surpassed the animals

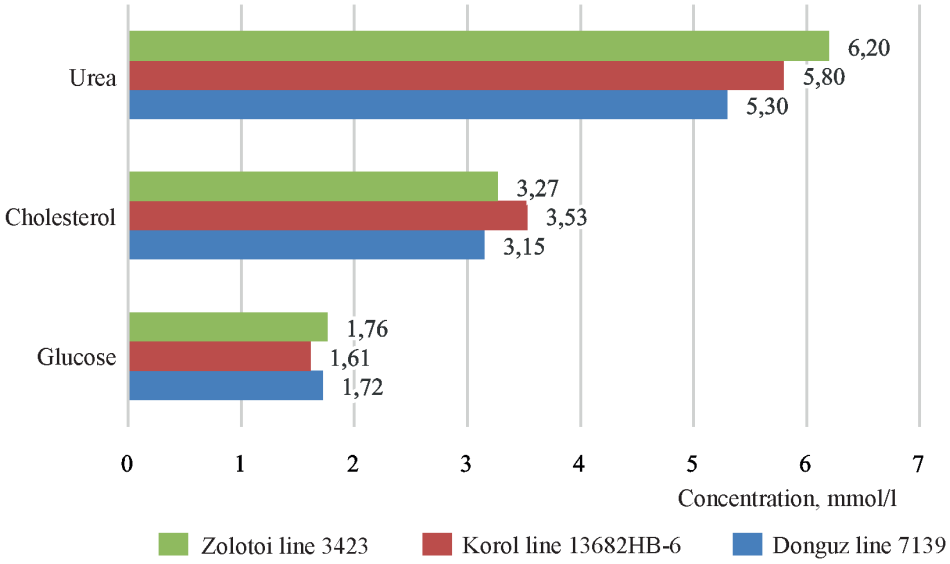


***Рис. 2.*** Концентрация мочевины, холестерина и глюкозы в крови телок разных линий

***Fig. 2.*** The content of urea, cholesterol and glucose in the blood of heifers of different lines

of the line Donguz 7139 in blood content of total protein (79.9 g/l) by 5.6%, albumin (36.8 g/l) – by 6.35%, AST (27.8 U/l) – by 4, 27%, ALT (105 U/l) – by 14,2%, erythrocytes (5,67 · 1012 kl/l) – by 15,24%, hemoglobin (79,6 g/l) – by 12,42%, that testifies about high speed of metabolism and redox processes in their organism.

3. On the basis of the conducted research it is established that the heifers of the created line (Zolotoi 3423) by the level of hematological parameters are not inferior to the line of Korol 13682NV-6 and significantly surpass the line Donguz 7139, which allows, taking into account the data of our previously published articles on productivity, to recommend animals of this line for breeding and replication in the stud flock.

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# ЧАСТОТА ВЫДЕЛЕНИЯ БАКТЕРИЙ *CLOSTRIDIUM* SPP. И ИХ АССОЦИАЦИЙ ПРИ РАЗЛИЧНЫХ ФОРМАХ КЛОСТРИДИОЗА КРУПНОГО РОГАТОГО СКОТА

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В статье представлены результаты выделения бактерий *Clostridium* spp. и их ассоциаций от крупного рогатого скота с различными клиническими формами клостридиоза. Бактериологическими методами с 2016 по 2023 г. исследовали 910 проб биоматериала, отобранных от коров, нетелей и телят в возрасте до 6 мес, а также от мертворожденных телят и абортированных плодов при патологиях воспроизводства у коров. В этиологии клостридиозов крупного рогатого скота основная роль принадлежит следующим видам: *C. perfringens*, *C. septicum*, *C. novyi* (*C. oedematiens*), *C. histolyticum* и *C. sordellii*. От коров и нетелей чаще всего выделяли *C. histolyticum* (65,2%), *C. septicum* (45,6), *C. perfringens* (29,7) и *C. sporogenes* (26,1), реже – *C. sordellii* (1,7) и *C. novyi* (0,9%). При энтеротоксемии и энтерите от животных выделяли бактерии *Clostridium* spp. шести видов, при вагините и эндометрите – пяти. При других клинических формах заболевания от коров и нетелей изолировали бактерии четырех видов. Спектр бактерий, участвующих в развитии абомазита, энтерита и энтеротоксемии у телят, был одинаковым и представлен четырьмя видами бактерий: *C. histolyticum*, *C. septicum*, *C. perfringens* и *C. sporogenes.* Бактерии пяти видов изолировали от телят с септической формой заболевания. Особенности клинического проявления и течения клостридиозов у крупного рогатого скота зависели от видового состава возбудителей и их ассоциаций. Болезни, вызываемые бактериями *Clostridium* spp., протекали остро или подостро, характеризовались видимыми поражениями органов и тканей уже через несколько часов после выявления у животного признаков болезни и в большинстве случаев заканчивались летальным исходом.

**Ключевые слова:** клостридиозы, анаэробные бактерии, крупный рогатый скот, токсины, токсемия, бактериологические методы

# THE FREQUENCY OF BACTERIAL ISOLATION OF *CLOSTRIDIUM* SPP. AND THEIR ASSOCIATIONS IN VARIOUS FORMS OF CLOSTRIDIOSIS IN CATTLE

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The article presents the results of isolation of *Clostridium* spp. bacteria and their associations from cattle with different clinical forms of clostridiosis. From 2016 to 2023, 910 samples of biomaterial collected from cows, heifers and calves under 6 months of age, as well as from stillborn calves and aborted fetuses in case of reproductive pathologies in cows were investigated by bacteriological methods. The following species play a major role in the etiology of bovine clostridiosis: *C. perfringens*, *C. septicum*, *C. novyi* (*C. oedematiens*), *C. histolyticum* and *C. sordellii*. *C. histolyticum* (65.2%), *C. septicum* (45.6), *C. perfringens* (29.7) and *C. sporogenes* (26.1) were isolated most frequently from cows and heifers, while *C. sordellii* (1.7) and *C. novyi* (0.9%) were isolated less frequently. *Clostridium* spp. bacteria of six species were isolated from animals in enterotoxemia and enteritis, and five species in vaginitis and endometritis. In other clinical forms of the disease, bacteria of four species were isolated from cows and heifers. The spectrum of bacteria involved in the development of abomasitis, enteritis and enterotoxemia in calves was similar and represented by four bacterial species: *C. histolyticum*, *C. septicum*, *C. perfringens* and *C. sporogenes*. Bacteria of five species were isolated from the calves with septicaemic form of the disease. The peculiarities of clinical manifestation and the course of clostridiosis in cattle depended on the species composition of pathogens and their associ-

ations. Diseases caused by *Clostridium* spp. bacteria were acute or subacute, characterized by visible lesions of organs and tissues in a few hours after the animal showed signs of disease and in most cases ended in death.

**Keywords:** clostridiosis, anaerobic bacteria, cattle, toxins, toxemia, bacteriological methods

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## INTRODUCTION

Clostridia belong to the genus *Clostridium*, family Clostridiaceae, order Clostridiales, class Clostridia, and phylum Firmicutes. The genus *Clostridium* is numerous and diverse, currently comprising about 240 species, most of which are saprophytes.

Typically, it is difficult to isolate a single pathogenic species as the primary etiological agent of diseases, as they are often caused by an association of pathogens, which may include species such as *C. perfringens*, *C. novyi* (*C. oedematiens*), *C. septicum*, *C. sordellii*, *C. histolyticum*, and *C. difficile*. Enterotoxemia in cattle (Bovine) is associated with *C. perfringens* types A, C, and D. *C. septicum* can be involved in the development of malignant edema, gas gangrene, and enterotoxemia. *C. chauvoei* is the causative agent of blackleg (emphysematous carbuncle). *C. sordellii* is often linked with sudden death, enterotoxemia, and malignant edema. Bovine bacillary hemoglobinuria is caused by *C. hemolyticum*[1] [1]. In recent years, a new species, *C. difficile*, which causes diseases in calves, lambs, and newborn piglets, has been identified [2–4]. Bovine clostridiosis can be caused by any of the listed Clostridium species (either singly or in various combinations), be clinically more severe, progressing rapidly, and in most cases, ending in the animal's death [5].

Despite species differences, many clostridia share a common set of similar virulence factors that facilitate the bacteria's realization of critical aspects of their reproduction and toxin production, including obtaining nutrients, binding and adhesion to host cells, evasion of host defenses, and environmental resilience [6]. Colonization of the gut by toxigenic *Clostridium* spp. involves local effects of their toxins and enzymes on the mucous membrane. Initially, the toxins act on endothelial cells, disrupting circulation and causing edema, hemorrhages, ischemia, and local necrosis. Under these conditions, the bacteria actively proliferate and produce even more toxins, while the enzymes they produce (collagenases, deoxyribonucleases, hyaluronidases, and neuraminidases) help evade immune system defenses and damage tissues, leading to the further spread of the infection [7].

[1] *Kapustin AV, Motorygin AV, Bukova N.K.* Species composition of clostridia of cattle // Vestnik veterinarii, 2013, N 1 (64), pp. 71-73.

Studies by international scientists have shown that increased permeability of the colon allows for bidirectional translocation, i.e., bacteria can cross the epithelial monolayer by two routes: paracellular (between cells) and transcellular (through cells), facilitating the development of bacteremia and the spread of clostridia throughout the body. Subsequent toxemia can lead to pathology in internal organs, including the brain, liver, lungs, and heart[2] [7]. Research on *C. difficile* has provided new insights into how bacteria traverse the intestinal barrier, causing severe damage to the epithelium of the colon, and the role of toxins produced by clostridia in systemic organ damage, including apoptosis of lymphocytes, disorganization of the thymus, red and white spleen pulp, and capsular lesions in the kidneys following barrier disruption[3, 4].

