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Editorial Board

Редакциялык коллегия

Редакционная коллегия

Contents

Мазмун

Содержание

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Optimisation of RT-PCR for the detection of rabies virus RNA

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Abstract. The relevance of accurate and rapid laboratory diagnosis of rabies is determined by the high epizootic and epidemiological significance of this disease, its widespread prevalence among wild and domestic animals, as well as the need for timely and effective anti-epizootic and preventive measures. The introduction of molecular genetic diagnostic methods, which reduce the time required for laboratory confirmation of infection and increase the sensitivity of virus detection in the early stages of the disease, is of additional importance. The aim of this work was to develop and optimise a one-step reverse transcription polymerase chain reaction (RT-PCR) designed for the reliable detection of rabies virus RNA in biological material. The study used molecular biological methods, including the selection and analysis of specific primers for the N gene of the rabies virus, as well as the optimisation of the main parameters of the one-step RT-PCR. As a result of the work, RabF_N and RabR_N primers were selected, targeting a conserved region of the rabies virus N gene, which ensured high amplification specificity. Key reaction conditions were investigated and analysed, including primer annealing temperature, $MgCl_2$ concentration, and primer concentration in the reaction mixture. Optimal RT-PCR parameters were established, ensuring stable and reproducible amplification of the target viral RNA fragment. It was shown that the developed protocol allows for the effective

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detection of rabies virus RNA and can be used for laboratory confirmation of the diagnosis. The results confirm the feasibility of using one-step RT-PCR as a rapid and sensitive method of molecular diagnosis. The practical value of the work lies in the possibility of introducing the developed and optimised RT-PCR method into the routine activities of veterinary diagnostic laboratories and reference centres for the diagnosis of rabies and epizootic monitoring

Keywords: diagnosis; N gene; primer; amplification; specificity; sensitivity

Introduction

Rabies is one of the most dangerous zoonotic infections, characterised by acute encephalitis and mortality in animals and humans when clinical symptoms develop. The causative agent of the disease, the rabies virus (*Rabies lyssavirus*, genus *Lyssavirus*, family *Rhabdoviridae*), is an RNA-containing virus with a negative polarity genome that encodes five structural proteins: nucleoprotein (N), phosphoprotein (P), matrix protein (M), glycoprotein (G) and RNA-dependent RNA polymerase (L) (Wang & Xing, 2024). According to D. Manalo *et al.* (2024), the N gene is a highly conserved region that is critical for identifying genetic clusters associated with rabies transmission in specific regions and animal species, making it an optimal target for molecular diagnostics. The spread of the virus among domestic and wild animals remains a serious problem for veterinary medicine and public health in many countries, including Kyrgyzstan, Kazakhstan and neighbouring regions of Central Asia. In Kazakhstan, according to A. Kabzhanova *et al.* (2023), rabies remains endemic and continues to pose a significant epizootic and epidemiological threat to both domestic and wild animals. The presence of stable natural foci of infection and active circulation of the virus in wild carnivore populations has been confirmed (Kabzhanova *et al.*, 2022).

Laboratory diagnostics play a significant role in the surveillance system, as the timeliness of management and preventive decisions depends on their accuracy and efficiency. Traditional methods of laboratory diagnosis of rabies, including direct fluorescent antibody (DFA) reaction to the virus glycoprotein and bioassay on laboratory animals, require considerable time and research under increased biosafety conditions (BSL-2/3). However, the use of DFA may be limited by antigen quality, staff expertise, and tissue sample condition, which reduces the sensitivity of the method, especially when examining autolysed tissues (Gigante *et al.*, 2024). Molecular genetic methods, such as reverse transcription polymerase chain reaction (RT-PCR), are recognised by the World Organisation for Animal Health (WOAH) and the World Health Organisation (WHO) as primary methods for the diagnosis of rabies. International guidelines recommend the use of pan-lyssavirus RT-PCR test systems with published validation data for diagnostic testing (WOAH, 2023). RT-PCR provides high sensitivity and specificity, rapid results, standardised reagents and objective criteria for interpreting results.

The development of pan-lyssavirus test systems based on real-time RT-PCR, such as LN34 pan-lyssavirus real-time RT-PCR assay (LN34), has demonstrated excellent diagnostic sensitivity (99.72-100%) and specificity (99.99-100%) compared to direct fluorescent testing (Gigante *et al.*, 2024). The use of a combination of degenerate nucleotides, multiplex primers and probes allows high sensitivity and specificity to be achieved in the detection of all known variants of the rabies virus and other types of lyssaviruses. In the work of C. Gigante *et al.* (2025), molecular methods proved effective in diagnosing rabies in samples with varying degrees of degradation, including roadkill material. Molecular diagnostics also play a key role in epidemiological studies, allowing genetic typing of isolates and phylogenetic analysis to understand the spread of the virus and identify the sources of outbreaks (Condori *et al.*, 2020; Bautista, 2025). In this regard, the importance of molecular biological methods that provide high sensitivity and specificity for pathogen detection regardless of the stage of the disease is increasing. The aim of this study was to optimise the conditions for classical one-step RT-PCR for reliable and sensitive identification of rabies virus RNA based on the selection of specific primers for the N region of the virus gene and the determination of optimal temperature and time parameters for the reaction, as well as reagent concentrations.

Materials and Methods

The work was carried out at the Research Institute for Biological Safety Problems LLP, QazBioPharm National Holding (Republic of Kazakhstan) in 2024-2025. Primers selected based on sequence analysis in the GenBank (n.d.) database were used to amplify the conserved region N of the rabies virus gene. A pair of primers, RabF_N (5′-CCGTGTACTACAAAGAGAAC-3′) and RabR_N (5′-AGGACACGACACGACGAC-3′), was used in the work. The estimated size of the amplicon was 155 base pairs (bp). The selection and analysis of primer nucleotide sequences was performed using Vector NTI software, which allowed for evaluating their correspondence to the target gene region, temperature characteristics, and potential formation of secondary structures. As a result of primer selection, an amplicon of 155 nucleotide pairs was obtained, corresponding to the calculated fragment of the N gene of the rabies virus. The selected primers demonstrated stable and reproducible amplification of the target site during one-step RT-PCR and did not lead to the formation of non-specific amplification products or primer dimers. Reaction conditions were optimised by selecting the annealing temperature, Mg^{2+} ion concentration, and primer concentration in the reaction mixture. The established parameters ensured clear visualisation of the amplification product of the specified size and high specificity of rabies virus RNA detection.

RNA from the CVS-11 reference strain of rabies virus, obtained from the institute's microorganism collection, was used in this study. The concentration and purity of viral RNA were determined spectrophotometrically using a NanoDrop 2000 instrument (Thermo Scientific, USA) by measuring absorbance ratios at 260 and 280 nm. One-step RT-PCR was performed in a total reaction volume of 25 µl containing the following components: 2.5 µl of 10× RT-PCR buffer; 0.5 µl of a 10 mM deoxynucleotide triphosphate (dNTP) mixture; $MgCl_2$ at a final concentration of 1.25 mM; 0.5 µl each of forward (RabF_N) and reverse (RabR_N) primers at a final concentration of 20 pmol per reaction; 1.0 µl of enzyme mixture; 1.0 µl of viral RNA template (approximately 10 ng/µl); and nuclease-free deionised water added to a final volume of 25 µl. The thermal cycling conditions were as follows: reverse transcription at 50°C for 15 min; initial denaturation at 95°C for 2 min; 35 amplification cycles consisting of denaturation at 94°C for 15 s, primer annealing at 50-60°C for 30 s (varied during optimisation), and extension at 68°C for 60 s; followed by a final extension at 68°C for 5 min. The reaction mixtures were then held at 4°C. Optimisation of the one-step RT-PCR protocol was performed by varying the primer annealing temperature, $MgCl_2$ concentration, enzyme concentration, and primer concentration. All reactions were carried out using a SuperScript III One-Step RT-PCR System with Platinum Taq DNA Polymerase (Invitrogen, USA). The enzyme mixture ("Enzim mix") supplied with the kit contained reverse transcriptase and Taq DNA polymerase.

To optimise the primer annealing temperature during one-step RT-PCR, a temperature gradient in the range of 50-60°C was used. The use of a gradient mode made it possible to evaluate the effect of annealing temperature on the efficiency and specificity of amplification of the target fragment of the N gene of the rabies virus. In each temperature mode, the intensity of the amplification products, the presence of non-specific bands, and the formation of primer dimers were analysed. To determine the optimal concentration of the "Enzim mix" enzyme complex in the one-step RT-PCR reaction, a concentration range of 0.25 to 1.0 units was selected, which allowed for evaluating the effect of the enzyme amount on the efficiency and reproducibility of the amplification of the target fragment of the N gene of the rabies virus. This range was chosen due to the need to determine the minimum enzyme concentration that ensures stable synthesis of the rabies virus N gene cDNA and subsequent PCR amplification, as well as to prevent possible undesirable effects associated with excessive enzymatic activity.

To optimise the concentration of magnesium ions ($MgCl_2$) in the one-step RT-PCR reaction, a range of concentrations corresponding to 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, and 4.0 mM in the reaction mixture. The $MgCl_2$ concentration was selected to determine the optimal conditions for maximum efficiency and specificity of amplification of the target fragment of the N gene of the rabies virus. The reactions were carried out under identical conditions with only the $MgCl_2$ concentration varying. To optimise the primer concentration in the one-step RT-PCR reaction, testing was carried out in the range of 5-40 pM. The reactions were performed at fixed values of the other parameters, including annealing temperature, $MgCl_2$ concentration, and enzyme complex amount, with only the concentration of RabF_N and RabR_N primers varying. The data obtained were used to select the optimal primer concentration for subsequent RT-PCR settings.

To determine the sensitivity of the primer and probe sets, a series of 10-fold dilutions of complementary DNA (cDNA) from 100 ng to 100 ag in the reaction mixture were prepared. RT-PCR was performed under optimised reaction conditions. Cross-reactivity testing of the developed RT-PCR with RNA/DNA of other viruses was performed: Aujeszky's disease virus (*Pseudorabies* virus, *Herpesviridae*), canine distemper virus (*Paramyxoviridae*), ruminant plague virus (*Morbillivirus*, *Paramyxoviridae*). All RT-PCR reactions were performed in three technical replicates. Each series of experiments included a positive control (RNA of the reference strain CVS-11 of known concentration) and a negative control (deionised water without matrix) to exclude contamination.

Results and Discussion

A pair of primers, RabF_N and RabR_N, was used to amplify the conserved region of the N gene of the rabies virus, ensuring high specificity and sensitivity of the reaction. As a result of a one-step RT-PCR, a clear amplification product of the expected size (155 bp) was formed in all positive samples, which corresponds to the calculated size of the target fragment of the N gene (Fig. 1). As shown in Figure 1, lane 1, containing rabies virus RNA, showed a distinct DNA band 155 bp in length, completely matching the size of the positive control amplicon (lane 2). This indicates the correctness of the selected primers and the effectiveness of the optimised reaction conditions. In the negative control, there were no amplification products, which confirms the absence of contamination of the reaction mixture and the high specificity of RT-PCR. The DNA marker (M) used allowed for clearly identifying the size of the obtained amplicons and confirm the correspondence of the experimental data to the theoretically expected result. The absence of non-specific bands and primer dimers indicates the correct selection of primer concentrations and the optimal amplification temperature regime. Thus, the use of RabF_N and RabR_N primers ensures reproducible and selective amplification of the N fragment of the rabies virus gene and can be used for reliable detection of the pathogen's RNA in laboratory diagnostics.

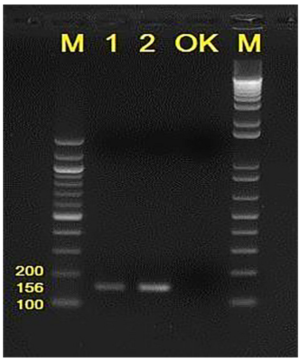

Figure 1. Electrophoregram of the N gene fragment of the rabies virus

Note: M – DNA marker; No. 1 – rabies virus RNA; No. 2 – positive control (155 bp); OK – negative control

Source: developed by the authors

The optimal temperature was found to be 56°C, at which the most intense specific band was formed without by-products and primer dimers. Amplicons become weaker at temperatures above 58°C. The results are presented in Figure 2. The optimal temperature range of 56°C ensured the formation of a clear and reproducible amplicon band of the expected size without the formation of by-products. The selected annealing temperature was used in all RT-PCR reactions in the study. The optimisation of the "Enzim mix" enzyme concentration is shown in Figure 3. RT-PCR results showed that the amplified product was well amplified at concentrations of 0.25-1 units of "Enzim mix" enzyme.

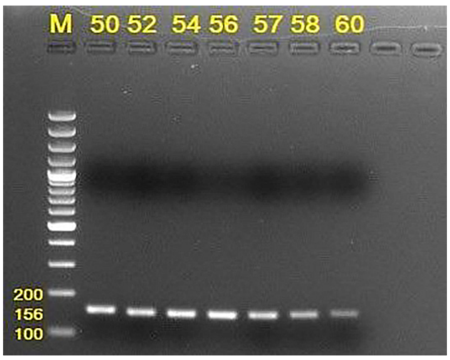

Figure 2. Electrophoregram of amplification of the N fragment of the rabies virus gene at a denaturation temperature gradient (50-60°C)

Note: M – DNA marker

Source: developed by the authors

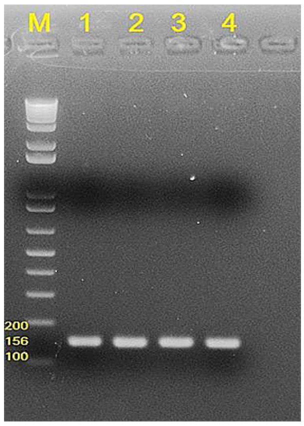

Figure 3. Optimisation of "Enzim mix" enzyme concentration

Source: developed by the authors

The results of RT-PCR optimisation showed that the efficiency of amplification of the target fragment of the N gene of the rabies virus largely depended on the concentration of the "Enzim mix" enzyme complex (reverse transcriptase/DNA polymerase). When testing the range of 0.25-1.0 units of "Enzim mix", a stable and reproducible accumulation of the expected size of the amplicon was observed, which was confirmed by clear visualisation of the band on the electropherogram and the absence of pronounced by-products. A specific amplification product was formed at all specified concentrations, indicating sufficient enzyme complex activity for effective cDNA synthesis and subsequent PCR amplification. When optimising $MgCl_2$, a range of 0.5-4 mM final $MgCl_2$ concentration was tested. The results are shown in Figure 4. The results of optimising the concentration of magnesium ions showed that the use of 1.25 mM $MgCl_2$ in a one-step RT-PCR reaction provides the most stable and reproducible amplification of the target fragment of the N gene of the rabies virus.

Figure 4. Electrophoregram of product amplification at different $MgCl_2$ concentrations

Note: M – size marker; lanes 1-9 correspond to concentrations of 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 4 mM, respectively; at 0.5-4 mM, increasing maximum intensity specific bands are visible

Source: developed by the authors

The optimal result was achieved at 20 pM, at which amplification was stable, intense, and without the formation of primer dimers (Fig. 5). The use of lower primer concentrations led to a decrease in the intensity of the amplification signal, while an increase in concentration above 20 pM resulted in the accumulation of PCR products. Thus, a concentration of 20 pM was determined to be optimal and was used in all subsequent one-step RT-PCR settings.