The etiological structure of pathogens causing pathologies of the gastrointestinal and reproductive systems in cattle at dairy complexes in Siberia is quite diverse and represented by viruses and bacteria. In recent years, due to the intensification of dairy farming, changes in the etiological structure of pathogens have been noted, with an increase in microbial associations and a predominance of *Clostridium* spp. bacteria in their spectrum [8].

The purpose of the study is to investigate the etiological structure of *Clostridium* spp. bacteria and their associations in the context of clinical forms of clostridiosis in cattle at dairy complexes in Siberia.

## MATERIAL AND METHODS

The study was conducted from 2016 to 2023 at the biotechnology laboratory – diagnostic center of the Institute of Experimental Veterinary Science of Siberia and the Far East of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences.

For bacteriological studies, biological material samples (contents of the small and large intestines, mesenteric lymph nodes, pieces of liver, affected muscles, abomasum, and rumen) from cows, heifers, and calves up to 6 months old, as well as vaginal swabs from cows after the first or second calving, heifers with clinical forms of endometritis or vaginitis, were collected. In cases of reproductive organ pathologies from aborted fetuses and stillborn calves, samples of liver, spleen, heart blood, and intestines were taken. Samples of milk and colostrum were collected in sterile tubes to maintain an anaerobic environment from the cows and heifers with clinical or subclinical forms of mastitis. Samples were collected as quickly as possible after the animal's death and delivered to the laboratory no later than 4–12 hours in a cooler with ice to avoid refreezing and thawing. A single freeze at –18 °C was possible; the samples were placed in small containers with tightly closed lids and delivered within 24 hours in cooler bags.

Cultures of bacteria were isolated and identified according to GOST 26503–85 "Methods of laboratory diagnosis of clostridiosis." For bacteriological studies, the samples were plated on nutritive media: Schaedler agar, Clostridium agar (HiMedia), blood meat peptone agar, and thioglycolate medium, and incubated at 37 °C under aerobic and anaerobic conditions for 24–48 hours. When studying the cultural-morphological properties of *Clostridium* spp. bacteria, their growth characteristics, micro-morphology in Gram-stained smears were noted. Species identification of bacteria was performed using the ANAEROTest 23 kit (Microlatest). Toxigenic and pathogenic properties of microorganisms were studied on outbred white mice.

[2] *Yu H., Chen K., Wu J., Yang Z., Shi L., Barlow L.L., Aronoff D.M., Garey K.W., Savidge T.C., von Rosenvinge E.C., Kelly C.P., Feng H.* Identification of toxemia in patients with Clostridium difficile infection // PLoS One, 2015, vol. 10 (4), pp. 124–235.

[3] *Carter G.P., Chakravorty A., Pham Nguyen T.A., Mileto S., Schreiber F., Li L., Howarth P., Clare S., Cunningham B., Sambol S.P., Cheknis A., Figueroa I., Johnson S., Gerding D., Rood J.I., Dougan G., Lawley T.D., Lyras D.* Defining the Roles of TcdA and TcdB in Localized Gastrointestinal Disease, Systemic Organ Damage, and the Host Response during Clostridium difficile Infections // mBio, 2015, vol. 6 (3), pp. 551.

[4] *Tao L., Zhang J., Meraner P., Tovaglieri A., Wu X., Gerhard R., Zhang X., Stallcup W.B., Miao J., He X., Hurdle J.G., Breault D.T., Brass A.L., Dong M.* Frizzled proteins are colonic epithelial receptors for *C. difficile* toxin B // Nature, 2016, vol. 538 (7625), pp. 350–355.

## RESULTS AND DISCUSSION

A total of 910 samples of biological material were examined from calves up to 6 months old, stillborn calves, aborted fetuses, cows, and heifers. To identify the species composition of *Clostridium* spp. and their associations in various clinical forms of clostridiosis, bacteriological studies of biomaterial samples were conducted, determining the number of isolated cultures and the percentage of the studied samples.

Figure 1 presents the spectrum of clinical forms of clostridiosis in cows and heifers. Mastitis (25%), abortion (17), vaginitis (15), septicemia (12), endometritis (10) were most commonly registered in animals, less frequently enterotoxemia (9), myositis (5), abomasitis (4), and enteritis (3%). The septic form of clostridiosis was characterized by pathological changes in the liver, lungs, and spleen. Enteritis, enterotoxemia, abomasitis, and myositis occurred in acute form leading to sudden animal death, while endometritis, vaginitis, and mastitis occurred in a subacute form followed by decreased animal productivity.

Tables 1 and 2 suggest that the clinical manifestations and progression of clostridiosis in cattle depended on the type of pathogens and their associations.

Analyzing the data presented in Table 1, it can be concluded that from cows and heifers, *C. histolyticum* (65.2%), *C. septicum* (45.6), *C. perfringens* (29.7), and *C. sporogenes* (26.1) were most frequently isolated, less often *C. sordellii* (1.7) and *C. novyi* (0.9%). In cases of enterotoxemia and enteritis, *Clostridium* spp. of six types were isolated from animals, and five types in cases of vaginitis and endometritis. In other clinical forms of the disease, bacteria of four types were isolated from cows and heifers. All isolated clostridium cultures were toxigenic to some degree in outbred white mice.

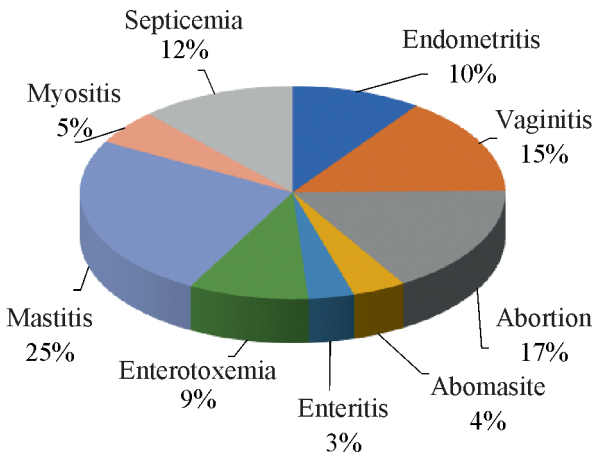



***Рис. 1.*** Клинические формы клостридиоза у коров и нетелей на молочных комплексах Сибири

***Fig. 1.*** Clinical forms of clostridiosis in cows and heifers at dairy complexes in Siberia

In acute forms of clostridiosis from cows and heifers, associations consisting of two or three different species of bacteria were most often isolated: *C. perfringens* + *C. septicum*; *C. perfringens* + *C. histolyticum* and *C. perfringens* + *C. sporogenes*; *C. perfringens* + *C. histolyticum* + *C. sordelli*, while in subacute forms – *C. septicum* + *C. sporogenes* + *C. histolyticum*; *C. perfringens* + *C. septicum* in combination with the representatives of opportunistic flora.

In calves, the disease most often occurred in the form of enterotoxemia and septicemia, characterized by sudden animal death and accompanied by pathological changes in the liver, lymph nodes, and intestines (see Fig.2). Additionally, enteritis and abomasitis were registered in the calves.

Table 3 presents the results of bacteriological studies of biomaterial samples from the calves.

The spectrum of bacteria involved in the development of abomasitis, enteritis, and enterotoxemia in calves was the same and represented by four types of bacteria. Septicemia in calves was caused by bacteria of five types: *C. histolyticum*, *C. septicum*, *C. perfringens*, *C. sporogenes*, *C. sordellii*.

According to Table 4, clinical forms of the disease in calves were most often caused by different bacterial associations. In cases of abomasitis, enteritis, and enterotoxemia, the most frequently isolated associations were: *C. perfringens* + *C. septicum*; *C. perfringens* + *C. histolyticum*; *C. perfringens* + *C. sporogenes*, while in septicemia – *C. septicum* + *C. sporogenes* + *C. histolyticum*; *C. perfringens* + *C. septicum* in combination with opportunistic flora.

The analysis of the obtained research results indicates the identification of a broad spectrum of clostridiosis pathogens in cattle at dairy com-

**Табл. 1.** Частота выделения культур бактерий *Clostridium* spp. из проб биоматериала от коров и нетелей с клиническими формами клостридиоза ($n$ = 640)

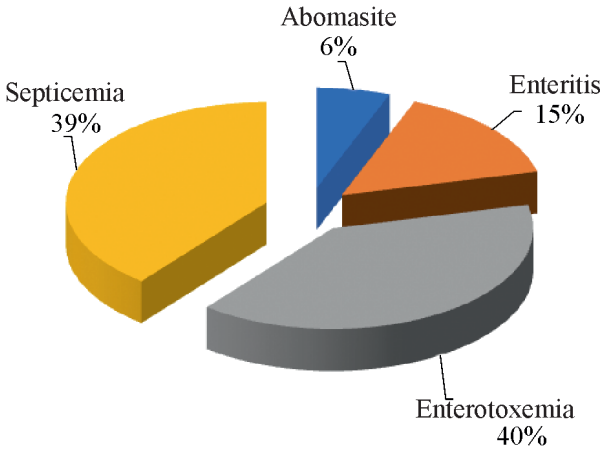
**Table 1.** The frequency of isolation of bacterial cultures *Clostridium* spp. from biomaterial samples from the cows and heifers with clinical forms of clostridiosis ($n$ = 640)

| Clinical form | Number of the cultures isolated/percentage of the samples tested | | | | | |
|---|---|---|---|---|---|---|
| | *C. histolyticum* | *C. septicum* | *C. perfringens* | *C. sporogenes* | *C. sordellii* | *C. novyi* |
| Endometritis | 34/5,4 | 34/5,3 | 17/2,6 | 16/2,5 | 4/0,6 | – |
| Vaginitis | 71/11,1 | 58/9,1 | 17/2,6 | 28/4,4 | 4/0,6 | – |
| Abortion | 96/15,0 | 47/7,3 | 30/4,7 | 3/0,4 | – | – |
| Abomasite | 8/1,25 | 9/1,4 | 14/2,2 | 12/1,9 | – | – |
| Enteritis | 8/1,25 | 4/0,6 | 13/2,2 | 10/1,6 | 1/0,2 | 1/0,1 |
| Enterotoxemia | 21/3,3 | 18/2,8 | 28/4,4 | 23/3,6 | 2/0,3 | 5/0,8 |
| Mastitis | 125/19,5 | 58/9,1 | 40/6,2 | 42/6,6 | – | – |
| Myositis | 11/1,7 | 21/3,3 | 13/2,0 | 11/1,7 | – | – |
| Clostridiosis of internal organs (septicemia) | 43/6,7 | 43/6,7 | 18/2,8 | 22/3,4 | – | – |
| Total… | 417/65,2 | 292/45,6 | 190/29,7 | 167/26,1 | 11/1,7 | 6/0,9 |