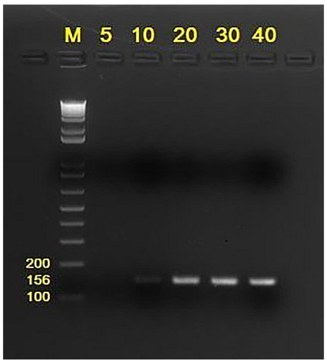

Figure 5. Electrophoregram of amplification of the N fragment of the rabies virus gene at different primer concentrations (5, 10, 20, 30, 40 pM)
Note: M – DNA marker; lanes 1-5 correspond to the specified concentrations
Source: developed by the authors

The sensitivity of the method is 10 fg and is comparable to published foreign methods for detecting other lyssaviruses (Faye *et al.*, 2017). This sensitivity is sufficient for the diagnosis of rabies using saliva and brain tissue samples from animals. The results of the sensitivity determination are presented in Figure 6.

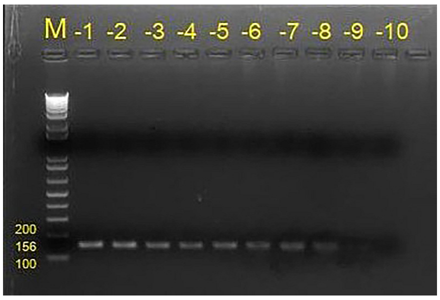

Figure 6. Electrophoregram showing RT-PCR sensitivity at different amounts of rabies virus RNA template
Note: 1 – 100 ng; 2 – 10 ng; 3 – 1 ng; 4 – 100 pg; 5 – 10 pg; 6 – 1 pg; 7 – 100 fg; 8 – 10 fg; 9 – 1 fg; 10 – 100 ag; M – DNA marker
Source: developed by the authors

RT-PCR specificity testing showed that the developed method is specific exclusively for the rabies virus and does not cross-react with the following viruses: Aujeszky's disease virus (*Pseudorabies*, *Herpesviridae*), canine distemper virus (*Paramyxoviridae*), ruminant plague virus (*Morbillivirus*, *Paramyxoviridae*) (Fig. 7).

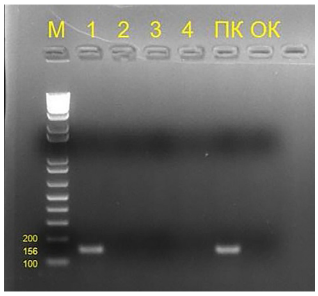

Figure 7. Electrophoregram determining the specificity of RT-PCR
Note: M – DNA marker; 1 – rabies virus RNA; 2 – ruminant plague virus; 3 – Aujeszky's disease virus; 4 – canine distemper virus; ПК – positive control, ОК – negative control
Source: developed by the authors

This study successfully optimised the parameters of a one-step RT-PCR for detecting rabies virus (*Rabies lyssavirus*) RNA using primers targeting the N gene region. The method provides high specificity and sufficient sensitivity for diagnosis. The simplified single-step protocol and the absence of the need for expensive equipment make this test system accessible to veterinary virology laboratories in Central Asian countries. The sensitivity of the method obtained in this study at the level of 10 fg of rabies virus RNA is consistent with data from publications demonstrating the high analytical sensitivity of molecular methods. The study by D. Dean *et al.* (1996) established the effectiveness of DFA, but pointed out its limitations when working with degraded samples, which confirms the relevance of molecular approaches. P. Heaton *et al.* (1997) demonstrated the advantages of semi-nested PCR for the detection of six genotypes of rabies and related viruses, which laid the foundation for the development of modern pan-lyssavirus test systems.

Molecular genetic methods such as RT-PCR are recognised as among the most reliable for the diagnosis of rabies, especially in situations where traditional methods – such as immunodiagnostics or virological testing – may be impossible or ineffective (Ashwini *et al.*, 2024; WOAH, 2024). A study by D. David *et al.* (2002) showed that RT-PCR is capable of detecting the rabies virus in decomposed brain samples that tested negative using a direct fluorescent test, confirming the advantages of molecular diagnostics in complex cases. The development of real-time RT-PCR technologies has significantly expanded the capabilities of laboratory diagnostics. At the same time, it is critical to optimise RT-PCR parameters to ensure the reliability and reproducibility of results. In this study, the optimal annealing temperature was found to be 56°C, the $MgCl_2$ concentration 1.25 mM, the primer concentration 20 pM, and the enzyme complex amount 0.25 units, which is consistent with the recommendations for optimising molecular test systems. D. Manalo *et al.* (2024), when developing real-time RT-PCR for Philippine strains of rabies virus, also emphasised the importance of optimising the annealing temperature to prevent non-specific amplification, limiting the number of cycles to 35 to improve the accuracy of the analysis.

The specificity of the test system developed in this study was confirmed by the absence of cross-reactivity with other viruses, including Aujeszky's disease virus, carnivore plague virus, and ruminant plague virus. These results are consistent with those of M. Faye *et al.* (2017), who showed no non-specific amplification and cross-reactivity with a wide range of other viruses belonging to the same taxonomic family. The use of conservative regions of the N gene for primer and probe design ensures high specificity while maintaining the ability to detect different variants of the rabies virus. At the same time, as pointed out by Yu. Gavrilova *et al.* (2021), the sensitivity and reliability of molecular systems can vary significantly depending on the quality of the material, the conditions of primer selection, and reaction optimisation.

One important application of molecular diagnostics is expanded epizootic surveillance, including the testing of poor-quality material. C. Gigante *et al.* (2025) showed that real-time RT-PCR successfully detected rabies virus RNA in low-quality roadkill samples, which informed rabies surveillance among wild animals in areas of high interest for rabies control among wild animals. J. Mauhay *et al.* (2023) investigated the possibility of using used lateral flow devices (LFDs) for molecular analysis of rabies virus, demonstrating high sensitivity (96.2-100%) of the LN34 test for rabies diagnosis regardless of the storage temperature of the devices. Molecular epidemiology based on RT-PCR is an important tool for classifying viral diseases in animals, including rabies, and provides a better understanding of epidemiological links (Cliquet *et al.*, 2014). Several aspects are important to consider for the further development of molecular diagnostic methods. M. Ashwini *et al.* (2024) noted in a review of recent updates in laboratory diagnosis of rabies the need to introduce portable PCR platforms and point-of-care tests for field conditions and remote regions with limited resources. P. Wang & L. Xing (2024) emphasised the role of rabies virus structural proteins in evading the immune response and the importance of this understanding for vaccine development, which is also relevant for molecular diagnostics, as mutations in genes can affect the effectiveness of primers and probes.

The data obtained confirm that careful primer selection and optimisation of conditions yield good results even at low viral RNA concentrations, similar to observations in regions with endemic rabies (Caraballo *et al.*, 2021; Faye *et al.*, 2021). The developed RT-PCR test system fits well into the modern practice of molecular diagnosis of rabies, both in terms of sensitivity and specificity, and can serve as a reliable tool for epizootic monitoring and rapid diagnosis. The results of the study demonstrate the high efficiency of the developed RT-PCR test system and confirm the feasibility of widespread use of molecular genetic methods for rapid and reliable detection of pathogens of particularly dangerous zoonotic infections. The use of this approach significantly reduces the time required for laboratory confirmation of the diagnosis compared to traditional methods, which is of fundamental importance for the timely adoption of anti-epizootic and preventive measures. The high sensitivity and specificity of the developed test system make it possible to detect the pathogen even at low concentrations of viral genetic material in the samples under investigation, which is especially important in the early stages of infection and when examining clinical material with limited pathogen content. The method can be recommended for implementation in routine diagnostic practice, as well as for epizootic monitoring of rabies virus circulation in wild animal populations.

Conclusions

During the studies, the optimal conditions for performing a one-step reverse transcription polymerase chain reaction for the detection of rabies virus RNA were experimentally determined. It was found that the best amplification efficiency and specificity were achieved at a primer annealing temperature of 56°C, a magnesium ion concentration of 1.25 mM, an "Enzim mix" enzyme complex concentration of 0.25 units, and a primer concentration of 20 pM. The combination of these parameters ensured stable and reproducible amplification of the target fragment of the N gene of the rabies virus. Under the optimised conditions, a clear amplification product of the expected size was formed without signs of non-specific amplification, which indicates the high selectivity of the developed RT-PCR test system. In negative controls, amplification products were absent, confirming the absence of contamination and the correctness of the reaction setup. The specificity of the test system was confirmed by the absence of cross-amplification when studying other viral samples, indicating that the reaction was directed exclusively at rabies virus RNA.

The sensitivity of the developed method was 10 fg of rabies virus RNA, which indicates the high analytical sensitivity of RT-PCR and the ability to detect viral genetic material at low concentrations in the samples studied. This indicator is of significant importance for early laboratory diagnosis and confirmation of the diagnosis, especially when studying clinical and pathological material with a minimal virus content. The results obtained demonstrate the high efficiency of the developed RT-PCR test system. Thus, the method can be recommended for implementation in the routine diagnostic practice of veterinary laboratories. Prospects for further research include: validation of the developed protocol on an expanded panel of field isolates of rabies virus from different geographical regions; adaptation of the method in the real-time RT-PCR format using fluorescent probes for quantitative determination of viral load; testing on clinical samples (saliva, cerebrospinal fluid) from animals in the early stages of infection; development of multiplex RT-PCR for the simultaneous detection of rabies virus and other neurotropic viruses.

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Conflict of Interest
None.

References
[1] Ashwini, M.A., Pattanaik, A., & Mani, R.S. (2024). Recent updates on laboratory diagnosis of rabies. *The Indian Journal of Medical Research*, 159(1), 48-61. doi: 10.4103/ijmr.ijmr_131_23.
[2] Bautista, C.T. (2025). *Genomics-informed surveillance for elimination of rabies in the Philippines*. (PhD thesis, University of Glasgow, Glasgow, Scotland).
[3] Caraballo, D.A., Lombardo, M.A., Becker, P., Sabio, M.S., Lema, C., Martínez, L.M., Beltrán, F.J., Li, Y., & Cisterna, D.M. (2021). Evaluation of two real-time, TaqMan reverse transcription-PCR assays for detection of rabies virus in circulating variants from Argentina: Influence of sequence variation. *Viruses*, 13(1), article number 23. doi: 10.3390/v13010023.
[4] Cliquet, F., Picard-Meyer, E., & Robardet, E. (2014). Rabies in Europe: What are the risks? *Expert Review of Anti-Infective Therapy*, 12(8), 905-908. doi: 10.1586/14787210.2014.921570.
[5] Condori, R.E., *et al*. (2020). Using the LN34 pan-lyssavirus real-time RT-PCR assay for rabies diagnosis and rapid genetic typing from formalin-fixed human brain tissue. *Viruses*, 12(1), article number 120. doi: 10.3390/v12010120.
[6] David, D., Yakobson, B., Rotenberg, D., Dveres, N., Davidson, I., & Stram, Y. (2002). Rabies virus detection by RT-PCR in decomposed naturally infected brains. *Veterinary Microbiology*, 87(2), 111-118. doi: 10.1016/s0378-1135(02)00041-x.
[7] Dean, D.J., Abelseth, M.K., & Atanasiu, P. (1996). The fluorescent antibody test. In F.X. Meslin, M.M. Kaplan & H. Koprowski (Eds.), *Laboratory techniques in rabies* (4th ed., pp. 88-95). Geneva: WHO.
[8] Faye, M., Abd El Wahed, A., Faye, O., Kissenkötter, J., Hoffmann, B., Sall, A.A., & Faye, O. (2021). A recombinase polymerase amplification assay for rapid detection of rabies virus. *Scientific Reports*, 11, article number 3131. doi: 10.1038/s41598-021-82479-8.
[9] Faye, M., Dacheux, L., Weidmann, M., Diop, S.A., Loucoubar, C., Bourhy, H., Sall, A.A., & Faye, O. (2017). Development and validation of sensitive real-time RT-PCR assay for broad detection of rabies virus. *Journal of Virological Methods*, 243, 120-130. doi: 10.1016/j.jviromet.2016.12.019.
[10] Finke, S., & Conzelmann, K.K. (2005). Replication strategies of rabies virus. *Virus Research*, 111(2), 120-131. doi: 10.1016/j.virusres.2005.04.004.
[11] Gavrilova, Yu.K., Generalov, S.V., Abramova, E.G., & Nikiforov, A.K. (2021). *In vitro* methods for rabies virus detection, and evaluation of their use in the production of rabies immunoglobulin. *BIOpreparations. Prevention, Diagnosis, Treatment*, 21(2), 76-84. doi: 10.30895/2221-996X-2021-21-2-76-84.
[12] GenBank. (n.d.). Retrieved from https://www.ncbi.nlm.nih.gov/genbank/.
[13] Gigante, C.M., *et al*. (2024). Optimization of pan-lyssavirus LN34 assay for streamlined rabies diagnostics by real-time RT-PCR. *Journal of Virological Methods*, 333, article number 115070. doi: 10.1016/j.jviromet.2024.115070.
[14] Gigante, C.M., Hartloge, C., Condori, R.E., Kirby, J.D., Hovis, L., Nelson, K.M., Wallace, R., Li, Y., & Chipman, R.B. (2025). Enhanced rabies surveillance in roadkill specimens by real-time RT-PCR. *PLOS Neglected Tropical Diseases*, 19(7), article number e0013348. doi: 10.1371/journal.pntd.0013348.
[15] Heaton, P.R., Johnstone, P., Mcelhinney, L.M., Cowley, R., O'Sullivan, E., & Whitby, J.E. (1997). Heminested PCR assay for detection of six genotypes of rabies and rabies-related viruses. *Journal of Clinical Microbiology*, 35(11), 2762-2766.
[16] Kabzhanova, A.M., Kadyrov, A.S., Mukhanbetkaliyeva, A.A., Yessembekova, G.N., Mukhanbetkaliyev, Y.Y., Korennoy, F.I., Perez, A.M., & Abdrakhmanov, S.K. (2023). Rabies in the Republic of Kazakhstan: Spatial and temporal characteristics of disease spread over one decade (2013-2022). *Frontiers in Veterinary Science*, 10, article number 1252265. doi: 10.3389/fvets.2023.1252265.
[17] Kabzhanova, A.M., Mukhanbetkaliyev, E.E., Yesembekova, G.N., Berdikulov, M.A., & Abdrakhmanov, S.K. (2022). Spatio-temporal analysis of the epizootic situation of animal rabies in Kazakhstan. *Herald of Science of S. Seifullin Kazakh Agrotechnical University*, 3(114), 51-58. doi: 10.51452/kazatu.2022.3(114).1118.
[18] Manalo, D.L., Bolivar, J.K.G., Bondoc, J.G., Nagataki, B.J., Nacion, L.B., Espino, M.J.M., Park, C.H., & Inoue, S. (2024). Development and validation of a real-time PCR assay for the diagnosis of rabies virus Philippine strain in non-brain samples. *medRxiv*. doi: 10.1101/2024.12.04.24318476.
[19] Mauhay, J.D., *et al*. (2023). Molecular analysis of rabies virus using RNA extracted from used lateral flow devices. *Journal of Clinical Microbiology*, 61(3), article number e0154322. doi: 10.1128/jcm.01543-22.
[20] Wang, P.H., & Xing, L. (2024). The roles of rabies virus structural proteins in immune evasion and implications for vaccine development. *Canadian Journal of Microbiology*, 70(11), 461-469. doi: 10.1139/cjm-2024-0023.

[21] World Organisation for Animal Health (WOAH). (2023). *Manual of diagnostic tests and vaccines for terrestrial animals (13th ed.). Chapter 3.1.19. Rabies (infection with rabies virus and other lyssaviruses)*. Retrieved from https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/3.01.19_RABIES.pdf.

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Аннотация. Кутурманы лабораториялык жактан так жана тез диагностикалоонун мааниси бул оорунун жогорку эпизоотиялык жана эпидемиологиялык мааниси, жапайы жана үй жаныбарларынын арасында кеңири таралышы жана эпидемияга каршы жана алдын алуу чараларын өз убагында жана натыйжалуу жүргүзүү зарылдыгы менен аныкталат. Инфекцияны лабораториялык ырастоо үчүн талап кылынган убакытты кыскарткан жана оорунун алгачкы стадияларында вирусту аныктоонун сезгичтигин жогорулаткан молекулярдык-генетикалык диагностикалык ыкмаларды киргизүү кошумча мааниге ээ. Бул изилдөөнүн максаты биологиялык материалдагы кутурма вирусунун РНКсын ишенимдүү аныктоо үчүн иштелип чыккан бир баскычтуу тескери транскриптаза полимераз чынжыр реакциясын (RT-PCR) иштеп чыгуу жана оптималдаштыруу болгон. Изилдөөдө кутурма вирусунун N гени үчүн белгилүү бир праймерлерди тандоо жана талдоо, ошондой эле бир баскычтуу RT-PCRдин негизги параметрлерин оптималдаштыруу сыяктуу молекулярдык биологиялык ыкмалар колдонулган. Бул изилдөөнүн натыйжасында кутурма вирусунун N генинин сакталган аймагына багытталган RabF_N жана RabR_N праймерлери тандалып алынган, бул жогорку амплификациялык өзгөчөлүктү камсыз кылат. Праймерди күйгүзүү температурасы, $MgCl_2$ ионунун концентрациясы жана реакция аралашмасындагы праймердин концентрациясы сыяктуу негизги реакция шарттары изилденип, талданды. Максаттуу вирустук РНК фрагментинин туруктуу жана кайталануучу күчөтүлүшүн камсыз кылган оптималдуу RT-PCR параметрлери белгиленди. Иштелип чыккан протокол кутурма вирусунун РНКсын натыйжалуу аныктай тургандыгы көрсөтүлдү жана диагнозду лабораториялык ырастоо үчүн колдонулушу мүмкүн. Алынган жыйынтыктар бир баскычтуу RT-PCRди тез жана сезгич молекулярдык диагностикалык ыкма катары колдонуунун мүмкүнчүлүгүн тастыктайт. Бул изилдөөнүн практикалык баалуулугу иштелип чыккан жана оптималдаштырылган RT-PCR ыкмасын кутурманы диагностикалоо жана эпизоотиялык мониторинг жүргүзүү үчүн ветеринардык диагностикалык лабораториялардын жана маалымдама борборлорунун күнүмдүк ишине киргизүү мүмкүнчүлүгүндө жатат

Негизги сөздөр: диагностика; N гени; праймер; күчөтүү; спецификалуулук; сезгичтик

Оптимизация ОТ-ПЦР для выявления РНК вируса бешенства

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Аннотация. Актуальность точной и быстрой лабораторной диагностики бешенства определяется высокой эпизоотической и эпидемиологической значимостью данного заболевания, его широкой распространенностью среди диких и домашних животных, а также необходимостью своевременного проведения эффективных противоэпизоотических и профилактических мероприятий. Дополнительную значимость приобретает внедрение молекулярно-генетических методов диагностики, позволяющих сократить сроки лабораторного подтверждения инфекции и повысить чувствительность выявления вируса на ранних стадиях заболевания. Целью настоящей работы являлась разработка и оптимизация одноступенчатой обратной транскриптазной полимеразной цепной реакции (ОТ-ПЦР), предназначенной для надежного выявления РНК вируса бешенства в биологическом материале. В ходе исследования использовали молекулярно-биологические методы, включающие подбор и анализ специфических праймеров к гену N вируса бешенства, а также оптимизацию основных параметров одноступенчатой ОТ-ПЦР. В результате работы были подобраны праймеры RabF_N и RabR_N, направленные на консервативный участок гена N вируса бешенства, что обеспечило высокую специфичность амплификации. Были исследованы и проанализированы ключевые условия проведения реакции, включая температуру отжига праймеров, концентрацию ионов $MgCl_2$ и концентрацию праймеров в реакционной смеси. Установлены оптимальные параметры ОТ-ПЦР, обеспечивающие стабильную и воспроизводимую амплификацию целевого фрагмента вирусной РНК. Показано, что разработанный протокол позволяет эффективно выявлять РНК вируса бешенства и может применяться для лабораторного подтверждения диагноза. Полученные результаты подтверждают целесообразность использования одноступенчатой ОТ-ПЦР как быстрого и чувствительного метода молекулярной диагностики. Практическая ценность работы заключается в возможности внедрения разработанного и оптимизированного метода ОТ-ПЦР в рутинную деятельность ветеринарных диагностических лабораторий и референсных центров для диагностики бешенства и проведения эпизоотического мониторинга

Ключевые слова: диагностика; ген N; праймер; амплификация; специфичность; чувствительность

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Epizootiological situation of brucellosis of cattle and small ruminants in the Almaty region of the Republic of Kazakhstan

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Abstract. Brucellosis poses a serious threat to livestock production, hindering herd expansion and reducing product quality. Effective control of the epizootic process requires timely diagnostics and early identification of brucella carriers. The aim of this work was epizootiological monitoring and analysis of the epizootiological situation of brucellosis in cattle and small ruminants in the Almaty region. Biological material samples (blood serum, whole blood, parenchymal organs, lymph nodes, aborted foetuses) were examined, and official veterinary reporting data from the Veterinary Control and Surveillance Committee of the Ministry of Agriculture of the Republic of Kazakhstan, the Republican Anti-Epizootic Unit, and the regional branch of the Republican Veterinary Laboratory for 2021-2023 were analysed. A total of 1,989 samples were collected and examined in the Almaty region: 867 cattle serum samples, 1,022 small ruminant serum samples, 30 cattle whole blood samples, 50 small ruminant whole blood samples, and 20 pathological material samples. Serological diagnostics revealed positive results in 16 cattle and 6 small ruminants. Bacterial culture growth from pathological material was not

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established by bacteriological methods. Based on statistical data, the epizootiological situation of brucellosis for 2021-2023 was studied, districts with varying degrees of infection were identified, and an epizootiological map of infection distribution was compiled. A decrease in cattle morbidity was established during 2021-2023, despite an increase in livestock numbers from 238,751 to 780,417 animals, indicating the effectiveness of anti-epizootic measures. In small ruminants, morbidity increased from 0.03 to 0.08% during 2021-2022 with a more than 15-fold increase in livestock numbers; however, in 2022-2023, morbidity decreased, demonstrating positive results of the implemented measures

Keywords: monitoring; biological material; serology; bacteriology; incidence rate; contagiousness

Introduction

An important prerequisite for the growth and development of livestock farming, as well as for ensuring the country's population is supplied with food, is the reduction and complete eradication of infectious diseases in farm animals. One such disease, causing significant damage to the meat and dairy production sectors, is brucellosis. The eradication of brucellosis is of paramount importance from an epidemiological and epizootiological perspective, as infected animals serve as a source of infection for humans and other animals. The disease poses a serious problem, requiring substantial expenditure of labour and material resources on a range of veterinary-sanitary and organisational-economic measures. Alongside general preventive measures, specific prevention plays a significant role in the prevention and eradication of brucellosis. Brucellosis remains one of the most pressing zoonotic infections in Kazakhstan, due to the country's historically agrarian economy and extensive private livestock sector. Despite the veterinary and sanitary control measures being implemented, the situation in the country is characterised as consistently tense, according to the findings of A. Askarov *et al*. (2024). The difficulty in eradicating the disease is linked to the unique biological properties of the pathogen. M. Dadar *et al*. (2020) highlight in their work the high environmental adaptability of Brucella: its ability to parasitise intracellularly and survive for long periods in the external environment, which creates constant risks of spontaneous outbreaks even in relatively healthy herds.

The severity of the clinical manifestations of the infection and its impact on herd reproduction are analysed in detail in the works of A. Haif *et al*. (2021) and B. Wakjira *et al*. (2022). The authors demonstrated a direct correlation between the circulation of the pathogen and a critical decline in the productivity of the breeding stock due to mass abortions and subsequent infertility, which transforms the veterinary problem into a serious economic threat to the agro-industrial complex. The methodological approach proposed by A. Robaj *et al*. (2021) allows brucellosis to be viewed not as an isolated pathology, but as a systemic problem directly dependent on the accuracy of serological monitoring and the strictness of controls on livestock movement. These findings correlate with the situation in the Republic of Kazakhstan, where the spatial distribution of the infection is largely determined by migration patterns in livestock farming.

It is necessary to implement the predictive modelling tools described in the works of M. Tito *et al*. (2023), which allow not merely to record cases of the disease, but to take preventive action on the most vulnerable links in the epizootic chain, preventing the spread of infection to disease-free farms and wildlife. Of particular significance in the context of brucellosis eradication are the findings of K. Franc *et al*. (2018), who characterise this disease as one of the most "forgotten" zoonotic infections in the developing world. The authors emphasise that the persistence of even a low level of infection in livestock creates a constant and hidden threat to human health, forming persistent foci capable of sudden outbreaks when environmental conditions or livestock density change. The aim of this study was to investigate the epizootic situation regarding cattle and small ruminants brucellosis in the Almaty region using official statistical data and the results of own laboratory studies.

Materials and Methods

Comprehensive research into the epizootic situation and the improvement of brucellosis diagnostics was carried out at the Brucellosis Laboratory of the Kazakh Scientific Research Veterinary Institute LLP between January and December 2024. The study focused on the epizootic situation regarding brucellosis in cattle and small ruminants on farms in the Almaty region of the Republic of Kazakhstan. Field visits were organised across the region in each district; samples were collected from varying numbers of rural districts, averaging between 2 and 4, depending on the epizootic situation regarding brucellosis. Districts were selected based on data from official veterinary reports for previous years, with priority given to areas with elevated incidence rates.

The following biomaterials were used for laboratory testing:

- Blood serum – for in vivo serological diagnosis and assessment of the immune response. The volume of material collected was 5-10 mL in vacuum tubes containing a coagulation activator, taken from the jugular vein or caudal vein. After serum separation, it was transferred to 2-mL Eppendorf-type tubes, each tube was labelled with the animal's serial number in accordance with the attached inventory, and frozen in a freezer at -20°C.

- Whole blood – for bacteriological examination by culture on erythritol agar. A blood sample of 4-5 mL was collected, each tube was labelled with the animal's serial number in accordance with the attached inventory, and placed in a refrigerator at a temperature of +4...+6°C.
- Parenchymal organs – for direct detection of the pathogen and isolation of pure cultures by inoculation onto erythritol agar. Organs were collected at specialised slaughterhouses from suspect animals in quantities of 50-100 g into 125-mL plastic containers for collecting biomaterial, and were subsequently frozen in a freezer at -20°C. No aborted foetuses were found.

Ethical standards were observed during the collection of whole blood and serum samples (Directive 2010/63/EU, 2010): minimisation of stress in animals, humane treatment, minimal restraint, involvement of qualified specialists to avoid punctures and injuries, use of sterile needles and vacuum tubes, and the blood collection site was treated with 70% alcohol to prevent infection of the animal and contamination of the sample. A total of 1,989 samples were collected across the Almaty region: 867 cattle serum samples, 1,022 small ruminants serum samples, 30 cattle whole blood samples, 50 small ruminants whole blood samples and 20 samples of pathological material from suspected animals. The criteria for selecting animals for testing were clinical signs (abortions, orchitis, bursitis), seropositivity in previous tests, and belonging to farms with a history of brucellosis. All biological samples were placed in thermal cases with frozen refrigerant upon dispatch, sealed, accompanied by the following documents: a cover letter, a certificate of work performed, and a list of animals, and sent to the institute via a specialised parcel delivery service. The samples reached the institute within 1 to 3 hours. Biological samples were collected in strict compliance with biosafety measures, using disposable gloves, masks, protective coveralls and safety goggles. After collection, the gloves, masks, coveralls and gowns were destroyed by incineration at specialised facilities.

To analyse the patterns of infection spread, an epizootiological method was applied, including field surveys of farms. A key feature of the work was the introduction of GIS technologies: the use of geographical coordinates of outbreak sites enabled electronic mapping and the identification of spatial clustering of the infection, which is necessary for forecasting epizootic risks in the region. Mapping was carried out using QGIS software version 3.28.

Serological diagnostic methods. In vivo diagnosis was carried out in accordance with GOST 34105-2017 (2017). The investigations were conducted according to a hierarchical scheme:

- screening: use of the Rose Bengal test (RBT) for rapid identification of positive individuals;
- titration and confirmation: use of the agglutination reaction (AR) and highly specific complement fixation reactions (CFR) and prolonged complement fixation reaction (PCFR).

For serological testing, antigen, haemolysin and Rose Bengal produced in-house by the Kazakh Scientific Research Veterinary Institute LLP were used, along with complement produced by the Antigen Scientific and Production Enterprise LLP. All diagnostic reagents had valid certificates of conformity and were within their expiry dates. To isolate the "gold standard" for diagnosis – a pure culture of Brucella bacteria – a set of methods was used in accordance with GOST 33675-2015 (2016). Biological material (whole blood, parenchymal organs) was inoculated onto specialised culture media: meat peptone broth (MPB), meat peptone agar (MPA) and erythritol agar, with the addition of selective antibiotics (polymyxin, bacitracin). Given the slow growth of the pathogen, cultures were incubated for 30 days at 37°C. When examining material from cattle, it was essential to create microaerophilic conditions with a CO_2 concentration of 5-10%.

For primary identification, the Kozlovsky and Stamp staining methods were used, which allow Brucella to be differentiated based on their ability to retain specific dyes (safranin, carbol fuchsin). The species of the isolated strains was determined by a combination of characteristics: the intensity of hydrogen sulphide (H_2S) production, the ability to grow on media containing aniline dyes (thionin and basic fuchsin), and sensitivity to specific bacteriophages (phage "Tb").

In cases involving material with heavy bacterial contamination or a low pathogen concentration, a bioassay was performed on guinea pigs by subcutaneous inoculation with a bacterial suspension taken from the MPB or erythritol agar of the test material. Female guinea pigs weighing 350-400 g were used for the bioassay. The results were evaluated after 15-30 days based on serological data and the results of post-mortem examination, with mandatory re-isolation of the culture from the lymph nodes and parenchymal organs of the animals.

The research also drew on official veterinary reporting data, which reflect serological tests carried out on farm animals for the diagnosis of particularly dangerous diseases during the period 2021-2023: data from the Ministry of Agriculture of the Republic of Kazakhstan, the Republican Anti-Epizootic Unit, and the regional branch of the Republican Veterinary Laboratory, which serves as a national-level surveillance and diagnostic centre. The data were provided in response to an official request from the Committee for Veterinary Control and Supervision. The prevalence of infection was expressed as a percentage and calculated using the formula: $P = (n / N) \times 100$, where P is the prevalence of infection (prevalence) in %; n is the number of animals that tested positive; N is the total number of animals tested in the herd or region. Statistical analysis of the results was performed using Microsoft Excel 2019 and included the calculation of means, standard deviations and confidence intervals ($p < 0.05$).

Results and Discussion

During the study, a comprehensive assessment of the epizootiological situation regarding brucellosis in the Almaty region was carried out based on serological and bacteriological diagnostic methods, as well as a retrospective analysis of official statistical data for the period 2021-2023. The results obtained made it possible to identify areas with varying degrees of epizootic risk and to assess the effectiveness of the anti-epizootic measures being implemented. The results of the serological and bacteriological studies are presented in Table 1.