**Табл. 2.** Ассоциации клостридий, выделенных от коров и нетелей с клиническими формами заболевания ($n$ = 640)

**Table 2.** Associations of clostridia isolated from the cows and heifers with clinical forms of the disease ($n$ = 640)

| Clinical form | Association of the pathogens | The number of positive samples of the number of the samples tested, % |
|---|---|---|
| Endometritis | *C. perfringens* + *C. histolyticum* + *C. sordellii* | 13,2 |
| | *C. septicum* + *C. sporogenes* + *C. histolyticum* | 8,6 |
| Vaginitis | *C. perfringens* + *C. histolyticum* + *C. sordellii* | 14,4 |
| | *C. perfringens* + *C. septicum* | 11,7 |
| | *C. septicum* + *C. sporogenes* + *C. histolyticum* | 24,5 |
| Abortion | *C. perfringens* + *C. histolyticum* | 19,7 |
| | *C. perfringens* + *C. septicum* | 12,0 |
| | *C. sporogenes* + *C. histolyticum* + *C. septicum* | 22,8 |
| | *C. histolyticum* + *C. septicum* | 22,4 |
| Abomasite | *C. perfringens* + *C. septicum* | 3,6 |
| | *C. perfringens* + *C. histolyticum* + *C. sporogenes* | 5,3 |
| Enteritis | *C. perfringens* + *C. septicum* | 2,6 |
| | *C. perfringens* + *C. sporogenes* | 3,6 |
| | *C. perfringens* + *C. histolyticum* + *C.sordelli* | 3,4 |
| | *C. novyi* (*C. oedomaties*) + *C. septicum* | 0,8 |
| Enterotoxemia | *C. perfringens* + *C. sporogenes* | 7,9 |
| | *C. perfringens* + *C. histolyticum* + *C. sordellii* | 7,9 |
| | *C. novyi* (*C. oedomaties*) + *C. septicum* | 3,6 |
| Mastitis | *C. perfringens* + *C. histolyticum* | 25,8 |
| | *C. septicum* + *C. sporogenes* | 15,6 |
| | *C. histolyticum* + *C. septicum* | 28,6 |
| Myositis | *C. septicum* + *C. sporogenes* | 5,0 |
| Clostridiosis of internal organs (septicemia) | *C. perfringens* + *C. sporogenes* | 6,3 |
| | *C. histolyticum* + *C. septicum* | 13,4 |
| | *C. perfringens* + *C. histolyticum* | 9,5 |




***Puc. 2.*** Клинические формы клостридиоза у телят на молочных комплексах Сибири

***Fig. 2.*** Clinical forms of clostridiosis in calves at dairy complexes of Siberia

plexes in Siberia. The identified species composition of *Clostridium* spp. and their associations largely correspond to the results obtained by other researchers [6, 9, 10], but there are slight differences in the species composition of bacteria causing different clinical forms of the disease.

## CONCLUSION

The conducted studies have determined the species composition of clostridia in various clinical forms of clostridiosis in cattle. In most cases, cows and heifers exhibited malignant edema of organs and tissues, as well as various clinical forms of the disease: necrotic enteritis, enterotoxemia, mastitis, vaginitis, endometritis, and abortions, mainly registered in cows and heifers

**Табл. 3.** Частота выделения возбудителей клостридиоза из проб биоматериала от телят и их связь с клинической формой клостридиоза ($n$ = 270)

**Table 3.** The frequency of isolation of clostridiosis pathogens from biomaterial samples from the calves and their relationship with the clinical form of clostridiosis ($n$ = 270)

| Clinical form | Number of the cultures isolated/percentage of the samples tested | | | | |
|---|---|---|---|---|---|
| | *C. histolyticum* | *C. septicum* | *C. perfringens* | *C. sporogenes* | *C. sordellii* |
| Abomasite | 5/1,9 | 8/3,0 | 14/5,2 | 5/1,8 | – |
| Enteritis | 18/6,7 | 19/7,0 | 24/8,9 | 22/8,2 | – |
| Enterotoxemia | 91/33,7 | 40/14,8 | 50/18,5 | 33/12,2 | – |
| Clostridiosis of internal organs (septicemia) | 86/31,9 | 57/21,1 | 36/13,3 | 34/12,6 | 2/0,7 |
| Total… | 200/74,2 | 124/45,9 | 124/45,9 | 94/34,8 | 2/0,7 |

**Табл. 4.** Ассоциации клостридий, выделенных от телят с различными клиническими формами заболевания ($n$ = 270)

**Table 4.** Associations of clostridia isolated from the calves with various clinical forms of the disease ($n$ = 270)

| Clinical form | Association of pathogens | Number of positive samples of the number of the samples tested, % |
|---|---|---|
| Abomasite | *C. perfringens* + *C. septicum* | 8,2 |
| | *C. perfringens* + *C. sporogenes* | 7,0 |
| Enteritis | *C. perfringens* + *C. septicum* | 14,8 |
| | *C. perfringens* + *C. sporogenes* | 16,3 |
| | *C. perfringens* + *C. histolyticum* | 15,2 |
| Enterotoxemia | *C. perfringens* + *C. sporogenes* | 30,7 |
| | *C. perfringens* + *C. histolyticum* | 52,2 |
| Clostridiosis of internal organs (septicemia) | *C. perfringens* + *C. sporogenes* | 25,9 |
| | *C. histolyticum* + *C. septicum* | 52,9 |
| | *C. perfringens* + *C. histolyticum* | 45,2 |

before their first and second calving or within a few months afterward. Anaerobic enterotoxemia and necrotic enteritis in calves manifested as acute toxico-infections, characterized by pronounced toxemia affecting the gastrointestinal organs.

The common clinical signs of clostridiosis in cattle included rapidly increasing depression caused by body intoxication, edemas, necrosis of the affected tissues. Depending on the toxigenicity of the pathogen strains and the duration of the disease, pronounced changes in the liver and mesenteric lymph nodes, lesions of the pelvic limb muscles, reproductive organs, udder, and less frequently other organs and tissues were observed.

It should be noted that regardless of the type of pathogen and their associations, different clinical forms of clostridiosis in cattle occurred acutely and subacutely, causing visible lesions of organs and tissues within a few hours after the first clinical signs of the disease were detected, and in most cases, they ended fatally.

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# ПРОИЗВОДСТВЕННО-ЭКОНОМИЧЕСКОЕ ОБОСНОВАНИЕ РАЗНЫХ СПОСОБОВ СКАРМЛИВАНИЯ ТЕЛЯТАМ ГРУБЫХ КОРМОВ

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Цель исследования – изучить хронометраж технологических операций и влияние разных способов скармливания грубых кормов телятам абердин-ангусской породы на возрастные изменения живой массы и эффективность выращивания в молочный период. Для проведения исследования были сформированы три группы новорожденных телят (по 10 гол. в каждой): 1-я (контрольная) – телята, которым скармливали грубые корма совместно со взрослым поголовьем, 2-я (контрольная) – телята, которых кормили в отдельном от матерей загоне (столовке), 3-я (опытная) – телята, которых кормили в расположенной в отдельном загоне экспериментальной кормушке с ограниченным доступом для взрослого поголовья. На выполнение основных технологических операций за весь период исследования в 3-й группе было затрачено 201 с (3,35 мин), что на 3847 с (64,12 мин) меньше, чем в 1-й группе, и на 609 с (10,15 мин) меньше, чем во 2-й группе. Фактическая поедаемость из экспериментальной кормушки (телята 3-й группы) была выше на 132 кг ($p > 0,999$), чем в 1-й группе, и на 66 кг ($p > 0,99$), чем во 2-й. Наименьшее количество несъеденных остатков сена отмечено в экспериментальной кормушке и составило 99 кг, что на 54 ($p > 0,999$) и 18 кг ($p > 0,99$) меньше относительно 1-й и 2-й групп соответственно. Минимальные потери сена зафиксированы в 3-й группе – 36 кг, в то время как в 1-й группе этот показатель составил 114 кг, во 2-й – 84 кг, что больше на 78 ($p > 0,999$) и 48 кг ($p > 0,999$) соответственно. В возрасте 6 мес телята 3-й группы превзошли по живой массе своих сверстников из других групп на 4,2–6,1 кг ($p > 0,95$–$0,99$). Их превосходство по среднесуточному приросту за весь период исследования составило 21–33 г ($p > 0,95$–$0,99$). Более рентабельным (на 2,8–4,7 абс.%) оказалось выращивание телят, которым скармливали сено из экспериментальной кормушки.

**Ключевые слова:** телята, молочный период, кормушка, технологические операции, сено, потери, поедаемость, рост, рентабельность

# PRODUCTION AND ECONOMIC JUSTIFICATION OF DIFFERENT METHODS OF FEEDING ROUGHAGE TO CALVES

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The purpose of the research is to study the timing of technological operations and the effect of different methods of feeding roughage to Aberdeen Angus calves on age-related changes in the body weight and the effectiveness of cultivation during the dairy period. 3 groups of newborn Aberdeen Angus calves of 10 heads each were formed: 1st (control) – calves fed roughage together with adult livestock, 2nd (control) – calves fed in a separate pen (canteen) from their mothers, 3rd (control) – calves fed in an experimental feeder with limited access for adult livestock located in a separate pen. For the entire period of research, 201 seconds or 3.35 minutes were spent on performing basic technological operations in the 3rd experimental group, which is 3847 seconds or 64.12 minutes, less than in the 1st group and 609 seconds or 10.15 minutes, less than in the 2nd group. The actual palatability from the experimental feeder (calves of the 3rd group) was higher by 132 kg ($p > 0.999$) than in the 1st group and by 66 kg ($p > 0.99$) than in the 2nd group. The smallest amount of uneaten hay residues was in the experimental feeder and amounted to 99 kg which is 54 kg less ($p > 0.999$), than in the 1st group and 18 kg less than in the 2nd group ($p > 0.99$). The minimum hay losses were 36 kg in the 3rd group, while in the 1st group this figure was 114 kg, and in the 2nd group 84 kg, which is

more by 78 ($p > 0.999$) and 48 kg ($p > 0.999$), respectively. At the age of six months, the calves of the 3rd group surpassed the live weight of the herdmates of other groups by 4.2–6.1 kg ($p > 0.95$–$0.99$). Their superiority in average daily growth over the entire study period was 21–33 g ($p > 0.95$–$0.99$). It turned out to be more cost-effective (by 2.8–4.7 abs. %) to raise the calves which were fed hay from a developed feeder.

**Keywords:** calves, dairy period, feeder, technological operations, hay, losses, palatability, growth, profitability

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## INTRODUCTION

In beef production, the milking period is considered the most critical, during which significant changes in the growth and development of calves occur due to both genetic and non-genetic factors. Establishing appropriate environmental conditions during this period ensures the fuller realization of the genetic potential of economically beneficial traits in the young stock.

The effectiveness of intensive rearing of cattle of various origins using different technological equipment and production-technical solutions is confirmed by numerous Russian [1–6] and international [7–9] studies. Nevertheless, the search continues for new ways to improve technological equipment and devices that can increase productivity, reduce labor costs, and expenses in raising different age and sex groups of cattle. The impact of different types of feeders on the behavior, productivity, and welfare of animals is also reflected in the works of foreign scientists[1,2] [10].

Given that modernizing the livestock sector's material and technical base is crucial for comprehensive improvement, it is necessary to shift the sub-sector towards intensive development, including aspects such as forage harvesting, preparation, and distribution [11, 12]. Since farms have varying financial capabilities, the transition to high-tech production is gradual. The absence of feeding tables and feed distributors in farms suggests using more accessible alternatives that, while different from traditional feeders, result in less feed waste and lower human and material resource costs.

Existing feeders have their unique features, both positive and negative. Considering this, we have attempted to create a feeder for roughage, including in rolls, for feeding all age and sex groups of cattle. This feeder aims to solve the following problems: reducing feed costs and the cost of its production, and increasing the economic efficiency of production. As a result, a decision was made to issue a patent for the invention.

The study aims to investigate the timing of technological operations and the impact of different methods of feeding roughage to Aberdeen Angus breed calves on age-related changes in live weight and rearing efficiency during the milking period.

## MATERIAL AND METHODS

The study was conducted on the basis of the peasant (farmer's) farm M.S. Sultanov, located in the plain zone in the Maisky District of the

[1]*Buskirk D.D., Zanella A.J., Harrigan T.M., Van Lente J.L., Gnagey L.M., Kaercher M.J.* Large round bale feeder design affects hay utilization and beef cow behavior // Journal of Animal Science, 2003, N 81 (1), pp. 109–115.

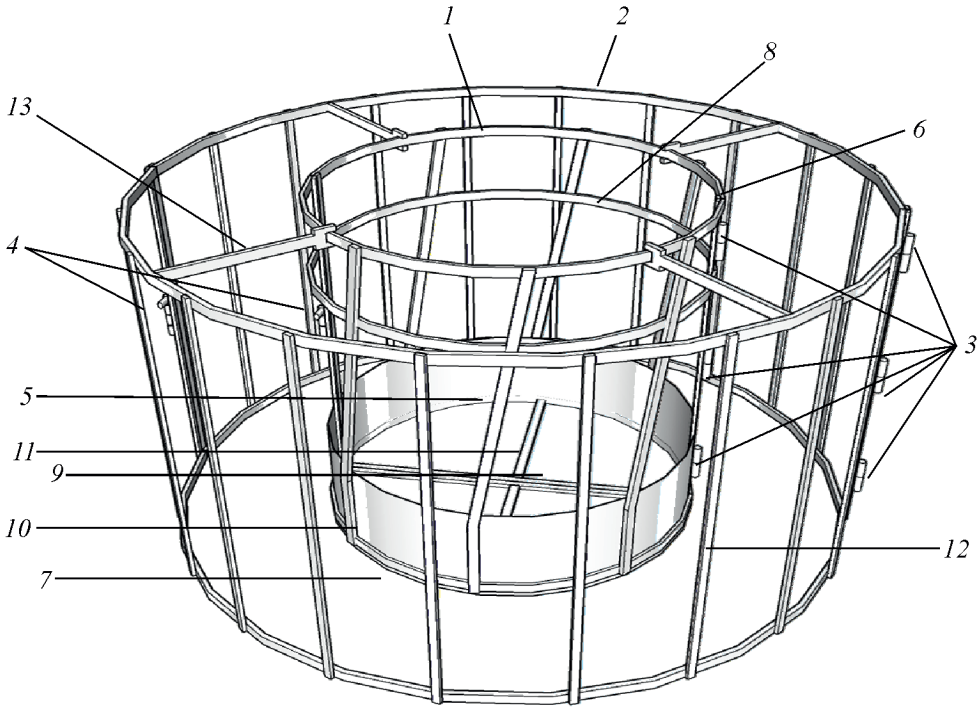
[2]*Martinson K., Wilson J., Cleary K., Lazarus W., Thomas W., Hathaway M.* Round-bale feeder design affects hay waste and economics during horse FEED-ING1,2 // Journal of Animal Science, 2012, N 90 (3), pp. 1047–1055.

Kabardino-Balkarian Republic. The subjects of the study were Aberdeen Angus breed calves during the milking period.

Three groups of newborn calves (10 animals each) were formed: the 1st group (control) – calves fed roughage together with the adult population, the 2nd group (control) – calves fed in a separate pen from the mothers (dining area), the 3rd group (experimental) – calves fed using an experimental feeder with limited access for the adult population. The diet for animals in all groups was the same. Calves in the 3rd group were fed roughage using our invention (decision to grant a patent for the invention "Feeder for roughage for all age and sex groups of cattle" under application No. 2023118316/10(039323) dated July 12, 2023). The design of this feeder allows limiting cows' access to the roughage intended for calves (see the figure).

The timing of technological operations for feeders of different types was studied based on the time required to load and clean feeders, as well as their filling frequency. Feed consumption and losses were monitored based on the amount of feed provided and consumed, their remnants, and losses. Weighing of animals was carried out at birth and at the ages of 3 and 6 months, based on which the average daily weight gain was determined.

Economic efficiency was calculated based on production costs, revenue from sales, and profitability levels. Experimental data were processed using methods of variation statistics. "Microsoft Office" and "Microsoft Excel" (Microsoft Corp., USA) were used as software. Data processing was conducted in "Statistica 6.0" (StatSoftInc, USA).




Кормушка для грубых кормов для всех половозрастных групп крупного рогатого скота:

*1* – внутренний каркас; *2* – съемный разборный внешний ограничительный каркас; *3* – навесные петли; *4* – фиксатор; *5* – наклонный стержень; *6* – верхняя рама; *7* – нижняя рама; *8* – горизонтальная дуга; *9* – дно; *10* – бортик; *11* – поперечные ребра жесткости; *12* – вертикальные стержни; *13* – фиксаторы

Roughage feeder for all age and sex groups of cattle:

*1* – internal frame; *2* – removable collapsible external limiting frame; *3* – hinges; *4* – lock; *5* – diagonal bar; *6* – upper frame; *7* – lower frame; *8* – horizontal arch; *9* – bottom; *10* – lip; *11* – transverse rib stiffeners; *12* – vertical rods; *13* – locks

## RESULTS AND DISCUSSION

In the process of the study, the time required for technological operations was taken into account: feed loading, cleaning of feeders from uneaten residues (see Table 1).

Throughout the study period, the total time spent on main technological operations in the 3rd experimental group was 201 seconds (or 3.35 minutes), which is 3847 seconds (64.12 minutes) less than in the 1st group, where feeding was done in the absence of mothers from a roughage feeder, and 609 seconds (10.15 minutes) less than in the 2nd group.

Data on the consumption and losses of rough feed are presented in Table 2.

It was established that the actual consumption from the experimental feeder (3rd group) was 132 kg higher ($p > 0.999$) than in the 1st group using the farm's technology, and 66 kg ($p > 0.99$) higher than the indicators of the 2nd group with classical feeding technology.

The smallest amount of uneaten hay residues was recorded in the experimental feeder – 99 kg, which is 54 ($p > 0.999$) and 18 kg ($p > 0.99$) less than in the 1st and 2nd groups, respectively.