Table 1. Results of serological and bacteriological tests on samples from cattle and small ruminants for brucellosis in the Almaty region for 2024

District	Rural district	Number of blood serum samples		Number of whole blood samples		Positive blood serum reactions detected		Positive whole blood reactions detected	
		Cattle	Small ruminants	Cattle	Small ruminants	Cattle	Small ruminants	Cattle	Small ruminants
Karasai	Shamalgan	50	100	5	10	0	0	0	0
Ili	Mezhdurechensk	50	50	5	5	0	0	0	0
	Ashibulak	50	100	5	10	0	0	0	0
	Zhetigen	50	100	5	10	6	0	0	0
	Karaoy	50	100	5	10	0	0	0	0
Raimbek	Saryzhaz	248	100	0	0	0	0	0	0
	Tekes	163	379	0	0	0	0	0	0
	Kainar	156	43	0	0	0	6	0	0
Almaty	Turksib	0	50	0	5	0	0	0	0
	Nauryzbay	50	0	5	0	10	0	0	0
Total		867	1,022	30	50	16	6	0	0

Source: compiled by the authors

During diagnostic testing in 2024, 867 cattle serum samples and 1,022 small ruminant serum samples, 30 cattle whole blood samples, 50 samples of small ruminant blood serum and 20 samples of pathological material from cattle from suspected animals, which made a total of 1,989 samples. Positive results of serological diagnosis of blood serum were detected in 16 animals of cattle and 6 animals of small ruminants. During bacteriological examinations of pathological material, no growth of cultures was observed. An analysis of the distribution of animals testing positive across the region's districts showed that the highest number of seropositive cattle was recorded in the Ili district (Zhetigen rural district) – 6 cases, accounting for 12% of the total number of samples taken in that settlement, and in the Nauryzbay district of Almaty – 10 cases (20% prevalence). Positive results for brucellosis were detected in the Raimbek district (Kainar rural district) – 6 cases, corresponding to a 13.9% prevalence rate. Based on the data obtained, these districts and their rural districts can be classified as areas with a high prevalence rate.

The phenomenon of "seropositivity with culture negativity" observed in this study warrants separate discussion. J. Papaparaskevas *et al.* (2023) emphasise that circulating strains in specific regions may have unique metabolic requirements that are not accounted for by standard culture media, leading to false-negative results in bacterial culture despite the presence of antibodies in the blood serum. J. Aliyev *et al.* (2022) attribute this in their studies to the adaptation of microorganisms to the environment and antibiotic therapy, which renders them uncultivable. In the context of high antibody titres detected in the Ili and Nauryzbay districts (12-20%), K. Tursunov *et al.* (2017) highlight the critical importance of verification via PCR and sequencing for areas with high incidence rates. Molecular methods allow not only the detection of pathogen DNA fragments when the live cell is not growing, but also the typing of strains to determine their origin, as well as the development of more accurate test systems specific to a particular region.

The results of serological studies for brucellosis of cattle and small ruminant serum samples, provided by the Committee for Veterinary Control and Supervision based on veterinary reports from the Almaty branch of the Republican Veterinary Laboratory for 2021-2023, are presented in Table 2. The data presented show that the highest incidence rate for cattle was recorded in the Ili district, whilst the infection rate for small ruminants remains low and is showing a downward trend. Overall, there has been a decline in the incidence rate among both cattle and small ruminant populations; however, the risk of infection remains, which allows the Ili district to be classified as an area with a high incidence of brucellosis. In the Enbekshikazakh district, the infection rate among cattle reached a record 0.44% in 2021, falling to 0.08% in 2022 despite an eightfold increase in the livestock population, which is an indicator of the veterinary service's effective work. However, in 2023, the rate rose again to 0.13%, which means this district can be classified as an area with a high incidence of livestock disease, as the infection rate exceeds the regional average.

Table 2. Trends in the incidence of brucellosis in cattle and small ruminants in the districts of Almaty region between 2021 and 2023

District	Cattle blood serum samples	Positive results	Infection rate	Small ruminants serum samples	Positive results	Percentage of infection
			2021			
Ili	31,354	145	0.46	97,887	25	0.03
Balkhash	10,000	0	0	12,700	0	0
Enbekshikazakh	16,930	75	0.44	11,214	8	0.07
Zhambyl	19,190	6	0.03	25,076	0	0
Karasai	3,569	0	0	5,055	0	0
Kegen	7,776	5	0.06	2,125	0	0
Raimbek	150,000	26	0.02	0	0	0
Talgar	4,962	2	0.04	3,579	0	0
Uyghur	8,800	3	0.03	0	0	0
Almaty	3,100	4	0.13	1,935	4	0.2
Total	238,751	191	Mean 0.12	148,357	29	Mean 0.03
			2022			
Ili	29,300	120	0.41	105,000	8	0.01
Balkhash	122,000	6	0.005	147,500	39	0.03
Enbekshikazakh	131,116	100	0.08	284,073	253	0.09
Zhambyl	163,366	11	0.007	925,907	3	0.0003
Karasai	33,177	0	0	55,745	0	0
Kegen	61,000	22	0.04	174,500	14	0.01
Raimbek	70,000	39	0.06	245,000	0	0
Talgar	37,632	23	0.06	70,165	62	0.09
Uyghur	105,200	3	0.003	260,600	9	0.003
Almaty	7,015	11	0.16	64,012	388	0.61
Total	759,806	335	Mean 0.08	2,332,502	766	Mean 0.08
			2023			
Ili	26,995	38	0.14	106,110	1	0.001
Balkhash	120 225	10	0.01	145,014	28	0.02
Enbekshikazakh	128,902	162	0.13	297,321	79	0.03
Zhambyl	183,433	26	0.01	151,020	10	0.01
Karasai	32,500	3	0.01	58,601	4	0.01
Kegen	60,618	7	0.01	165,100	7	0.004
Raimbek	75,000	23	0.03	350,000	6	0.002
Talgar	35,608	16	0.04	74,081	6	0.01
Uyghur	106,000	1	0.001	260,000	14	0.01
Almaty	11,136	10	0.09	51,700	14	0.03
Total	780,417	296	Mean 0.05	1,658,947	169	Mean 0.01

Source: compiled by the authors

The incidence rate of cattle brucellosis in Almaty over the three-year observation period exceeds the average incidence rate and stands at 0.12%. In 2022, the percentage of infected livestock increased slightly compared to 2021; however, a significant decrease in infection rates was observed in 2023. Thus, Almaty can be classified as an area with a high incidence of brucellosis, as the annual figures exceed the regional average incidence rate. For small ruminants, the incidence rate for 2022-2023 also exceeded the average, allowing this region to be classified as an area with a high incidence of the disease. In the Raimbek district, during the authors' own research in 2024, six animals of small ruminants were identified as testing positive for brucellosis. According to statistical data, the incidence rate for 2021-2023 remains low, which is likely due to sporadic cases of the disease in livestock.

A. Dahmani *et al.* (2022) emphasise in their research that traditional control measures are often insufficiently effective without taking into account the spatio-temporal dynamics and density of contact between different animal species sharing common water and feed resources. The status of the Ili and Enbekshikazakh districts as high-risk areas may be due to several factors. Firstly, cross-border and migratory flows associated with high livestock movement density near the Almaty metropolitan area. Secondly, the natural and climatic conditions, the specific characteristics of the pastures, and the presence of natural reservoirs of infection in these districts. Y. Hegazy *et al.* (2022) identify the uncontrolled movement of animals as a key factor in the instability of the epizootic situation in developing agricultural regions. Cross-border transmission is due to the fact that the Almaty region borders Kyrgyzstan and China, creating corridors for the circulation of strains different from local ones. The migration of small ruminant herds under traditional transhumance practices contributes to the "mixing" of the infectious background of different farms at watering points and along migration routes. H. Brangsch *et al.* (2023) highlight the problem of "reservoir species". On farms where small and large ruminants are kept together or use shared pastures, an interspecies transmission effect occurs, during which the pathogen adapts. Some infections can circulate between species, with one species acting as an asymptomatic carrier, constantly fuelling the infection focus in the other. Mixed farms are statistically more difficult to completely sanitise, as they require simultaneous and strict control of all links in the biological chain.

The results of tests on livestock for cattle and small ruminants' brucellosis in the Almaty region for the period 2021-2023 are presented in Table 3. For cattle, the Ili district is by far the worst-affected, where the infection rate (1.01%) is four times higher than the regional average. An alarming situation is also observed in the Enbekshikazakh district (0.65%). These areas require enhanced veterinary surveillance. For small ruminants, a sudden surge has been recorded in the city of Almaty, where, despite a relatively small herd size, 406 positive cases (0.83%) were detected, which is six times higher than the regional average. This may indicate specific husbandry conditions or control issues regarding the import of livestock into the city limits.

Table 3. Summary data on the total number of animals tested and confirmed cases of brucellosis among cattle and small ruminants in the Almaty region for the period 2021-2023

District	Cattle	Positive	Infection rate	Small ruminants	Positive	Infection rate
Ili	87,649	303	1.01	308,997	34	0.04
Balkhash	252,225	16	0.013	305,214	67	0.05
Enbekshikazakh	276,948	337	0.65	592,608	340	0.19
Zhambyl	365,989	43	0.047	1,102,003	13	0.010
Karasai	69,246	3	0.01	119,401	4	0.01
Kegen	129,394	34	0.11	341,725	21	0.01
Raimbek	295,000	88	0.1	595,000	6	0.002
Talgar	78,202	41	0.14	147,825	68	0.1
Uyghur	220,000	7	0.034	520,600	23	0.013
Almaty	21,251	25	0.37	117,647	406	0.83
Total	1,795,904	897	Mean 0.25	4,151,020	982	Mean 0.13

Source: compiled by the authors

The trend in the incidence rate for cattle and small ruminants is shown in Figure 1. During the period 2021-2023, a steady decline in the incidence rate of brucellosis was observed in cattle, particularly given that the livestock population tripled between 2021 and 2022, which demonstrates the effectiveness of the anti-epizootic measures implemented. For small ruminants, an increase in the incidence rate from 0.03% to 0.08% was observed between 2021 and 2022, alongside a simultaneous increase in the livestock population from 148,357 to 2,332,502 animals. However, between 2022 and 2023, the livestock population decreased to 1,658,947 animals, and the incidence rate fell from 0.08% to 0.01%, indicating a decline in animal disease incidence and the positive impact of anti-epizootic safety measures.

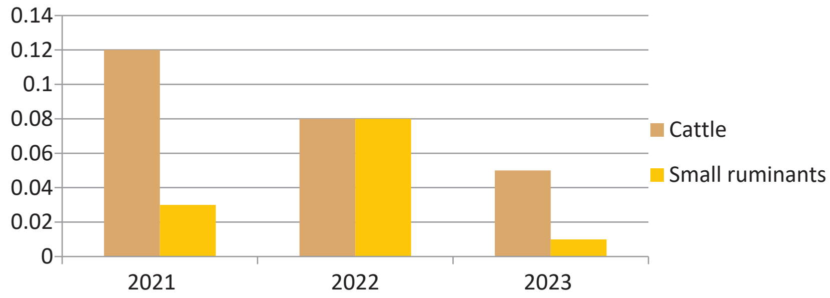

Figure 1. Incidence rate of brucellosis in cattle and small ruminants in the Almaty region between 2021 and 2023

Source: compiled by the authors

A. Taipova *et al.* (2023) note the high effectiveness of current veterinary measures in Kazakhstan, despite the country's overall status as an endemic zone for brucellosis. An analysis of the epizootic situation in the Almaty region for 2021-2023 revealed a steady downward trend in the incidence of brucellosis among cattle, which correlates with the data from these researchers. The achieved level of cattle infection (0.05%) places the region in a more favourable position compared to neighbouring territories. W. Liu *et al.* (2025) indicate that in the border regions of Russia and Kyrgyzstan, rates vary from 0.5 to 1.0%. Such a low prevalence in the Almaty region (below the 1% threshold) allows, in accordance with the recommendations of the WOAH (2023), a shift from a containment strategy to the strict "test-and-cull" approach, which has proven effective in eradicating the infection in EU countries and Australia. However, the presence of high-risk zones (Ili district) and areas with a medium risk level (Enbekshikazakh district, Almaty city) indicates the persistence of natural foci. B. Ntirandekura *et al.* (2021), as well as A. Abutalip *et al.* (2024), note that environmental factors – in particular, the use of leased pastures and the presence of wetlands – significantly increase the survival *of Brucella abortus*. Cross-border migration and the illegal movement of livestock remain critical risk factors, bringing the situation in Central Asia into line with the problems faced in the Middle East and Africa, as indicated by W. Oyetola *et al.* (2021).

Based on a retrospective analysis of statistical data, this study notes a sustained positive trend in the control of brucellosis among cattle. From 2021 to 2023, the incidence rate in cattle has shown a steady decline, indicating the effectiveness of the veterinary and preventive measures being implemented and the high-quality coverage of the herd by serological testing. In the small ruminant sector, the situation is characterised by volatility: slight fluctuations in incidence are observed, driven by sharp changes in herd numbers (increases and decreases by a factor of ten in different periods). Nevertheless, when calculating relative indicators, the infection rate in recent years has shown a downward trend, which confirms the effectiveness of the region's veterinary service. Based on the results of diagnostic studies for 2024, the districts of the region were categorised according to their level of epizootic safety. The Ili district has been classified as the most high-risk and requires enhanced monitoring and updated quarantine measures. The Enbekshikazakh district and the city of Almaty are classified as medium-risk areas, where a moderate level of detection of animals testing positive persists. The Balkhash, Zhambyl, Karasai, Kegen, Talgar and Uyghur districts are classified as conditionally safe areas, where the infection rate varies within minimal limits (0.001-0.02%), allowing these administrative units to be considered areas with a low epidemiological threshold. Based on a comprehensive analysis of the epizootic chain (wild animals – livestock – external environment) and an assessment of the current situation in the Almaty region, it has been established that the process is characterised by a marked decline. The decrease in cattle disease incidence against a backdrop of growing livestock numbers confirms the effectiveness of current veterinary control measures. However, fluctuations in brucellosis cases require enhanced surveillance of animal movements. A. Daugalieva & S. Daugalieva (2025) note that the genetic stability of the isolates detected indicates the presence of persistent foci, making the control of animal movement routes a priority.

The analysis conducted allowed for the differentiation of districts according to their level of epizootic risk. Whilst most of the region has achieved the status of conditionally safe areas with a minimal level of infection, the Ili district remains a zone of priority veterinary surveillance. This area requires targeted health improvement measures and enhanced laboratory screening. The region is in the final stage of brucellosis eradication. The main barrier to achieving infection-free status remains the cross-border movement of animals and contact between livestock and wildlife on cross-border pastures. In this regard, the introduction of digital traceability systems and the tightening of administrative controls over all livestock movements within and beyond the region appear to be of critical importance.

Conclusions

An analysis of the epizootic situation regarding brucellosis in the Almaty region for the period 2021-2024 indicates that there is a steady downward trend in the incidence rate among cattle in the region, which had reached 0.05% by 2024. Despite a significant increase in livestock numbers and minor fluctuations in the incidence rate among small ruminants, the overall trend is assessed as positive. The figures achieved demonstrate the high effectiveness of the veterinary and preventive measures being implemented and bring the region closer to the international threshold for the complete eradication of the infection (below 0.1% according to WOAH criteria). Variations in the epizootic status of districts have been identified. The Ili district has been identified as the most high-risk area, requiring enhanced veterinary surveillance. The Enbekshikazakh district and the city of Almaty have been classified as medium-risk zones. At the same time, the Balkhash, Zhambyl, Karasai, Kegen, Talgar and Uyghur districts demonstrate a minimal level of infection (0.001-0.02%), which allows them to be classified as conditionally favourable territories. Brucellosis in the region remains a naturally occurring focal infection, with domestic, wild and carnivorous animals involved in the epizootic chain. The key factors contributing to the persistence of *Brucella abortus* in the environment are the presence of wetlands, the use of communal pastures and uncontrolled migration flows.

To definitively control the infection, it is necessary to shift from a passive control strategy to comprehensive epizootic monitoring, employing a strict "test-and-cull" strategy in areas with low prevalence, timely diagnosis in cases of mass disease (abortions, mastitis) and the elimination of all links in the chain of transmission by breaking contact between livestock and wildlife. The implementation of these measures will minimise economic damage to the agricultural sector and significantly reduce epidemiological pressure among the region's population. Prospects for further research include the introduction of molecular genetic diagnostic methods (PCR, sequencing) to identify circulating Brucella strains and establish their phylogeographic origin, which will enable the development of region-specific test systems with increased sensitivity. In-depth epizootiological studies are required to investigate the role of wild animals as potential reservoirs of infection in natural foci in the Almaty region. A key priority is the development and validation of mathematical models for predicting epizootic risks using GIS technologies and big data analysis, which will facilitate a shift towards a preventive strategy for brucellosis control. Furthermore, an assessment of the cost-effectiveness of various strategies for the rehabilitation of affected areas is required in order to optimise the allocation of the region's veterinary service resources.

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Conflict of Interest

None.

References

[1] Abutalip, A., Bizhanov, A., Matikhan, N., Karabassova, A., & Orynbayeva, B. (2024). Regional epidemiology of brucellosis infection in modern conditions of animal husbandry technology in Kazakhstan (by the degree of spread and incidence). *Scientific Horizons*, 27(5), 20-31. doi: 10.48077/scihor5.2024.20.

[2] Aliyev, J., Alakbarova, M., Garayusifova, A., Omarov, A., Aliyeva, S., Freti, D., & Godfroid, J. (2022). Identification and molecular characterization of *Brucella abortus* and *Brucella melitensis* isolated from milk in cattle in Azerbaijan. *BMC Veterinary Research*, 18, article number 71. doi: 10.1186/s12917-022-03155-1.

[3] Askarov, A.M., Bekshin, Zh.M., Kundashev, K.U., Bissenova, G.N., Temirkhanov, A.Zh., & Serikovna, S.Z. (2024). Brucellosis – an analysis of the epidemiological and epizootological situation in the world and the Republic of Kazakhstan. *Micribiology and Virology*, 3(46), 9-31. doi: 10.53729/MV-AS.2024.03.01.

[4] Brangsch, H., *et al.* (2023). Genotype diversity of brucellosis agents isolated from humans and animals in Greece based on whole-genome sequencing. *BMC Infectious Diseases*, 23(1), article number 529. doi: 10.1186/s12879-023-08518-z.

[5] Dadar, M., Shahali, Y., & Fakhri, Y. (2020). A primary investigation of the relation between the incidence of brucellosis and climatic factors in Iran. *Microbial Pathogenesis*, 139, article number 103858. doi: 10.1016/j.micpath.2019.103858.

[6] Dahmani, A., Khelifi-Touhami, N.A., Khelifi-Touhami, M.K.-T., & Ouchene, N. (2022). Brucellosis: A retrospective sero-epidemiological study. *Journal of Veterinary Physiology and Pathology*, 1(2), 43-48. doi: 10.58803/jvpp.v1i2.1.

[7] Daugalieva, A., & Daugalieva, S. (2025). Molecular and genetic characteristics and epidemiological significance of brucella isolates circulating in Kazakhstan. *Science and Education*, 1(3(80)), 283-307. doi: 10.52578/2305-9397-2025-3-1-283-307.

[8] Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes. (2010, September). Retrieved from https://surl.li/cfyfwb.

[9] Franc, K.A., Krecek, R.C., Häsler, B.N., & Arenas-Gamboa, A.M. (2018). Brucellosis remains a neglected disease in the developing world: A call for interdisciplinary action. *BMC Public Health*, 18(1), article number 125. doi: 10.1186/s12889-017-5016-y.

[10] GOST 33675-2015. (2016). *Interstate standard. Animals. Laboratory diagnosis of brucellosis. Bacteriological methods*. Retrieved from https://meganorm.ru/Data2/1/4293758/4293758087.pdf.

[11] GOST 34105-2017. (2017). *Interstate standard. Animals. Laboratory diagnosis of brucellosis. Serological methods*. Retrieved from https://meganorm.ru/Data/646/64665.pdf.

[12] Haif, A., Khelifi-Ouchene, N.A., Khelifi, M., Ouchetati, I., Zeroual, F., & Ouchene, N. (2021). Abortive diseases and their various associated risk factors in small ruminants in Algeria: A systematic review. *Tropical Animal Health and Production*, 53(6), article number 520. doi: 10.1007/s11250-021-02926-6.

[13] Hegazy Y., *et al*. (2022). Trans-species transmission of Brucellae among ruminants hampering brucellosis control efforts in Egypt. *Applied Microbiology*, 132(1), 90-100. doi: 10.22541/au.164865111.12602771/v1.

[14] Liu, W., Dong, Y., Zhou, W., & Sun, A. (2025). Global research hotspots and trends in brucellosis: A bibliometric and visualization analysis based on CiteSpace and VOSviewer. *Frontiers in Medicine*, 12, article number 1617217. doi: 10.3389/fmed.2025.1617217.

[15] Ntirandekura, B.J., Matemba, E.L., Kimera, S.S., Muma, B.J., & Karimuribo, E.D. (2021). Brucellosis and its associated risk factors to humans and domestic ruminants in Kagera Ecosystem, Tanzania. *African Health Sciences*, 21(2), 523-530. doi: 10.4314/ahs.v21i2.6.

[16] Oyetola, W.D., Diallo, K., Kreppel, K., Kone, P.S., Schelling, E., Bonfoh, B., & Alambedji, R.B. (2021). Factors influencing the transborder transmission of brucellosis in cattle between Côte d'Ivoire and Mali: Evidence from literature and current key stakeholders. *Frontiers in Veterinary Science*, 8, article number 630580. doi: 10.3389/fvets.2021.630580.

[17] Papaparaskevas, J., Procopiou, A., Routsias, J., Vrioni, G., & Tsakris, A. (2023). Detection of virulence-associated genes among *Brucella melitensis* and *Brucella abortus* clinical isolates in Greece, 2001-2022. *Pathogens*, 12(11), article number 1274. doi: 10.3390/pathogens12111274.

[18] Robaj, A., *et al*. (2021). Infectious abortions in small ruminants: Challenges for diagnosis and public health. *Vector Borne and Zoonotic Diseases*, 21(6), 475-477. doi: 10.1089/vbz.2020.2731.

[19] Taipova, A.A., Beishova, I.S., Alikhanov, K.D., Otarbayev, B.K., Ulyanov, V.A., Ginayatov, N.S., & Dushaeva, L.Zh. (2023). Monitoring of the epizootic situation on animal brucellosis in the Republic of Kazakhstan. *Science and Education*, 2(2(71), 161-169. doi: 10.52578/2305-9397-2023-2-2-161-169.

[20] Tito, M.H., Arifuzzaman, M., Jannat, M.H.E., Rahman, M.S., Sharmy, S.T., Nasrin, A., Asaduzzaman, M., Ashrafuzzaman, M., Prince, D.B., & Asif, A.H. (2023). A comparative study of ensemble machine learning algorithms for brucellosis disease prediction. *Letters in Animal Biology*, 3(2), 23-27. doi: 10.62310/liab.v3i2.119.

[21] Tursunov, K.T., Bulashev, A.K., & Zhumalin, A.Kh. (2017). Using recombinant brucella proteins to determine antibiotics in serum-positive animals. *Science Bulletin of the Kazakh Agrotechnical University named after S. Seifullin (Interdisciplinary)*, 1(92), 65-74.

[22] Wakjira, B.S., Jorga, E., Lakew, M., Olani, A., Tadesse, B., Tuli, G., Belaineh, R., Abera, S., Kinfe, G., & Gebre, S. (2022). Animal brucellosis: Seropositivity rates, isolation and molecular detection in Southern and Central Ethiopia. *Veterinary Medicine: Research and Reports*, 13, 201-211. doi: 10.2147/VMRR.S372455.

[23] World Organisation for Animal Health (WOAH). (2023). *Brucellosis (Brucella abortus, B. melitensis, and B. suis). B: Manual of diagnostic tests and vaccines for terrestrial animals*. Retrieved from https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-manual-online-access/.

Казакстан республикасынын Алматы облусундагы ИММ жана МММ бруцеллезу боюнча эпизоотологиялык кырдаал

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Аннотация. Бруцеллез инфекциясы мал чарбасы үчүн олуттуу коркунуч түзүп, малдын санын көбөйтүүгө тоскоолдук жаратат жана продукциянын сапатын төмөндөтөт. Эпизоотиялык процессти эффективдүү көзөмөлдөө өз убагында диагностиканы жана бруцелла ташуучуларын эрте аныктоону талап кылат. Иштин максаты Алматы облусундагы ири мүйүздүү малдын (ИММ) жана майда мүйүздүү малдын (МММ) бруцеллезине байланыштуу эпизоотиялык мониторинг жана анализ болуп саналган. Биологиялык материалдын сынамыктары (кандын сары суусу, бүт кан, паренхиматоздук органдар, лимфа түйүндөрү, бойдон алдырылган жемиштер) изилденген, ошондой эле ҚР АЧМ-нын ветеринардык контролдоо жана көзөмөлдөө комитетинин, Республикалык анти-эпизоотикалык отряддын жана Республикалык ветеринардык лабораториянын облустук филиалынын 2021-2023-жылдар боюнча расмий ветеринардык отчеттук маалыматтары талданган. Алматы облусунда 1989 үлгү алынып изилденген: 867 ИММ сары суусу, 1022 МММ сары суусу, 30 ИММ бүт каны, 50 МММ бүт каны жана 20 патологиялык материал үлгүлөрү. Серологиялык диагностика 16 баш ИММ жана 6 баш МММ боюнча оң жыйынтыктарды аныктаган. Бактериологиялык ыкма менен патологиялык материалдан өсүү аныкталган жок. Статистикалык маалыматтардын негизинде 2021-2023-жылдар аралыгында бруцеллез боюнча эпизоотиялык абал изилденип, ар кандай жуккан деңгээлдеги аймактар аныкталып, инфекциянын жайылуусунун эпизоотиялык картасы түзүлгөн. 2021-2023-жылдар аралыгында ИММ боюнча оорулуулук деңгээлинин төмөндөгөнү аныкталды, малдын саны 238 751 баштан 780 417 башка көбөйгөнүнө карабастан, бул эпизоотияга каршы иш-чаралардын натыйжалуулугун көрсөткөн. МММ боюнча 2021-2022-жылдары оорулуулук 0,03төн 0,08 %га чейин жогорулаган, малдын саны 15 эсеге көбөйгөн, бирок 2022-2023-жылдары оорулуулук төмөндөп, жүргүзүлгөн чаралардын оң жыйынтыктарын көрсөткөн

Негизги сөздөр: мониторинг; биологиялық матриал; серология; бактериология; оорунун пайызы; контагиозность

Эпизоотологическая ситуация по бруцеллезу КРС и МРС в Алматинской области Республики Казахстан

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Аннотация. Бруцеллез представляет серьезную угрозу для животноводства, препятствуя увеличению поголовья скота и снижая качество продукции. Эффективный контроль эпизоотического процесса требует своевременной диагностики и раннего выявления бруцеллоносителей. Целью работы являлись эпизоотологический мониторинг и анализ эпизоотологической ситуации по бруцеллезу крупного рогатого скота (КРС) и мелкого рогатого скота (МРС) на территории Алматинской области. Исследовались пробы биологического материала (сыворотка крови, цельная кровь, паренхиматозные органы, лимфатические узлы, абортированные плоды), а также анализировались официальные данные ветеринарной отчетности Комитета ветеринарного контроля и надзора Министерства сельского хозяйства Республики Казахстан, Республиканского противоэпизоотического отряда и областного филиала Республиканской ветеринарной лаборатории за 2021-2023 годы. В Алматинской области было отобрано и исследовано 1989 проб: 867 проб сыворотки крови КРС, 1022 пробы сыворотки МРС, 30 проб цельной крови КРС, 50 проб цельной крови МРС и 20 проб патологического материала. Серологическая диагностика выявила положительные результаты у 16 голов КРС и 6 голов МРС. Бактериологическим методом рост культур из патологического материала не был установлен. На основе статистических данных была изучена эпизоотологическая ситуация по бруцеллезу за период 2021-2023 годов, определены районы с различной степенью зараженности и составлена эпизоотологическая карта распространения инфекции. Установлено снижение заболеваемости КРС в период 2021-2023 годов, несмотря на увеличение поголовья с 238 751 до 780 417 голов, что свидетельствует об эффективности противоэпизоотических мероприятий. По МРС отмечено повышение заболеваемости с 0,03 до 0,08 % в период 2021-2022 годов при росте поголовья более чем в 15 раз, однако в 2022-2023 годах заболеваемость снизилась, демонстрируя положительные результаты проводимых мер

Ключевые слова: мониторинг; биологческий материал; серология; бактериология; заболеваемость; контагиозность

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Prevalence and antibiotic resistance of *Listeria monocytogenes* isolated from livestock products in Kazakhstan

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Abstract. *Listeria monocytogenes* is the causative agent of listeriosis in humans and animals, posing a significant threat to the safety of animal-derived products. The high survival capacity of this bacterium in dairy and meat products, along with potential antimicrobial resistance, necessitated monitoring the prevalence and susceptibility of *Listeria* isolates in the Republic of Kazakhstan. The aim of this study was to determine the prevalence, species composition, and antimicrobial susceptibility profile of *Listeria* in animal-derived products collected in 2025. A total of 521 samples of meat and dairy products were examined, collected during cold and warm seasons in Almaty and Almaty region. *Listeria* isolation was performed using Half Fraser and full-strength Fraser broths, followed by plating on CHROMagar™ *Listeria* and PALCAM selective media. Species identification was carried out using the CAMP test and biochemical assays. Antimicrobial susceptibility was determined by the disc diffusion method on Mueller-Hinton agar according to EUCAST guidelines. From 521 samples, 116 *Listeria* isolates were recovered (22.3%), of which 40 isolates (34.5% of all Listeria and 7.7% of total samples) were identified as *L. monocytogenes*. The highest number of *L. monocytogenes* isolates was detected in dairy products – 24 isolates (60.0%), whilst

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16 isolates (40.0%) were found in meat products. The CAMP test confirmed the pathogenicity of the isolated strains. Antimicrobial susceptibility testing demonstrated high sensitivity to ampicillin, ampicillin/sulbactam, chloramphenicol, and tetracyclines; however, isolates exhibiting multidrug resistance to benzylpenicillin and linezolid were detected. The findings emphasise the necessity of regular monitoring of *L. monocytogenes* in livestock products and surveillance of antimicrobial susceptibility to prevent the dissemination of resistant strains

Keywords: foodborne pathogens; antimicrobial resistance; animal-derived products; microbiological contamination; public health risk; phenotypic resistance; food safety monitoring

Introduction

Listeriosis remains one of the most dangerous foodborne infections, characterised by a high case-fatality rate among vulnerable population groups, despite its relatively low incidence. In reports by various international organisations, *Listeria monocytogenes* consistently ranks among the leading causes of death from zoonotic infections, including in European Union countries. At the same time, one of the pressing global challenges facing public health and veterinary medicine is the growing resistance of pathogenic microorganisms to antimicrobial agents, which is directly linked to the widespread and often uncontrolled use of antibiotics in medicine, animal husbandry and the food industry. In this context, *L. monocytogenes* is of particular epidemiological significance – the causative agent of listeriosis, a dangerous zoonotic disease characterised by high mortality among at-risk groups, including pregnant women, newborns, the elderly and individuals with immunodeficiency conditions (Alharbi *et al.*, 2025)

An important aspect of the study of listeriosis is the biological characterisation of the pathogen. *L. monocytogenes* belongs to Group III pathogens, capable of causing infectious diseases in humans and animals, as confirmed by international and regional regulatory documents in the field of public health and food safety, in particular the WHO (2018). Despite its low contagiousness, this pathogen poses a significant threat to public health due to the severe clinical course of the disease in vulnerable population groups. Given *L. monocytogenes'* ability to persist for long periods in food products of animal origin and to contaminate raw materials and finished products, the systematic testing of food products for the presence of this pathogen is a prerequisite for ensuring their microbiological safety and compliance with technical regulatory requirements

L. monocytogenes is widespread in the environment and is capable of surviving for long periods in meat, milk, dairy products and processed dairy products. As noted by Y. Liu *et al.* (2025), the unique biological properties of this microorganism, including its ability to grow at low temperatures, form biofilms and withstand processing stresses, contribute to its persistence in the food chain and increase the risk of contamination of finished products. According to data from EFSA & ECDC (2024), *Listeria monocytogenes* remains one of the leading causes of hospitalisations and fatalities among bacterial foodborne infections in European Union countries, despite a relatively low incidence compared to other foodborne bacterial diseases. Similar trends are observed in the USA and East Asian countries, where there has been an increase in the detection of the pathogen in products of animal origin and the emergence of strains with multiple drug resistance (Lee *et al.*, 2022; CDC, 2024).