The minimum hay losses were observed in the 3rd group (36 kg), whereas in the 1st group, this indicator was 114 kg, and in the 2nd – 84 kg, which are 78 ($p > 0.999$) and 48 kg ($p > 0.999$) more, respectively.

Furthermore, to study the efficiency of using the improved feeder for rolled hay, the live weight of the test animals was recorded at different age periods, based on which the average daily live weight gain and relative growth rate were calculated (see Table 3).

Differences between the groups in live weight at birth were insignificant. However, by the age of 3 months, calves in the 3rd group had a greater live weight than those in the 2nd and 1st groups, exceeding their peers by 2.1 and 2.7 kg, respectively, and at 6 months by 4.2 ($p > 0.95$) and 6.1 kg ($p > 0.99$).

A similar pattern was observed in the average daily live weight gain. Throughout the study period, calves in the 3rd group surpassed their

**Табл. 1.** Хронометраж технологических операций и кратность заполнения для кормушек разных типов
**Table 1.** Timing of technological operations for different types of feeders

| Indicator | Group | | |
|---|---|---|---|
| | 1st | 2nd | 3rd |
| Time required to load the feeder, s | 12 ± 1,054*** | 77 ± 8,340** | 46 ± 0,577 |
| Time required to clean the feeder, s | 10 ± 0,428*** | 13 ± 0,824*** | 21 ± 0,577 |
| Feeder filling frequency, times | 184 | 9 | 3 |
| Total time spent: | | | |
| s | 4048 | 810 | 201 |
| min | 67,47 | 13,50 | 3,35 |

Note. Differences in comparison with group 3: **$p > 0,99$; ***$p > 0,999$.

**Табл. 2.** Учет поедаемости и потерь грубых кормов ($n = 10$)
**Table 2.** Recording of roughage palatability and losses ($n = 10$)

| Indicator | Group | | |
|---|---|---|---|
| | 1st | 2nd | 3rd |
| Total volume of the specified feed, kg | 1110 ± 0,24 | 1110 ± 14,71 | 1110 ± 6,24 |
| Amount of the feed remaining in the feeder, kg | 153 ± 0,06*** | 117 ± 5,23** | 99 ± 1,56 |
| Feed losses, kg | 114 ± 0,02*** | 84 ± 0,01*** | 36 ± 0,02 |
| Amount of the feed eaten, kg | 843 ± 0,27*** | 909 ± 4,75** | 975 ± 16,90 |

Note. Differences in comparison with group 3: **$p > 0,99$; ***$p > 0,999$.

peers from the 1st and 2nd groups by 33 ($p > 0.99$) and 21 g ($p > 0.95$), respectively.

No significant differences in growth energy were found in individual age periods, but it was higher in the 3rd group.

The economic justification for using different methods of feeding hay in calf rearing technology is presented in Table 4.

Different indicators of absolute live weight gain in experimental groups of calves provided a difference in the cost of 1 kg of live weight gain and varied production costs during their rearing. Simultaneously, an equal sale price with different live weight gains led to different revenue amounts. Thus, the sale of calves from the 3rd group generated 759.7 and 1279.3 rubles more than from calves of the 1st and 2nd groups, respectively, providing them an advantage in profitability level by 2.8 and 4.7 abs.% respectively.

## CONCLUSION

The use of a new feeder for feeding roughage during the milking period of raising Aberdeen Angus calves ensured an increase in live weight and growth intensity of the animals. This result was achieved by increasing the consumption of hay and reducing its losses, which led to an improvement in the economic efficiency of production by 2.8–4.7 abs.% compared to other variants (feeding together with adult cattle, and separately from mothers). By the end of the milking period, the calves that were fed rolled hay were heavier and exceeded their peers by 4.2–6.1 kg ($p > 0.95$–$0.99$). The superiority in

**Табл. 3.** Динамика живой массы телят разных групп ($n = 10$)
**Table 3.** Dynamics of live weight of calves of different groups ($n = 10$)

| Age | Group | | |
|---|---|---|---|
| | 1st | 2nd | 3rd |
| *Live weight, kg* | | | |
| At birth | 22,5 ± 0,2 | 22,3 ± 0,2 | 22,6 ± 0,2 |
| 3 months | 89,6 ± 1,0 | 90,2 ± 0,9 | 92,3 ± 1,2 |
| 6 months | 168,4 ± 1,3** | 170,3 ± 1,4* | 174,5 ± 1,5 |
| *Average daily live weight gain, g* | | | |
| From birth to 3 months | 746 ± 8,4* | 754 ± 9,1 | 774 ± 9,6 |
| From 3 to 6 months | 866 ± 7,2** | 880 ± 8,0 | 903 ± 8,5 |
| For the entire period | 806 ± 7,6** | 818 ± 4,3* | 839 ± 8,3 |
| *Relative growth rate, %* | | | |
| From birth to 3 months | 119,7 ± 0,7 | 120,7 ± 0,8 | 121,3 ± 0,9 |
| From 3 to 6 months | 61,1 ± 0,4 | 61,5 ± 0,5 | 61,6 ± 0,5 |

Note. Differences in comparison with group 3: **$p > 0,99$; ***$p > 0,999$.

**Табл. 4.** Экономическое обоснование использования разных способов скармливания сена в технологии выращивания телят
**Table 4.** Economic justification for the use of different methods of hay feeding in calf rearing technology

| Indicator | Group | | |
|---|---|---|---|
| | 1st | 2nd | 3rd |
| Absolute live weight gain, kg | 145,9 | 148,0 | 151,9 |
| Cost of 1 kg of live weight gain, rubles | 184 | 181 | 177 |
| Production costs, rubles | 26 845,6 | 26 788,0 | 26 886,3 |
| Realization price of 1 kg, rubles | 220 | 220 | 220 |
| Sales revenue, rubles | 32 098 | 32 560 | 33 418 |
| Profit, rubles | 5252,4 | 5772,0 | 6531,7 |
| Profitability level, % | 19,6 | 21,5 | 24,3 |

growth intensity was also confirmed by the average daily gain in live weight: in the group of calves fed hay using the new feeder, the excess in live weight indicators was 21–33 g ($p > 0.95$–0.99) throughout the study period. Additionally, the use of the new feeder significantly reduced time and labor resources. The results of testing the developed feeder indicate the effectiveness and appropriateness of using such technological equipment. The use of the proposed invention, along with improving economically beneficial traits, allowed for reducing costs and the cost per unit of live weight gain. It appears promising to continue such research into the post-milk rearing period.

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# ИННОВАЦИОННЫЕ МЕТОДЫ ИЗВЛЕЧЕНИЯ ПОЛЕЗНЫХ ВЕЩЕСТВ ИЗ РАСТИТЕЛЬНОГО СЫРЬЯ: ОБЗОР ЛИТЕРАТУРЫ

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В статье представлен обзор литературы, посвященной биоактивным веществам и инновационным методам экстракции биологически активных веществ из растительного сырья, обсуждается необходимость разработки новых методов экстракции для сохранения структурных и функциональных свойств экстрагируемых соединений. Исследование включает анализ недавних публикаций по методам экстракции и библиометрическое картирование с использованием программного обеспечения VOSviewer. Авторы рассматривают различные методы, включая сверхкритическую флюидную экстракцию, ферментацию, ультразвуковую и микроволновую обработку. Особое внимание уделено комбинированным методам, таким как ферментная экстракция с применением ультразвука и микроволн. Определены достоинства и недостатки новых методов экстракции, а также комбинаций техник с точки зрения повышения потенциала извлечения биоактивных соединений из растительного сырья. Работа призвана стимулировать интерес к развитию новых методов экстракции и продвижению исследований в этой области.

**Ключевые слова:** обзор литературы, биоактивные соединения, экстракция, растительное сырье

# INNOVATIVE METHODS FOR EXTRACTING USEFUL SUBSTANCES FROM PLANT RAW MATERIALS: LITERATURE REVIEW

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The article presents a review of literature on bioactive substances and innovative methods of extraction of biologically active substances from plant raw materials, discusses the need to develop new extraction methods to preserve the structural and functional properties of the extracted compounds. The study includes analysis of recent publications on extraction methods and bibliometric mapping using VOSviewer software. The authors review various methods including supercritical fluid extraction, fermentation, ultrasonic and microwave processing. Special attention is given to combined methods such as enzyme extraction using ultrasound and microwaves. The advantages and disadvantages of new extraction methods, as well as combinations of techniques in terms of increasing the potential for extraction of bioactive compounds from plant raw materials are determined. The work is intended to stimulate interest in the development of new extraction methods and to promote research in this field.

**Keywords:** literature review, bioactive compounds, extraction, plant material

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The authors declare no conflict of interest.

## INTRODUCTION

Plant-based foods play a crucial role in human nutrition. Since ancient times, plants have been a key element of a healthy lifestyle due to their nutritional and medicinal properties, with their bioactive compounds playing a vital role in maintaining health. Centuries of human use of medicinal plants have led to the development of advanced methods for processing and utilizing them today[1].

The need for new extraction methods to preserve the structural and functional properties of extracted compounds is increasingly pressing. This topic has been extensively explored in both new and traditional methods.

The main objectives of this review are to briefly explore a series of recently published studies on innovative extraction methods for bioactive substances from plant materials, and to perform a literature analysis on this topic.