In the Republic of Kazakhstan, the issue of *L. monocytogenes* contamination in livestock products and the assessment of antibiotic resistance in this pathogen remains understudied, despite the rapid development of the livestock sector and the increase in food production volumes. The scarcity of systematic data on the prevalence and biological properties of circulating strains necessitates comprehensive studies aimed at assessing the microbiological safety of food products. The aim of this study was to determine the prevalence of *L. monocytogenes* in livestock products produced and sold within the Republic of Kazakhstan. The objectives of the study included the species identification of the isolated strains and the assessment of their antibiotic susceptibility to determine the epidemiological significance of the pathogen and to justify measures to ensure food safety.

Literature Review

Recent studies highlight the widespread prevalence of *Listeria monocytogenes* in food of animal origin and the significant diversity of antibiotic resistance profiles, including the emergence of multidrug-resistant strains in various regions of the world (Silva *et al.*, 2024; Nikolaou *et al.*, 2025). According to the CDC (2024), approximately 1,600 cases of listeriosis are reported annually in the US, with a case fatality rate of 20-30%. Researchers S. Shaaban *et al.* (2025) analysed *Listeria monocytogenes* isolates obtained from dairy products, farm animals and clinical samples in North Africa. The presence of multidrug-resistant strains, resistant to several classes of antimicrobial agents simultaneously, including β-lactams, tetracyclines and macrolides, was established. Genotyping revealed a combination of antibiotic resistance genes with virulence factors, indicating an increased epidemiological risk posed by circulating strains in the food chain.

The study by A. Kayode & A. Okoh (2023) analyses the antibiotic resistance profiles of *Listeria monocytogenes* strains isolated from ready-to-eat foods in

South Africa. The authors identified a high level of resistance to a range of antimicrobial agents, indicating a significant risk to food safety and the complexity of empirical treatment for listeriosis. The findings highlight the need for regular monitoring of pathogen resistance in the food chain and the implementation of safety control measures for ready-to-eat products. A number of studies have shown that antibiotic-resistant strains of *Listeria* spp. isolated from dairy products possess a high ability to form biofilms, which hinders their elimination by conventional sanitation methods. In particular, E. Abdullah *et al.* (2025) demonstrated the efficacy of lytic bacteriophages in suppressing the growth of resistant *Listeria* spp. isolates and destroying formed biofilms. Despite the traditional clinical efficacy of β-lactam antibiotics against *Listeria monocytogenes*, strains resistant to tetracyclines, macrolides and lincosamides have been increasingly reported in recent years, indicating the emergence of diverse antibiotic resistance profiles (Conter *et al.*, 2009; Li *et al.*, 2024; Wiśniewski *et al.*, 2025).

In the post-Soviet states, the problem of *Listeria monocytogenes* contamination in livestock products remains a pressing issue, as confirmed by the results of bacteriological studies conducted in the Russian Federation and Central Asian countries. Russian researchers L. Logatskaya *et al.* (2025) reported contamination of meat, fish and dairy products with *L. monocytogenes* in the Nizhny Novgorod region of the Russian Federation between 2023 and 2024. According to the study results, the highest levels of *L. monocytogenes* contamination were found in minced beef (10.7%), in semi-finished poultry products in a dough casing (9.3%), and in mechanically deboned poultry meat. Bacteriological analysis of food products conducted in the Russian Federation from 2016 to 2020 to determine *Listeria* contamination in food products by researchers Ya. Aleksandrova *et al.* (2023) showed that out of 1,954,742 samples tested, *Listeria* was detected in 11,177, with the proportion of positive results ranging from 0.4% (2017) to 0.96% (2018). The increase in the detection rate of the pathogen is attributed to the rise in the production and processing of animal-derived products, as well as to the insufficient effectiveness of sanitary and hygiene controls.

Zh. Kirkimbayeva *et al.* (2022), who have been conducting epizootiological monitoring of this infection for a number of years, report on the prevalence of listeriosis among cattle and small ruminants in Kazakhstan. Thus, according to the results of the authors' serological study for listeriosis of 270 head of cattle and 270 head of small ruminants from farms in the Almaty region using the enzyme-linked immunosorbent assay (ELISA), seropositive animals were identified. Bacteriological studies enabled the isolation of *L. monocytogenes* from the genital tracts of 16% of cows and 11.7% of sheep. The seropositive cases identified among the animals studied and the positive bacteriological samples indicate the presence of natural foci of *L. monocytogenes* on farms in the Almaty region. The results obtained indicate the circulation of the pathogen among animals in the region, which may have epizootiological and potentially significant public health implications.

Some researchers emphasise that phenotypic methods alone are insufficient for accurately predicting the phenotypic properties and assessing the epidemiological significance of circulating strains of *L. monocytogenes*. In particular, it has been shown that the use of molecular genetic approaches, including whole-genome sequencing (NGS/WGS) and genetic mapping of antibiotic resistance determinants, enables the identification of resistance genes, predict phenotypic resistance and more accurately assess the epidemiological risks associated with the circulation of the pathogen in the food chain (Wiśniewski *et al.*, 2025). Despite individual publications on the detection of *L. monocytogenes* in food products and production environments, issues relating to a comprehensive assessment of the prevalence and antibiotic susceptibility of the pathogen within the Republic of Kazakhstan remain insufficiently studied. For instance, A. Byahut *et al.* (2026) analysed the prevalence of *L. monocytogenes* and the resistance profiles of isolates in various food products; however, the study was regional in scope and did not cover the countries of Central Asia. A. Tsitsos *et al.* (2025) focused on the molecular characterisation and antibiotic resistance of *L. monocytogenes* strains in meat-processing plants, without addressing products from the retail sector. Thus, the literature confirms the relevance of monitoring *Listeria monocytogenes* in livestock products, the use of molecular methods for identification and the assessment of antibiotic susceptibility, which is particularly important for developing countries with growing livestock production, including Kazakhstan.

Materials and Methods

A study on the isolation and characterisation of the phenotypic properties of *L. monocytogenes* was conducted at the "Bacteriology" and "Molecular Biology and Food Safety" laboratories of the Kazakh Scientific Research Veterinary Institute LLP. The study was conducted in 2025 during two seasonal periods: the cold season (January-March) and the warm season (July-September). During the cold season, meat products and eggs (n = 305) were sampled, whereas during the warm season, dairy products (n = 216) were sampled. It should therefore be borne in mind that the differences identified reflect the combined influence of seasonal factors and the sample structure.

Study subjects and sampling. The study subjects comprised products of animal origin, including beef, lamb, horse meat, pork, poultry (chicken, duck, goose), chicken and quail eggs, as well as dairy products (raw milk, cream, sour cream and cottage cheese). Samples were collected within the city of Almaty and the Almaty region of the Republic of Kazakhstan from various types of retail outlets, including wholesale and retail markets, supermarkets and specialist shops selling meat and dairy products. The following retail outlets were included in the study: “Zeleny Bazaar”, “Altyn Orda”, “Zhetigen”, “Turksib”, “Kamenka”, “Arystan”, “Zhuldys”, “Tuzdybastau”, “Optovka”, “Tabak Sovkhoz”, “Ili District”, “Tastak”, “Sary Arka” and “Orbita”. The study included retail outlets and product samples meeting the following criteria: possession of an official licence or authorisation to sell meat and/or dairy products; the sale of products of animal origin produced within the relevant region; products with a specified shelf life: no more than 7 days from the date of production for dairy products and no more than 14 days for meat products; compliance with standard storage conditions and temperature regimes in accordance with current sanitary and hygiene requirements; the possibility of safe and correct sampling without compromising the integrity of the packaging or the storage conditions of the products. The study excluded retail outlets and product samples where one or more of the following factors were present: illegal retail outlets or premises that failed to provide authorisation documents for the products being sold; products with an expired use-by date or showing signs of a breach of storage temperature conditions; products that had been reprocessed, mixed with other ingredients or subjected to additional heat treatment, which could have distorted the results of the microbiological analysis; retail outlets that did not allow for safe and representative sampling (restricted access, refusal by staff).

Samples were collected using a random stratified sampling method, covering various categories of retail outlets. A total of 521 samples were collected for bacteriological testing, of which 305 were obtained during the cold season (beef – 67, lamb – 55, horse meat – 50, pork – 33, poultry – 46, eggs – 54) and 216 samples during the warmer months (raw milk – 69, sour cream – 50, cream – 47, quark – 50). Microbiological analysis identified 116 isolates of the genus *Listeria*, including 40 isolates of *Listeria monocytogenes*. Samples were collected and transported in sterile containers at a controlled temperature (4-6°C) in accordance with health and hygiene standards. Each sample was assigned a unique code containing information on the product type, sampling location and date. The weight of meat samples was 500 g, the volume of dairy products was 200 mL, and the number of eggs was three per sample. The samples were transported to the laboratory in temperature-controlled containers and stored at 4°C until analysis began. The maximum interval between sampling and the start of analysis did not exceed 24 hours. All procedures were carried out in accordance with GOST 26668-85 (1986).

Isolation and identification of *Listeria* spp. For primary enrichment, 25 g (or 25 mL) of the test material was placed in 225 mL of Half Fraser broth (HiMedia, India), mixed thoroughly and incubated at 30 ± 1°C for 24 hours. Subsequently, 1 mL of the primary enrichment was transferred to 10 mL of full-strength Fraser broth for secondary enrichment and incubated at 37 ± 1°C for 24-48 hours. Bacterial growth was assessed by the turbidity of the medium and a change in its colour due to esculin fermentation (blackening of the medium). The enriched cultures were inoculated onto CHROMagar™ *Listeria* (France) and PALCAM (Federal State Budgetary Institution “National Medical Research Centre for Therapy and Preventive Medicine” of the Ministry of Health of the Russian Federation) media, followed by incubation at 37 ± 1°C for 48 hours. Suspicious colonies with a characteristic green-blue colour on CHROMagar™ *Listeria* and a grey-green colour on PALCAM medium were subjected to microscopic examination (Gram staining), testing for catalase activity and assessment of motility.

The following tests were carried out to confirm the species identity of *Listeria* spp.: Catalase activity – addition of 3% H_2O_2 to the colony; the appearance of bubbles indicates a positive result; carbohydrate fermentation – glucose, lactose, mannitol, maltose in media with a pH indicator, incubated at 37°C for 24-48 hours; motility – assessed in soft agar at 25°C, characterised by “blurring” of the colony with the formation of umbrella-shaped growth; haemolytic activity – on 5% blood agar, detection of β-haemolysis in the form of a narrow zone of complete clearing around the colonies; CAMP test – on 5% blood agar, a line of the control strain Staphylococcus aureus ATCC 6538 (National Bioresource Centre “All-Russian Collection of Industrial Microorganisms”) and a perpendicularly inoculated strain of *Listeria* spp.; after incubation at 37°C for 24-48 hours, a triangular area of enhanced haemolysis was observed at the intersection of the growth lines of the control and test strains. To differentiate *Listeria ivanovii*, the *Rhodococcus equi* ATCC 6939 strain was additionally used as a control microorganism. The results were recorded after incubation at 37°C for 24-48 hours.

Determination of antibiotic susceptibility in *Listeria* spp. isolates. Antibiotic susceptibility was determined for all isolated *Listeria* spp. isolates (n = 116), including *Listeria monocytogenes* isolates (n = 40). Antimicrobial susceptibility testing was performed using the disc diffusion method (Kirby-Bauer) on Mueller-Hinton agar manufactured by HiMedia (India) in accordance with EUCAST recommendations (2023). Standard Thermo Scientific™ Oxoid™ Antimicrobial Susceptibility Test Disks (Thermo Fisher Scientific, UK/USA) were used in the study. The antimicrobial agents tested were antibiotics used in veterinary and clinical practice: ampicillin (10 μg), benzylpenicillin (1 μg), ampicillin-sulbactam (20 μg), chloramphenicol (30 μg), linezolid (10 μg), vancomycin (30 μg), tetracycline (30 μg) and doxycycline (30 μg). Incubation was carried out at 37°C for 24 hours.

To prepare the inoculum, a one-day culture of the isolated microorganisms was diluted in 3-5 mL of sterile isotonic sodium chloride solution until a turbidity equivalent to 0.5 on the McFarland scale was achieved (DEN-1 McFarland Densitometer, BIOSAN, Latvia), with direct inoculation of the plates using a sterile cotton swab. The inoculum was applied evenly to the agar surface in three directions, rotating the plate by 60° to ensure a continuous bacterial growth lawn. After the surface had dried (no more than 15 minutes), antibiotic discs were applied to the medium using sterile forceps or a dispenser. The plates were incubated under aerobic conditions at 37 ± 0.5°C for 18-24 hours. At the end of incubation, the diameters of the zones of growth inhibition were measured using a vernier calliper to an accuracy of 1 mm, and the results (susceptible, resistant) were interpreted in accordance with the EUCAST (2023) clinical breakpoint tables.

Statistical analysis of the data was performed using Microsoft Excel 2019 (Microsoft Corporation, USA). To assess the prevalence of *Listeria* spp., the frequencies and percentages of positive samples were calculated. The frequencies of isolate detection were compared using the χ^2 (chi-square) test. Differences were considered statistically significant at a $p\text{-value} < 0.05$.

Results and Discussion

Prevalence of *Listeria* spp. in food of animal origin

Samples were collected during the cold and warm seasons to assess possible differences in the frequency of *Listeria* spp. contamination. Of the total number of samples collected (n = 521), 305 were taken during the cold season (winter, early spring), from which 33 *Listeria* spp. isolates were identified (10.8%). Most of these samples consisted of meat (beef, lamb, horse meat, pork and chicken), as well as eggs, stored at low temperatures. The low detection rate of *Listeria* spp. during this period can be explained by the slower growth of bacteria at low temperatures, as well as stricter sanitary conditions for storage and transport. The data are presented in Table 1.

Table 1. The prevalence of *Listeria* spp. in meat products and eggs during the colder months

Product type	Number of samples (n)	Positive for *Listeria* spp.	%
Beef	67	7	10.4
Horse meat	50	6	12
Lamb	55	9	16.4
Pork	33	3	9.1
Chicken	46	2	4.3
Eggs	54	6	11.1
Total	305	33	10.9

Source: compiled by the authors

The data in Table 1 show that the highest frequency of *Listeria* isolation was observed in lamb (16.4%), and the lowest in chicken (4.3%). The data indicate that *Listeria* is present in all the product types examined, suggesting a potential risk to consumer health. The highest risk of *Listeria* detection is observed in lamb and beef, indicating the need for enhanced control during the production and sale of these products. It is worth noting that the studies were conducted during the cold season, when ambient temperatures were low. *Listeria* spp. are capable of surviving and multiplying at low temperatures, including in refrigerated conditions, which increases the risk of product contamination and prolongs the period during which they pose a potential hazard to consumers. When comparing the results obtained with European data, significant differences in contamination levels should be noted. According to EFSA & ECDC (2022), only 2.1% of meat product samples tested at the retail level in European Union countries tested positive for *L. monocytogenes*, which is significantly lower than the figures obtained in this study. Possible reasons for the higher contamination levels in beef and lamb may include slaughter, processing and storage conditions, as well as longer transit times, which create favourable conditions for bacterial growth.

During the warmer months (summer and early autumn), 216 samples of dairy products – including sour cream, cream, quark and raw milk – collected in the city of Almaty and the Almaty region were analysed. A total of 83 *Listeria* spp. isolates were identified from the 216 samples (38.4%). Increased contamination during the warmer months may be linked to higher ambient temperatures, which accelerate bacterial growth, as well as to possible breaches in the storage and transport conditions of products of animal origin. This is particularly relevant for dairy products, which are prone to rapid spoilage at elevated temperatures. The data are presented in Table 2.

Table 2. The prevalence of *Listeria* spp. in dairy products during the warmer months

Product type	Number of samples (n)	Positive for *Listeria* spp.	%
Sour cream	50	18	36.0
Cream	47	24	51.1
Cottage cheese	50	20	40.0

Table 2. Continued

Product type	Number of samples (n)	Positive for *Listeria* spp.	%
Milk	69	21	30.4
Total	216	83	38.4

Source: compiled by the authors

The data in Table 2 show that the highest risk of *Listeria* spp. contamination in dairy products is observed in cream and quark, the average risk in sour cream, and the lowest risk in milk. The overall proportion of positive samples was 38.4%, which is significantly higher than in international studies. In the study by X. Li *et al.* (2024), a meta-analysis of global data showed that the detection rate of *Listeria monocytogenes* in dairy products was 1-5%. Similar figures are reported by M. Bashiry *et al.* (2022) for Middle Eastern countries and by P. Şanlıbaba & B. Tezel (2018) for Turkey. The increase in *Listeria* spp. isolates during the summer months in the present study is explained by favourable temperature conditions for bacterial growth and possible breaches in product storage and transport, which is consistent with the observations of S. Arslan & F. Özdemir (2008) and E. Dalzini *et al.* (2016). However, the majority of the isolates belonged to saprophytic, non-pathogenic *Listeria* species, such as *L. innocua*, which is consistent with the findings of the Turkish researchers P. Şanlıbaba & B. Tezel (2018). The results highlight the need for stricter control of temperature and sanitary conditions during the production, storage and sale of dairy products in the summer months to minimise the risk of contamination with pathogenic *Listeria* species.

Characteristics of the isolated *Listeria* strains

The phenotypic and biochemical characterisation of the isolates identified made it possible to distinguish between pathogenic and non-pathogenic species within the genus. To systematise and clearly present the biochemical characteristics of the isolated *Listeria* spp. isolates, Table 3 was compiled, reflecting their ability to ferment major carbohydrates (glucose, maltose, mannitol, lactose), as well as indicators of catalase activity and the CAMP test. Table 3 presents the results of a comparative analysis of the fermentation of major carbohydrates and the biochemical properties of various *Listeria* species. For each species, the results of glucose, mannitol, maltose and lactose fermentation, catalase activity, CAMP test results, as well as comments on pathogenicity and haemolysis are shown. The results of the studies made it possible to identify differences between pathogenic and non-pathogenic *Listeria* species, to assess the phenotypic diversity of the isolates, to compare the results with data from the literature, and to determine the potential pathogenicity of the isolates.

Table 3. Fermentation of major carbohydrates and the biochemical properties of *Listeria* species

Types of *Listeria*	Glucose	Mannite	Maltose	Lactose	Catalase	CAMP test	Comment
Listeria monocytogenes	+	+	+	+	+	+	Pathogenic to humans, exhibits beta-haemolysis
Listeria ivanovii	+	+	+	+	+	+	Pathogenic to animals; beta-haemolysis is more pronounced
Listeria innocua	+	-	+	-	+	-	Non-pathogenic; no mannitol fermentation or haemolysis
Listeria welchimeri	+	+	+	-	+	-	Non-pathogenic; slight or no haemolysis
Listeria seeligeri	+	+	+	-	+	-	Non-pathogenic; may cause mild haemolysis
Listeriagrayi	+	+	-	-	+	-	Non-pathogenic, rarely ferments maltose, no haemolysis

Note: "+" – positive reaction; "-" – negative reaction
Source: compiled by the authors

Table 3 shows that *Listeria monocytogenes* and *Listeria ivanovii* test positive for all carbohydrates and catalase, and also yield a positive CAMP test, which is consistent with their pathogenicity (*L. monocytogenes* is pathogenic to humans, *L. ivanovii* – pathogenic to animals, with more pronounced beta-haemolytic activity). The remaining species (*L. innocua*, *L. welchimeri*, *L. seeligeri*, *L. grayi*) are non-pathogenic, exhibiting differences in the fermentation of mannitol and maltose, as well as weak or absent haemolytic activity. For example, *L. innocua* does not ferment mannitol and does not exhibit haemolysis, whilst *L. grayi* rarely ferments maltose and no haemolysis is observed. Thus, the table allows for the visual distinction of pathogenic and non-pathogenic *Listeria* species based on biochemical reactions, which is important for the identification and risk assessment of microbial contamination in food of animal origin. It has been noted that pathogenic species (*L. monocytogenes* and *L. ivanovii*) ferment glucose, maltose and mannitol, do not ferment lactose, exhibit β-haemolysis and a positive reaction to the CAMP test. Non-pathogenic species (*L. innocua*, *L. welshimeri*, *L. seeligeri*, *L. grayi*) exhibit differences in the fermentation of mannitol and maltose and do not exhibit β-haemolysis (with the exception of a weak reaction in *L. seeligeri*), which allows them to be distinguished from pathogenic species. Catalase activity is present in all species, which is a common genus-specific characteristic.

Table 4 presents the results of the identification of the isolated *Listeria* spp. isolates using the CAMP test, which is one of the key methods for distinguishing between pathogenic and non-pathogenic species of the genus *Listeria*, as well as the type of CAMP reaction, the control microorganisms used, the nature of haemolysis, the presumed *Listeria* species and the number of corresponding isolates (n).

Table 4. Results of the CAMP test for *Listeria* spp. isolates obtained from livestock products

CAMP reaction	Control microorganism	The nature of haemolysis	Expected appearance *Listeria* spp.	Number of isolates (n = 116)
Positive	*Staphylococcus aureus*	An arrow-shaped area of increased haemolysis	*Listeria monocytogenes*	40
Positive	*Rhodococcus equi*	Zone of pronounced synergistic haemolysis	*Listeria ivanovii*	7
Negative	*Staphylococcus aureus*	Absence of increased haemolysis	*Listeria innocua*	38
Negative	*Staphylococcus aureus*	Absence of increased haemolysis	*Listeria welshimeri*	10
Negative	*Staphylococcus aureus*	Absence of increased haemolysis	*Listeria seeligeri*	12
Negative	*Staphylococcus aureus*	Absence of increased haemolysis	*Listeria grayi*	9

Note: n – the number of isolates
Source: compiled by the authors

The data in Table 4 show that a positive CAMP reaction was observed in pathogenic species of *Listeria*. Thus, *Listeria monocytogenes* produced a characteristic arrow-shaped zone of enhanced haemolysis when co-cultured with Staphylococcus aureus in the CAMP test, which is described as a typical manifestation of this reaction for this species (Fernández-Garayzábal *et al.*, 1996). When *Rhodococcus equi* was used as a control microorganism, a distinct zone of synergistic haemolysis was observed in *Listeria ivanovii*, which also corresponds to the species differentiation schemes described in classical guides to the identification of *Listeria*. A negative CAMP reaction was characteristic of non-pathogenic *Listeria* species. In *Listeria innocua* (n = 38), *Listeria welshimeri* (n = 10), *Listeria seeligeri* (n = 12) and *Listeria grayi* (n = 9), no enhanced haemolysis was observed during co-cultivation with *Staphylococcus aureus*. The absence of synergistic haemolysis confirms their non-pathogenic status and allows these species to be reliably distinguished from clinically significant members of the genus. Thus, the data obtained demonstrate the high diagnostic value of the CAMP test for the species identification of *Listeria* spp. and confirm its effectiveness in distinguishing between pathogenic and non-pathogenic isolates isolated from products of animal origin.

Antibiotic susceptibility of *Listeria* spp. isolates

An analysis of the results of susceptibility testing of 40 *Listeria monocytogenes* isolates to the antibiotics for which the highest frequency of resistance was identified showed that, among the antimicrobials tested, resistance in *L. monocytogenes* isolates was most frequently observed against certain β-lactam antibiotics, tetracyclines and linezolid, indicating the formation of resistant populations of the pathogen in animal products. The results obtained are consistent with data from a number of researchers. For instance, in a study by S. Jadhav *et al.* (2012), *L. monocytogenes* isolates isolated from milk and dairy products demonstrated increased resistance to tetracycline and erythromycin, which the authors attribute to the widespread use of these antibiotics in animal husbandry. Similar results were obtained by H. Castro *et al.* (2020), who noted an increase in the proportion of resistant *L. monocytogenes* strains in food products, particularly to drugs used in both veterinary and clinical practice.

Studies by European researchers also report that *L. monocytogenes* retains high susceptibility to ampicillin and penicillin, which remain the drugs of choice for the treatment of listeriosis in humans (Ryser & Marth, 2007; EFSA & ECDC, 2022). However, the presence of resistant isolates identified in the present study confirms a trend towards a gradual decline in the efficacy of traditional treatment regimens, a finding also noted in the works of M. Gray *et al.* (2006) and K. Linke *et al.* (2014). It should be noted that the antibiotic resistance observed in *L. monocytogenes* may be associated with the presence of resistance genes encoding efflux pumps and promoting biofilm formation, which significantly increases the pathogen's survival in food products and on production surfaces. Such resistance mechanisms are described in detail in the study by X. Li *et al.* (2024).

Figure 1 shows Petri dishes containing agar, on the surface of which antibiotic discs are placed to determine the sensitivity of bacteria to various antibiotics using the disc diffusion method (the Kirby-Bauer method). Each disc shows a zone of bacterial growth inhibition around it, appearing as a clear circle. The size of these zones allows the sensitivity of the microorganisms to a specific antibiotic to be determined: the larger the zone, the higher the sensitivity. The photograph shows that some discs are surrounded by wider zones, whilst others have smaller zones or show almost no inhibitory effect, indicating partial or complete resistance. Figure 1 illustrates the phenotypic heterogeneity of *L. monocytogenes* isolates in terms of their antibiotic resistance profile.

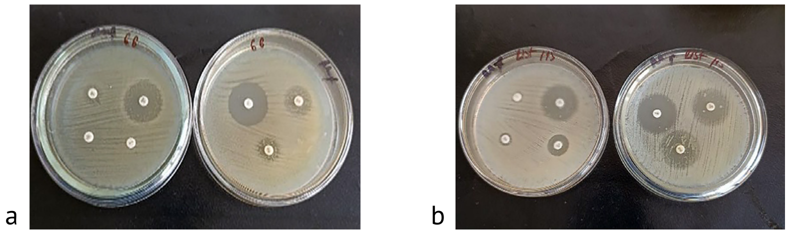

Figure 1. Determination of the susceptibility of *L. monocytogenes* isolates to antibiotics using the disc diffusion method (Kirby-Bauer method)

Note: a – strain ML66, resistant to ampicillin, benzylpenicillin and linezolid; b – strain SL115, resistant to benzylpenicillin

Source: photo by the authors

Figure 1 shows that isolate ML66, isolated from milk, exhibited resistance to ampicillin, benzylpenicillin and linezolid, indicating the development of multidrug resistance. At the same time, isolate SL115, isolated from cream, was resistant only to benzylpenicillin, whilst remaining susceptible to the other antimicrobial agents tested. Analysis showed that among all the resistant isolates identified, different resistance profiles to individual antibiotics were observed, indicating the presence of different mechanisms of antibiotic resistance. Table 5 presents the results of susceptibility testing of *Listeria monocytogenes* isolates (n = 40) to antibiotics for which the highest frequency of resistance was identified. Susceptibility testing to antimicrobial agents was performed using the disc diffusion method on Mueller-Hinton agar.

Table 5. Results of antibiotic susceptibility testing of *L. monocytogenes* isolates, characterised by the highest frequency of resistance

	Name of the antibiotic	Number of selected crops	Sensitive, %	Resistant, %
	Listeria			
1	Ampicillin 10 mcg – penicillins (beta-lactams)	40	85	15
2	Benzylpenicillin 1 mcg – penicillins (beta-lactams)		75	25
3	Ampicillin-sulbactam 10 mcg – penicillins (beta-lactams)		92.5	7.5
4	Linezolid 10 µg – oxazolidinones		82.5	17.5
5	Chloramphenicol 30 µg – aminoglycosides		92.5	7.5
6	Doxycycline 30 µg – polyketides		90	10
7	Tetracycline 30 µg – polyketides		92.5	7.5
8	Vancomycin 30 mcg – glycopeptides		90	10

Source: compiled by the authors

The data in Table 5 show that, among β-lactam antibiotics, the highest level of resistance was observed for benzylpenicillin – 25% of isolates were classified as resistant, whereas resistance to ampicillin stood at 15%. At the same time, the ampicillin/sulbactam combination demonstrated higher activity: 92.5% of isolates remained susceptible and only 7.5% showed resistance. This indicates the effectiveness of β-lactamase inhibitors in enhancing the activity of antibiotics against *L. monocytogenes*. Linezolid was characterised by a comparatively high level of susceptibility (82.5%); however, the detection of 17.5% resistant isolates warrants attention, given the clinical significance of this drug in the treatment of invasive forms of listeriosis. High susceptibility was also noted for chloramphenicol and tetracycline antibiotics (doxycycline and tetracycline), where the susceptibility rate ranged from 90% to 92.5%, which is consistent with data from international studies. Vancomycin demonstrated good antimicrobial activity – 90% of isolates were susceptible; however, the presence of 10% resistant strains indicates the development of resistance even to reserve drugs. The highest proportion of resistant isolates was found with benzylpenicillin, confirming the reduced efficacy of traditional penicillins against *L. monocytogenes*. The lowest resistance rates were observed for ampicillin/sulbactam, chloramphenicol and tetracycline antibiotics. Overall, the data obtained indicate that the majority of *L. monocytogenes* isolates remain highly susceptible to the main antimicrobial agents. At the same time, the resistance detected, particularly to penicillins, highlights the need for continuous monitoring of antibiotic resistance in this pathogen.

To summarise the findings of the studies, it should be emphasised that this is the first comprehensive assessment of the prevalence of *Listeria* spp. and *L. monocytogenes* in various animal-derived products across different seasons in the Almaty region, accompanied by an analysis of the antibiotic resistance of the isolates. The data obtained supplement international findings on the circulation of *L. monocytogenes* and highlight the need for regular monitoring of contamination and the resistance of the pathogen in livestock products to ensure food and epidemiological safety.

Conclusions

A study conducted in 2025 assessed the prevalence and antibiotic susceptibility of *Listeria* spp. isolates recovered from food of animal origin. Of the 521 samples tested, 116 *Listeria* isolates were recovered (22.3%); with differences noted in the frequency of isolation across different seasons: during the warmer months, the rate was 28.7%, whereas during the colder months it was 15.4%. The highest number of *Listeria* isolates was recovered from dairy products: cream – 24 out of 47 samples (51.1%), cottage cheese – 20 out of 50 samples (40.0%), milk – 21 out of 69 samples (30.4%), indicating an increased risk of contamination in products with minimal heat treatment. Among meat products, *Listeria* was most frequently isolated from beef – 7 out of 67 samples (10.4%) and lamb – 9 out of 55 samples (16.4%), which is associated with the specific characteristics of slaughter, processing and storage of raw materials. The CAMP test proved highly informative for the species identification of *Listeria* isolates, enabling reliable differentiation between pathogenic and non-pathogenic (saprophytic) species. Among the isolates from dairy products, the saprophytic species *L. innocua* and *L. welshimeri* predominated, whilst the proportion of the pathogenic *Listeria monocytogenes* accounted for 34.5% of all isolates.