## MATERIAL AND METHODS

During the analysis of publications, the VOSviewer software for bibliometric mapping was used. Developed by two Dutch researchers, VOSviewer is a program for constructing and viewing bibliometric maps, freely available to the bibliometric research community. VOSviewer can be used, for instance, to create maps of authors or journals based on co-citation data, or to construct keyword maps based on their co-occurrence. The program provides viewing tools that allow for detailed examination of bibliometric maps. Unlike most computer programs used for bibliometric mapping, VOSviewer does not display these maps satisfactorily. When building a map, VOSviewer employs the VOS (Visualization of Similarities) methods, developed by Nees Jan van Eck and Ludo Waltman[2,3], where VOS stands for 'visualization of similarity'. Thus, the program can display maps constructed not only using VOS but also using multidimensional scaling and other methods of information analysis and visualization. Data can be automatically loaded via VOSviewer using the download function with a search query for keywords from the OpenAlex database, an open-access index of scientific papers, authors, places, institutions, and concepts [1].

Figure 1 presents the result of mapping scientific papers published since 2018, with the keywords "extraction" and "bioactive" found in the titles (*а*), abstracts (*в*), and full texts (*г*) of the articles. Figure 1, *б* depicts the same map with the "food science" cluster highlighted and color differentiation by publication years. The mapping illustrates the interconnectedness of the query elements, determined by the number of documents in which they occur together. The stated keywords were found in the titles of 21 scientific papers, with 146 related keywords used to construct a map colored by distribution. Keywords were found in the abstracts of 21 documents and in the full texts of 225 documents, with 137 and 706 connections found, respectively.

According to the conducted mapping, the topic of extracting bioactive compounds has been increasingly covered in fields such as chemistry, biology, biochemistry, medicine, biomedical engineering, food sciences, materials science, nutraceuticals, etc. (see Figs. 1, *а*, *б*). Based on the publication analysis over the last two years (see Figs. 1, *б–г*; highlighted in light yellow and light green), it is possible to identify the scien-

[1]*Petrovska B.* Historical review of medicinal plants′ usage // Pharmacognosy Reviews, 2012, vol. 6, N 11, p. 1.

[2]V*an Eck N.J., Waltman L.* Software survey: VOS viewer, a computer program for bibliometric mapping // Scientometrics, 2009, vol. 84, N 2, pp. 523–538.

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tific areas and topics related to the extraction of bioactive compounds. Among these, the most prominent are chemistry, food sciences, materials science, chromatography, antioxidants, polyphenols, polysaccharides, flavonoids, etc.

For this literature review, a map was constructed where the affinity of elements is determined by the number of shared references. The elements selected were the most cited articles by authors whose works contain the same keywords. Figure 2 presents the mapping result. A total of 653 documents were found, 215 of which were published no earlier than 2018. A map was constructed from the bibliometric data of these 215 works, color-differentiated by years.

The map shown in Figure 2 displays the diversity of publications from 2018 to 2023 by the most cited authors, who mention the extraction of bioactive compounds in their texts, with at least 30 references each. The size of the circle indicates citation frequency, and the circles highlighted in yellow reflect the most recent publications.

## RESULTS AND DISCUSSION

This section provides a brief overview of the literature on bioactive substances and innovative extraction methods.

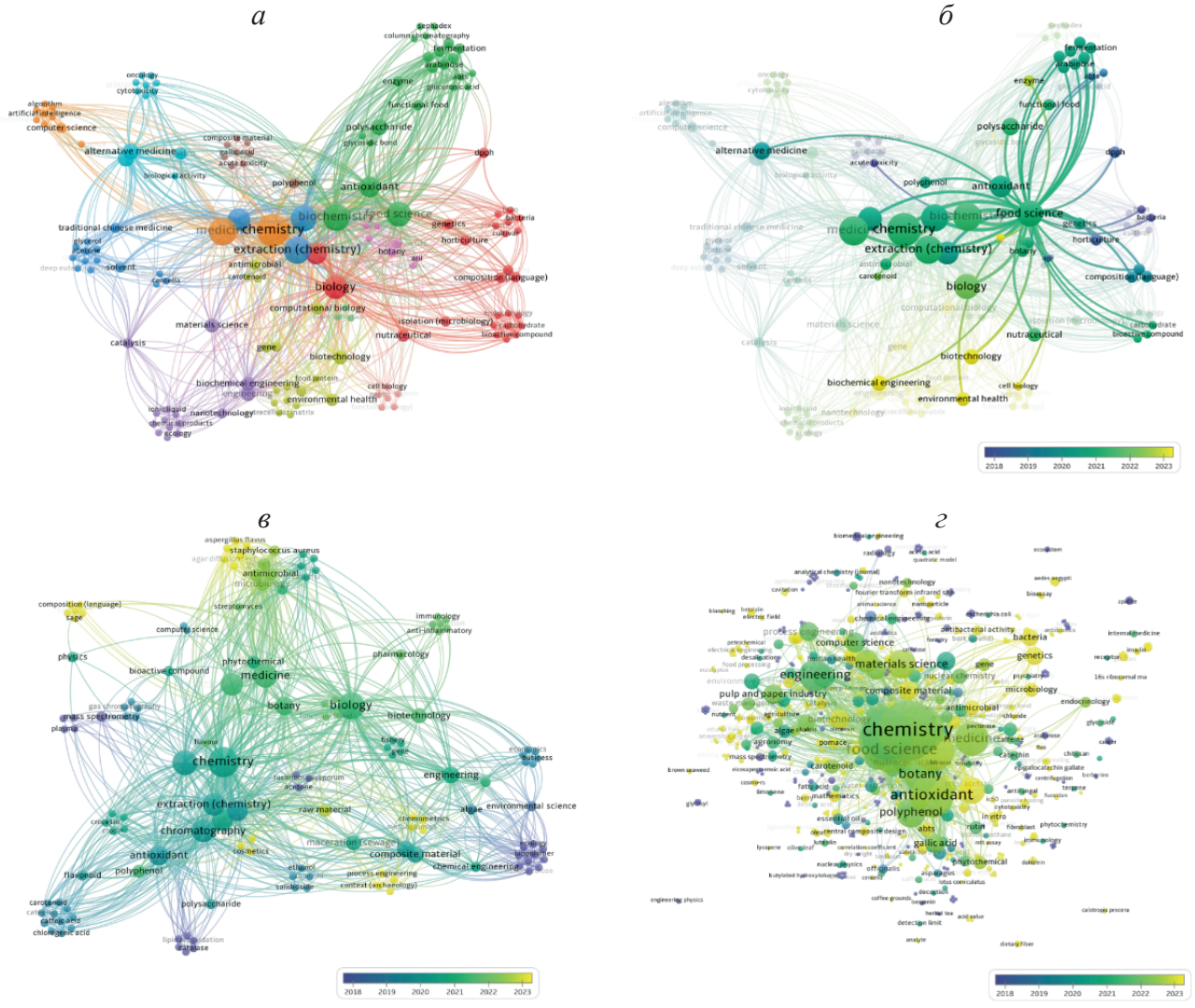


***Рис. 1.*** Результат библиометрического картирования с анализом связанности элементов
***Fig. 1.*** The results of bibliometric mapping with co-occurrence analysis

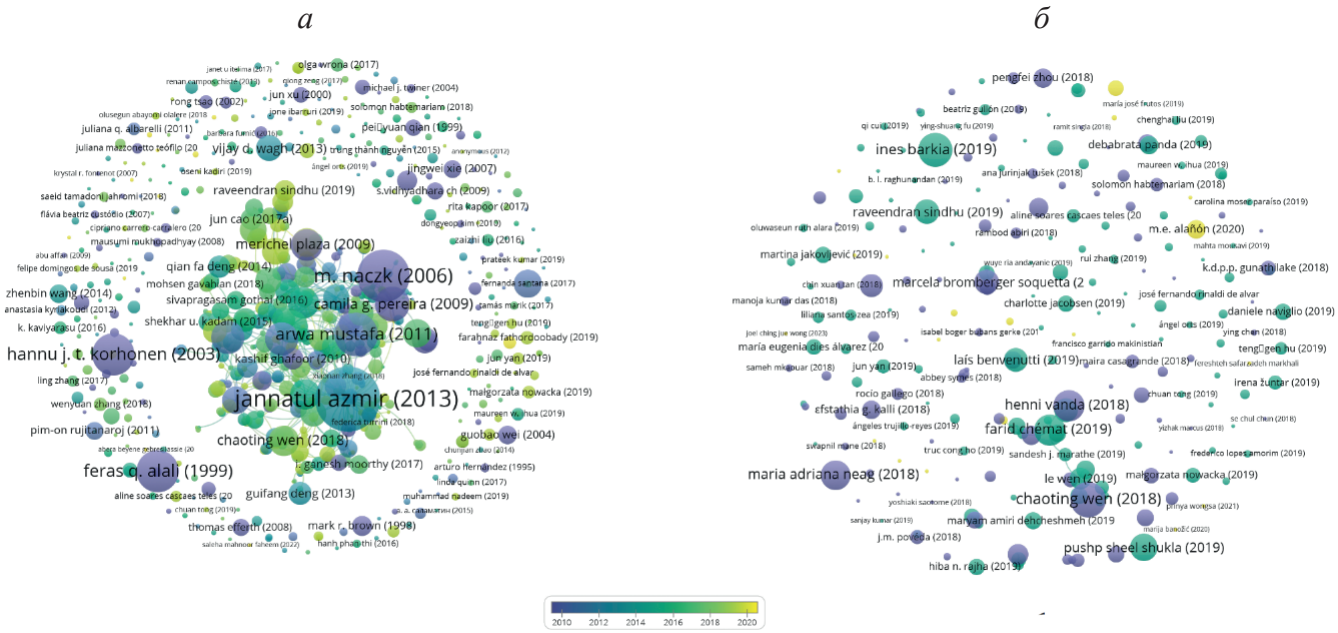


***Рис. 2.*** Результат библиометрического картирования по запросу данных из базы OpenAlex по ключевым словам *extraction* + *bioactive*:

*а* – за все время; *б* – с 2018 г.

***Fig. 2.*** Result of bibliometric mapping on data query from OpenAlex database for the keyword phrase *extraction* + *bioactive*:

*а* – for all time; *б* – since 2018

***I. Extraction of bioactive compounds from plant products***

In their recent review article, scientists from India highlighted that the extraction of bioactive compounds from food products requires careful consideration of various physicochemical parameters including solvent, concentration, temperature, pressure, and time [2]. Furthermore, the authors note that these factors are not inherently interrelated, but their combination changes not only the efficiency of the extraction process but also its cost.

An international team of scientists published a review on the bioactive compounds of citrus, providing comprehensive details about the composition and health benefits of carotenoids, flavonoids, limonoids, and terpenes [3]. The authors discuss existing issues and the insufficient understanding (e.g., cellular and molecular mechanisms of citrus bioactive compounds in the body) and contemplate the possibilities of processing citrus waste, which could potentially serve as an inexpensive and environmentally friendly source of bioactive substances. The experts emphasize the need for further research in the context of effective extraction of bioactive substances from citrus fruit waste.

Researchers from Indonesia in their study discussed terpenes and terpenoids (the main bioactive compounds of essential oils), their role in human health maintenance, and their potential use as natural food preservatives [4]. The article presents current knowledge on the use of essential oils in the pharmaceutical and medical industries, describing the primary spectrum of biological activity of essential oils, including anticancer, antimicrobial, anti-inflammatory, antioxidant, and anti-allergic properties.

A publication by scientists from Germany presented a review of existing databases on the composition of over 400,000 natural products and the most comprehensive list of open sources listing bioactive compounds found in plants and products [5]. The article also contains interesting information, such as listing the five most frequently occurring metabolites identified based on the analysis of 50 open databases (see Fig. 3).

## *II. Innovative extraction methods*

*Liquid-liquid and solid-liquid extraction*

Scientists from the Arctic University of Norway compared liquid-liquid extraction using ethyl acetate and solid-liquid extraction using resin in the process of isolating natural microbial products to prepare an extract from a bacterial culture [6]. During the extraction, resin and fermentation broth with natural products were used. The authors suggest that both extraction methods are utterly unsuitable for very polar and hydrophilic compounds. However, liquid-liquid and solid-liquid methods are comparable in extracting natural products from microbial fermentation broth or aqueous solutions at different pH levels. Liquid-liquid extract contains fewer medium components, but this method is less suitable for extracting larger cultures due to the high consumption of organic solvents.

*Supercritical fluid extraction*

A team of scientists from Iran in their review article explored the possibilities of using supercritical fluid extraction for extracting oils from seeds, characterized the corresponding extraction systems related to extraction with supercritical carbon dioxide, including extraction mechanisms, parameters used, and response surface methodology for process optimization [7].

The paper consolidates findings from various authors, presents tables indicating optimal parameters for seeds like pomegranate, gurum, babassu, ucuhuba, chia, white mustard, etc. Additionally, hybrid schemes (notably using ultrasound) are proposed, and a comparative analysis of SC-extraction and traditional methods of oil extraction from seeds is conducted.

A group of authors from South America published a review discussing the potential of natural products in extracting flavonoids using so-called "green" solvents and advanced methods, including supercritical fluid extraction [8]. The article aims to facilitate a review of directions for improving available methods, offering broader scope for understanding the extraction of flavonoids from various matrices, which will be studied by researchers working in this field. The article references other reviews dedicated to one or several extraction methods, compounds and classes of compounds, as well as types of tissue and plants. Due to the complex nature of the plant material matrix and the diversity of chemical characteristics of flavonoids, scientists

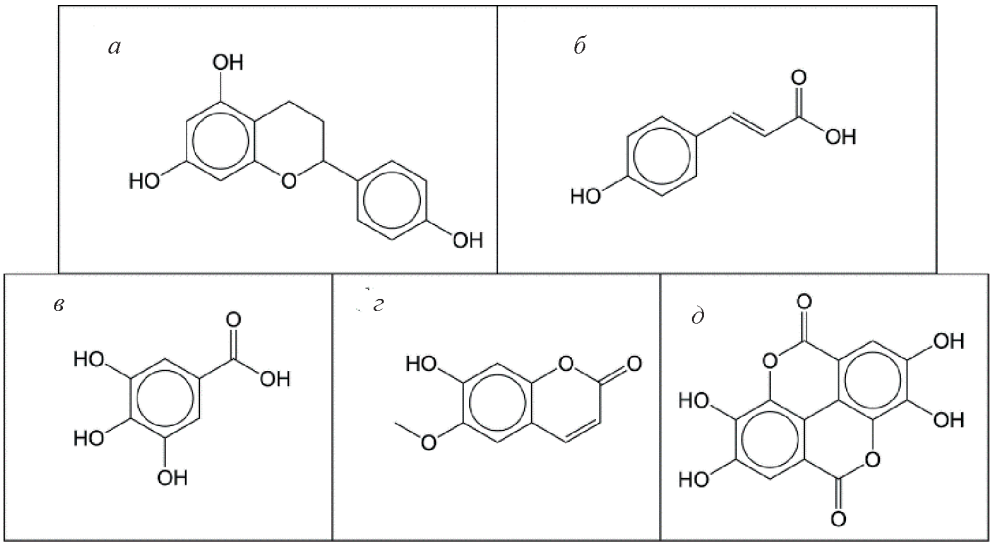


***Рис. 3.*** Молекулы, наиболее часто упоминаемые в открытых базах данных:

*а* – общая самая большая субструктура, обнаруженная в пяти наиболее часто встречающихся молекулах; *б* – кумаровая кислота; *в* – галловая кислота; *г* – скополетин; *д* – эллаговая кислота

***Fig. 3.*** The most frequently occurring molecules in public databases:

*а* – the common largest substructure in the five most frequently occurring molecules; *б* – coumaric acid; *в* – gallic acid; *г* – scopoletin; *д* – ellagic acid

agree that at present, there is no single standard method that can be used for each material or flavonoid currently being extracted.

*Extraction using pulsed electric field (PEF) and high voltage electric discharges (HVED)*

An international group of scientists presented findings on the impact of extraction methods on extracting bioactive phenolic compounds from by-products of the food industry [9]. The article contains information on advanced technologies for sustainable and efficient extraction of phenolic compounds from plant matrices, including non-thermal and electrochemical methods such as PEF and HVED. Additionally, it addresses the complexity of resolving the compositional heterogeneity of phenolic fractions from plant matrices, considering important factors influencing the extraction of phenolic compounds.

A Portuguese research article described methods for extracting pigments from microalgae and cyanobacteria. The authors noted that PEF and HVED are innovative methods that have not yet been used for industrial applications and, despite their high efficiency, have a drawback of high energy consumption [10].

*Ultrasound extraction*

A group of Chinese experts recently presented a comprehensive review of the mechanisms of ultrasonic extraction, various ultrasonic devices, and their applications for extracting bioactive compounds [11]. The authors explored the potential uses of ultrasonic extraction for producing functional and healthy food products. The article includes data on obtaining various compounds from medicinal and oil plants using ultrasonic extraction methods: from rosemary, marjoram, saffron, mint, pomegranate peel, jaboticaba, orange, lotus fruits, jujube, longan pericarp, red raspberry berries, garlic cloves, caraway seeds, tomato pressings, etc.

*Enzymatic extraction*

An article by Indian scientists is dedicated to a comparative analysis of various methods for extracting bioactive compounds (enzymes, organic acids, etc.), obtained from fruit and vegetable waste [12]. It discusses the method of enzymatic pre-treatment, which the authors recognize as a new and useful way to extract bound compounds and increase their yield. The publication also details various types of phenolic components and enzymes in different food products.

Another group of Indian scientists published a review article focusing on various aspects related to extraction using enzymes [13]. The paper discusses the possibilities of using enzymes to extract various biomolecules such as polyphenols, oils, polysaccharides, flavorings, and dyes; it describes enhanced extraction technologies that combine traditional methods with the use of ultrasound, microwaves, high pressure, and supercritical carbon dioxide; it touches on the topic of immobilizing enzymes on magnetic nanoparticles, which could improve the operational characteristics of the extraction system by allowing for the multiple uses of expensive enzymes, making the process industrially and economically viable.

*Combinations of new technologies*

An Irish research article reviewed new extraction technologies involving ultrasound, microwaves, enzymes, and their combinations, summarizing their mechanisms of action, advantages, and disadvantages (particularly, the issues of extracting phyto-bioactive compounds from plant materials) [14]. It shows that combinations of methods are complementary and have more promising potential.

Another review discusses methods and technologies (traditional, new, and integrative) used to extract bioactive compounds of plant origin, as well as their advantages and disadvantages [15]. The article describes combined methods, such as enzymatic extraction with ultrasound and microwaves, combinations of ultrasound, electric pulses, and high hydrostatic pressure.

## CONCLUSION

Combined methods of extracting bioactive substances show promising results, often enhancing efficiency, yet these processes remain under-researched. Scientists emphasize the importance of further studies in the area of combined methods for extracting bioactive sub-

stances from plant materials. They recommend conducting more in-depth research aimed at optimizing extraction processes and improving the efficiency of obtaining bioactive compounds. It is important to focus on developing new technologies and techniques that could enhance the quality and increase the quantity of extracted compounds. When creating new extraction methods, economic and environmental aspects must be considered. Research should continue to evaluate the potential of combined methods on an industrial scale. According to scientists, developing innovative approaches to the extraction of bioactive compounds should be conducted by interdisciplinary teams. Furthermore, priorities should include standardizing extraction processes and developing industry guidelines. Further research in this field is crucial for enhancing the efficiency and sustainability of the extraction processes of bioactive compounds.

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# ЧТО НУЖНО АГРАРНОЙ НАУКЕ СЕГОДНЯ?

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В статье представлен краткий анализ существования аграрной науки в современном мире в условиях постпандемичекского периода, интенсивного развития цифровизации и внедрения искусственного интеллекта. Развитие отрасли идет совместно с междисциплинарными науками, благодаря которым могут создаваться будущие сценарии ее успешного внедрения в практику. Имея колоссальное продвижение, аграрная наука все еще сталкивается с вызовами и проблемами, такими как устаревший парк сельскохозяйственной техники и слабая инфраструктура во многих развивающихся странах. В глобальном масштабе наука решает вопросы создания устойчивого развития, улучшения плодородия почвы и сохранения биоразнообразия в условиях изменения климата. Многие пути решения создавшихся антропогенных проблем ведут к сильному образованию и переквалификации людей по принципу «образование на протяжении всей жизни». Благодаря таким подходам вырастет экономическая составляющая сельского хозяйства. С точки зрения исследовательской среды, необходимо расширять исследовательские тематики, чтобы закрыть слабые звенья в цепи «человек – природа». Достижения аграрной науки должны найти практическое применение на местном уровне «фермер – чиновник – ученый». В настоящее время существуют множество сообществ, семинаров и платформ, пропагандирующих образовательные и практические цели по вопросам улучшения качества ведения аграрной науки, борьбы с голодом, полноценного питания и изменения климата, где можно проявить личную точку зрения и выслушать мнения профессионалов. Данные мероприятия проводятся при поддержке таких международных организаций, как ООН и ПРООН, которые отводят особую роль женщинам, работающим в аграрных сферах с целью развития необходимых качеств для ведения аграрной науки. Сегодняшние возможности имеют все предпосылки развивать аграрные направления наук, перенимая опыт передовых стран и адаптируя их под местные условия, возможности и менталитет с целью обеспечения качественного и стабильного зернового производства для пищевых потребностей человека.

**Ключевые слова:** сельскохозяйственная наука, цифровизация, интердисциплинарный подход, здоровые экосистемы, устойчивое развитие, сохранение биоразнообразия, образование

# WHAT DOES AGRICULTURAL SCIENCE NEED TODAY?

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The article presents some key points of agricultural science existence in the world during the post-pandemic period, the intensive development of digitalization, and the deployment of artificial intelligence. The industry's development is coupled with interdisciplinary sciences, enabling the creation of future scenarios for successful implementation into practice. With tremendous advancement, agricultural science still faces challenges and problems such as outdated agricultural machinery and poor infrastructure in many developing countries. On a global scale, the science addresses sustainable development, soil fertility improvement, and biodiversity conservation in the face of climate change.

Many of the solutions to the man-made problems that have been created lead to strong education and reskilling of people on the principle of "life-long learning". Through such approaches, the economic component of agriculture will grow. From the point of view of the research environment, it is necessary to expand research topics in order to close the weak links in the “human-nature” chain. The achievements of agrarian science should find practical application at the local level, involving "farmer-official-scientist" collaboration. There are now many communities, workshops, and platforms promoting educational and practical goals for better agricultural science, combating hunger, nutritious food, and climate change, where one can express personal perspectives and hear from professionals. These events are supported by international organizations such as the United Nations and UNDP, which give a special role to women working in agrarian spheres in order to develop the necessary qualities for practicing agrarian science. Present opportunities have the potential to advance agrarian sciences, drawing from the experiences of advanced countries and adapting them to local conditions, opportunities, and mentalities, with the aim of ensuring high-quality and stable grain production for human food demands.

**Keywords:** agricultural science, digitalization, interdisciplinary approach, healthy ecosystems, sustainable development, biodiversity conservation, education

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Throughout history, despite natural, social, or geopolitical challenges, humans have engaged in agricultural science. Today, we conduct scientific research in a post-pandemic period marked by intense digitalization and the integration of artificial intelligence [1].

Agricultural science is developing in many countries and is considered a strategically important field for ensuring food security. Today, it is actively and fruitfully pursued at the intersection of interdisciplinary sciences (bioinformatics, biostatistics, space sensing) and STEM (Science, Technology, Engineering, and Mathematics). In the dynamically developing world, all areas of science are also changing towards development and adaptation to new living conditions for humanity.

As a result, many scientists have started using platforms (Zoom) and messengers. These formats are effective for conducting trainings, conferences, and seminars, saving participants financial resources and time on travel [2]. In 2019, about 10 million people used Zoom daily, whereas in 2020, the number rose to 200 million daily[1].

Research methods demonstrate significant development in the sciences, yet many challenges remain. One of the global problems is finding a balance between satisfying humanity's food needs and preserving ecosystems, biodiversity, and global ecological sustainability. Attention is paid to ecological processes on farms. Food security limits the prospects for changing food systems. It is necessary to bridge the gaps between historical and structural factors that create opportunities for equality and food security in various aspects of human life[2].

In this context, emphasis should be placed on education, which promotes the acquisition of critical and analytical thinking skills, enabling future graduates to approach solving issues in modern agriculture competently and creatively [3].

Global higher education practice shows that a new specialist, having a theoretical base of

[1]URL: https://blog.zoom.us/a-message-to-our-users/.

[2]*Barishpolets, V.A.* Analysis of global environmental problems // RENSIT, 2011, N 1, pp. 79 –96.

knowledge and little practical experience, must survive in a competitive environment in the job market across all sectors, including education and production [4–6]. For example, in the USA, the educational system focuses on training specialists in a "knowledge-based economy"[3] [7, 8]. In the Gulf Cooperation Council countries, future specialists are trained to protect the population from social, economic, and political challenges, including combating unprofessionalism and falling oil prices [9], Arab countries (Qatar and UAE) adopt the best educational practices[4].

Education in agriculture is an essential component for solving real-world problems in providing food for the growing population, protecting the environment, and finding a balance between nature and the production of nutritious products for humanity[5] [10–12].

One solution could be the expansion of research topics and their development in practice. Eradicating "zero hunger" should be achieved at the local level using adaptive and collaborative solutions that simultaneously consider local institutional capabilities, diversification of agroecosystems and ecological management, and the quality of local diets.

Two conceptual foundations—socio-ecological systems and sustainable diets—offer systemic lenses for a comprehensive analysis of agriculture and food security, which can be used in developing effective policies [13].

Previously, there was a trend of obtaining agronomic education at a young age, and adults did not even consider education in adulthood. Now, there is a move towards lifelong education [14].

Individuals can not only improve their knowledge through online accessible courses, but they can also obtain a second and entirely new education, vastly different from their existing one. As a result, many institutions are adapting to people's dynamic schedules, providing the opportunity to study at any age. Such approaches contribute to the development of the educational level of the population, which will be economically beneficial for the country [15].

Currently, it is popular to be a member of communities that promote goals to combat hunger, ensure adequate nutrition, and address climate change. Today, summits for the youth serve as such platforms, where one can express their viewpoint and learn from professionals.

Seminars are organized that facilitate rapid focus adjustments and corrections, allowing adaptation to modern methods of conducting agricultural sciences. The UN and UNDP have taken a significant role in this regard. For example, at one seminar ("Skillathon"), organized with the support of UNDP for women scientists from agrobiological fields, they were encouraged to develop "soft" skills for career growth and continue research for success and recognition. Speakers paid significant attention to the importance of women in science, and it was openly stated that there are too few due to stereotypes and mentalities in some societies [16].

Society must equally acknowledge the contributions of women to new trend disciplines and STEM. Their activities will help improve the socio-economic situation in the country (UNDP Permanent Representative in Kazakhstan – Katarzyna Wawrzeniecka). Kazakhstan is a country undergoing systemic transformations in science and education. Thanks to educational grants, young women can receive an education. Women are eager to study in undergraduate and graduate programs in the country. But at the highest levels of society, these processes decrease. Women prioritize family. The next challenge for the country is to carry out reforms so that women can engage in studies and science in doctoral programs while paying attention to their families (Minister of Science and Higher Education – Sayasat Nurbek). Marathon trainers were people from various fields, drawing

[3] *Wang H.H., Moore T.J., Roehrig G.H., Park M.S.* STEM integration: teacher perceptions and practice // Journal of Pre-College Engineering Education Research, 2011, vol. 1, N 2, pp. 1–13. DOI: 10.5703/1288284314636.

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attention to the fact that scientists can develop using diverse resources and approaches. These include journalists, coaches, specialists in grant writing, project commercialization, and systemic thinking. Today, agrarian scientists are encouraged to use systemic thinking. Focusing on one research theme, one must analyze it from various angles, incorporating interdisciplinary approaches. It is essential to have a national role model in science—someone like Marie Sklodowska-Curie. Today's trend in science is to provide people with information, collaborate with local and foreign colleagues, and share experiences (Tiffany Sprague, STEM4ALL Platform Lead, UNDP Istanbul Regional Hub). The seminar also addressed issues of popularizing science in Kazakhstan. Today's social networks can be used to attract attention to individual scientists and research institutions so that active network users can see how interesting agricultural science can be when combined with interdisciplines (Galiya Idoiatova, media expert, founder of the creative solutions agency "Point": "Media presence. Image. Expert positioning in social networks")[6].

Thus, there are all the prerequisites for developing agricultural science directions in Kazakhstan, learning from the experience of other countries, setting tasks to ensure quality and stable grain production for human food needs.

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## ИНФОРМАЦИЯ ОБ АВТОРАХ

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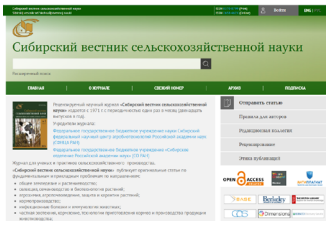


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