Antibiotic susceptibility testing revealed that the majority of *Listeria monocytogenes* isolates remained susceptible to major antimicrobial agents, including ampicillin, erythromycin and tetracyclines. At the same time, isolates with multiple resistance to antibiotics of different classes were identified: 15% of isolates exhibited resistance to 2-5 agents simultaneously, most frequently to benzylpenicillin, indicating a decline in the efficacy of traditional β-lactam antibiotics. The observed variability in antibiotic resistance profiles indicates the circulation of heterogeneous strains of *Listeria monocytogenes* in animal products and highlights the need for regular monitoring of the antibiotic susceptibility of this pathogen. Prospects for further research include the study of seasonal and regional factors influencing the prevalence of *Listeria* spp. in dairy and meat products; the genetic characterisation of resistant strains and the identification of resistance genes using Whole Genome Sequencing (WGS); the development of new control approaches, including the use of lytic bacteriophages and biocides, to reduce the number of resistant isolates during production and storage; the evaluation of the effectiveness of sanitary and microbiological measures in industrial settings; and the establishment of an integrated system for the prevention of listeriosis in the food chain.

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References

[1] Abdullah, E.M., Elariny, E.Y.T., Abdelaziz, R., Albalawi, A.S., Almutrafy, A.M., Zaki, M.S.A., Abdel-Karim, S.A., & Tartor, Y.H. (2025). Lytic bacteriophage disrupts biofilm and inhibits growth of pan-drug-resistant *Listeria monocytogenes* in dairy products. *Frontiers in Microbiology*, 16, article number 1653368. doi: 10.3389/fmicb.2025.1653368.

[2] Aleksandrova, Ya.R., Kozak, S.S., Baranovich, E.S., & Kozak, Yu.A. (2023). Detection of *Listeria* spp. in biological material from animals, poultry, and livestock products. *Bulletin of the Chuvash State Agrarian University*, 1, 50-55. doi: 10.48612/vch/4m53-45gb-5fgn.

[3] Alharbi, N.K., *et al.* (2025). Exploring the dynamic relationship between antimicrobial resistance, virulence fitness, and host responses in *Listeria monocytogenes* infections. *Scientific Reports*, 15, article number 32644. doi: 10.1038/s41598-025-10093-z.

[4] Arslan, S., & Özdemir, F. (2008). Prevalence and antimicrobial resistance of *Listeria* spp. in homemade white cheese. *Food Control*, 19(4), 360-363. doi: 10.1016/j.foodcont.2007.04.009.

[5] Bashiry, M., *et al.* (2022). *Listeria monocytogenes* in dairy products of the Middle East region: A systematic review, meta-analysis, and meta-regression study. *Iranian Journal of Public Health*, 51(2), 292-305. doi: 10.18502/ijph.v51i2.8682.

[6] Byahut, A., Das, M., Chowdhury, G., Mukhopadhyay, A.K., Khati, R., Das, S., Ramamurthy, T., & Dolma, K.G. (2026). Exploring the prevalence and antibiotic resistance of *Listeria monocytogenes* in diverse food commodities across Sikkim, India. *Brazilian Journal of Microbiology*, 57, article number 23. doi: 10.1007/s42770-025-01853-0.
[7] Castro, H., Douillard, F.P., Korkeala, H., & Lindström, M. (2021). Mobile elements harboring heavy metal and bacitracin resistance genes are common among *Listeria monocytogenes* strains persisting on dairy farms. *mSphere*, 6(4), article number e0038321. doi: 10.1128/mSphere.00383-21.
[8] Centers for Disease Control and Prevention (CDC). (2024). *Listeria infection (listeriosis)*. Retrieved from https://www.cdc.gov/listeria.
[9] Conter, M., Paludi, D., Zanardi, E., Ghidini, S., Vergara, A., & Ianieri, A. (2009). Characterization of antimicrobial resistance of foodborne *Listeria monocytogenes*. *International Journal of Food Microbiology*, 128(3), 497-500. doi: 10.1016/j.ijfoodmicro.2008.10.018.
[10] Dalzini, E., Bernini, V., Bertasi, B., Daminelli, P., Losio Marina, N., & Varisco, G. (2016). Survey of prevalence and seasonal variability of *Listeria monocytogenes* in raw cow milk from Northern Italy. *Food Control*, 60, 466-470. doi: 10.1016/j.foodcont.2015.08.019.
[11] European Committee on Antimicrobial Susceptibility Testing (EUCAST). (2023). *The 13.0 versions of breakpoints, dosing and QC*. Retrieved from https://www.eucast.org/news-detail/the-130-versions-of-breakpoints-dosing-and-qc-2023-published/.
[12] European Food Safety Authority & European Centre for Disease Prevention and Control (EFSA & ECDC). (2024). The European Union One Health 2023 Zoonoses report. *EFSA Journal*, 22(12), article number e9106. doi: 10.2903/j.efsa.2024.9106.
[13] European Food Safety Authority & European Centre for Disease Prevention and Control (EFSA & ECDC). (2022). The European Union One Health 2021 Zoonoses report. *EFSA Journal*, 20(12), article number 7666. doi: 10.2903/j.efsa.2022.7666.
[14] Fernánández-Garayzábal, J.F., Delgado, C., Blanco, M.M., Suárez, G., & Domínguez, L. (1996). Cholesterol oxidase from *Rhodococcus equi* is likely the major factor involved in the cooperative lytic process (CAMP reaction) with *Listeria monocytogenes*. *Letters in Applied Microbiology*, 22(3), 249-252. doi: 10.1111/j.1472-765x.1996.tb01153.x.
[15] GOST 26668-85. (1986). *Food-stuff and food additives. Methods of sampling for microbiological analyses. State Standard of the USSR*. Retrieved from https://gluvexlab.com/uploads/storage/GOSTi/gost-26668-85.pdf.
[16] Gray, M.J., Freitag, N.E., & Boor, K.J. (2006). How the bacterial pathogen *Listeria monocytogenes* mediates the switch from environmental Dr. Jekyll to pathogenic Mr. Hyde. *Infection and Immunity*, 74(5), 2505-2512. doi: 10.1128/IAI.74.5.2505-2512.2006.
[17] Jadhav, S., Bhave, M., & Palombo, E.A. (2012). Methods used for the detection and subtyping of *Listeria monocytogenes*. *Journal of Microbiological Methods*, 88(3), 327-341. doi: 10.1016/j.mimet.2012.01.002.
[18] Kayode, A.J., & Okoh, A.I. (2023). Antimicrobial-resistant *Listeria monocytogenes* in ready-to-eat foods: Implications for food safety and risk assessment. *Foods*, 12(6), article number 1346. doi: 10.3390/foods12061346.
[19] Kirkimbayeva, Zh.S., Musayeva, A., Yegorova, N., Kuzembekova, G., & Sarybayeva, D. (2022). Distribution of *Listeria monocynogenes* in farms in the Almaty region. *Science and Education*, 1(3(68), 96-104. doi: 10.56339/2305-9397-2022-3-1-96-104.
[20] Lee, J.-E., Kim, M.J., Park, J., & Cho, Y.S. (2025). Prevalence and characterization of *Listeria monocytogenes* in food court cold noodles and associated contact surfaces in Korea. *Journal of Food Protection*, 88(12), article number 100661. doi: 10.1016/j.jfp.2025.100661.
[21] Li, X., Zheng, J., Zhao, W., & Wu, Y. (2024). Prevalence of *Listeria monocytogenes* in milk and dairy product supply chains: A global systematic review and meta-analysis. *Foodborne Pathogens and Disease*, 21(9), 526-535. doi: 10.1089/fpd.2024.0029.
[22] Linke, K., Rückerl, I., Brugger, K., Karpiskova, R., Walland, J., Muri-Klinger, S., Tichy, A., Wagner, M., & Stessl, B. (2014). Reservoirs of *Listeria* species in three environmental ecosystems. *Applied and Environmental Microbiology*, 80(18), 5583-5592. doi: 10.1128/AEM.01018-14.
[23] Liu, Y., Zhang, P., Wang, D., Wang, B., Zhang, Y., & Zhang, X. (2025). Prevalence and characteristics of *Listeria monocytogenes* in ready-to-eat chilled pot skewer products. *Frontiers in Microbiology*, 16, article number 1681344. doi: 10.3389/fmicb.2025.1681344.
[24] Logatskaya, L.N., Pruntova, O.V., & Zhbanova, T.V. (2025). Detection of *Listeria monocytogenes* while testing food raw materials and products of animal origin for microbiological contamination. *Veterinary Science Today*, 14(4), 418-425. doi: 10.29326/2304-196X-2025-14-4-418-425.
[25] Nikolaou, F.G., Colobatiu, L.M., Ciupescu, L.M., Tabaran, A., Hategan, A.R., Mihaiu, R., Tanasuica, R., Poenaru, M.M., & Mihaiu, M. (2025). Prevalence and antimicrobial resistance of *Listeria monocytogenes* isolated from dairy products in Romania. *Antibiotics*, 14(5), article number 482. doi: 10.3390/antibiotics14050482.

[26] Ryser, E.T., & Marth, E.H. (Eds). (2007). *Listeria, listeriosis, and food safety* (3rd ed.). Boca Raton: CRC Press.
[27] Şanlıbaba, P., & Tezel, B.U. (2018). Prevalence and characterization of *Listeria* species from raw milk and dairy products from Çanakkale province. *Turkish Journal of Agriculture – Food Science and Technology*, 6(1), 61-64. doi: 10.24925/turjaf.v6i1.61-64.1641.
[28] Shaaban, S.I., Awwad, N., Nossair, M., Ayoub, M., & Eid, A.E.-M. (2025). Gene profiling and serotyping of multidrug-resistant *Listeria monocytogenes* isolated from humans, animals, and dairy products. *BMC Veterinary Research*, 21(1), article number 702. doi: 10.1186/s12917-025-05138-4.
[29] Silva, A., *et al*. (2024). *Listeria monocytogenes* from food products and food-associated environments: Antimicrobial resistance, genetic clustering and biofilm insights. *Antibiotics*, 13(5), article number 447. doi: 10.3390/antibiotics13050447.
[30] Tsitsos, A., Peratikos, P., Damianos, A., Kyritsi, M.A., Arsenos, G., Hadjichristodoulou, C., Soultos, N., Gousia, P., & Economou, V. (2025). Prevalence, molecular characterization, antibiotic resistance, and investigation of transmission pathways of *Listeria monocytogenes* strains isolated along the beef production chain. *Food Microbiology*, 129, article number 104745. doi: 10.1016/j.fm.2025.104745.
[31] Wiśniewski, P., Adamski, P., Trymers, M., Chajęcka-Wierzchowska, W., & Zadernowska, A. (2025). Predicting antibiotic resistance in *Listeria monocytogenes* from food and food-processing environments using next-generation sequencing: A systematic review. *International Journal of Molecular Sciences*, 26(20), article number 10112. doi: 10.3390/ijms262010112.
[32] World Health Organization (WHO). (2018). *Listeriosis*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/listeriosis.

Казакстанда мал чарба продукцияларынан бөлүнүп алынган *Listeria monocytogenes* бактериясынын таралышы жана антибиотиктерге туруктуулугу

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Аннотация. *Listeria monocytogenes* адамда жана жаныбарларда листериоз оорусун пайда кылуучу козгогуч болуп саналат жана жаныбар тектүү азык-түлүктөрдүн коопсуздугуна олуттуу коркунуч жаратат. Бактериялардын сүт жана эт продукцияларында жогорку жашап калуу жөндөмдүүлүгү, ошондой эле мүмкүн болгон антибиотиктерге туруктуулугу Казакстан Республикасында *Listeria* изоляттарынын таралышын жана сезгичтигин көзөмөлдөөнү талап кылат. Изилдөөнүн максаты – 2025-жылы алынган жаныбар тектүү азыктарда *Listeria* бактериясынын таралышын, түрдүк курамын жана антибиотиктерге сезгичтик профилин аныктоо болду. Изилдөөдө Алматы шаары жана Алматы облусунун аймагында жылдын суук жана жылуу мезгилдеринде алынган эт жана сүт продукциясынын 521 үлгүсү каралды. *Listeria* бөлүп алуу Half Fraser жана толук концентрациядагы Fraser сорполорун колдонуу менен жүргүзүлүп, андан соң CHROMagar™ *Listeria* жана PALCAM селективдүү чөйрөлөрүнө себилди. Түрдүк идентификация CAMP-тести жана биохимиялык реакциялар аркылуу жүргүзүлдү. Антибиотиктерге сезгичтик EUCAST сунуштарына ылайык Мюллер-Хинтон агарында диско-диффузия ыкмасы менен аныкталды. 521 үлгүдөн *Listeria* тукумуна таандык 116 изолят (22,3 %) бөлүнүп алынып, алардын ичинен 40 изолят (жалпы листериялардын 34,5 % жана жалпы үлгүлөрдүн 7,7 %) *L. monocytogenes* катары идентификацияланды. *L. monocytogenes* изоляттарынын көбү сүт продукцияларында – 24 изолят (60,0 %), ал эми эт продукцияларында 16 изолят (40,0 %) аныкталды. CAMP-тест бөлүнүп алынган штаммдардын патогендик касиеттерин тастыктады. Антибиотиктерге сезгичтик анализи ампициллинге, ампициллин/сульбактамга, хлорамфениколго жана тетрациклиндерге жогорку сезгичтик бар экенин көрсөттү, бирок бензилпенициллинге жана линезолидге көптөгөн туруктуулукка ээ изоляттар да аныкталды. Алынган жыйынтыктар жаныбар тектүү азыктарда *L. monocytogenes* бактериясын туруктуу мониторинг жүргүзүү жана антибиотиктерге сезгичтикти көзөмөлдөө зарылдыгын көрсөтөт

Негизги сөздөр: азык-түлүк патогендери; антимикробдук туруктуулук; жаныбар тектүү азыктар; микробиологиялык булгануу; калктын ден соолугу үчүн коркунуч; фенотиптик туруктуулук; азык-түлүк коопсуздугун мониторингдөө

Распространенность и антибиотикорезистентность *Listeria monocytogenes*, выделенных из продуктов животноводства в Казахстане

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Аннотация. *Listeria monocytogenes* является возбудителем листериоза у человека и животных, представляя значительную угрозу безопасности продуктов животного происхождения. Высокая выживаемость бактерий в молочной и мясной продукции, а также возможная антибиотикорезистентность обусловили необходимость мониторинга распространенности и чувствительности изолятов *Listeria* в Республике Казахстан. Целью исследования было определение распространенности, видовой структуры и профиля антибиотикочувствительности *Listeria* в продуктах животного происхождения, отобранных в 2025 году. Исследовали 521 пробу мясной и молочной продукции, отобранную в холодный и теплый периоды года на территории г. Алматы и Алматинской области. Выделение *Listeria* проводили с использованием бульонов Half Fraser и Fraser полной концентрации с последующим посевом на селективные среды CHROMagar™ *Listeria* и PALCAM. Видовую идентификацию осуществляли с помощью CAMP-теста и биохимических реакций. Чувствительность к антибиотикам определяли методом диско-диффузии на агаре Мюллера-Хинтона согласно рекомендациям EUCAST. Из 521 пробы выделили 116 изолятов рода *Listeria* (22,3 %), из которых 40 изолятов (34,5 % от всех листерий и 7,7 % от общего числа проб) идентифицировали как *L. monocytogenes*. Наибольшее количество изолятов *L. monocytogenes* обнаружили в молочных продуктах – 24 изолята (60,0 %), в мясной продукции выявили 16 изолятов (40,0 %). CAMP-тест подтвердил патогенность выделенных штаммов. Анализ антибиотикочувствительности показал высокую чувствительность к ампициллину, ампициллин/сульбактаму, хлорамфениколу и тетрациклинам, однако были выявлены изоляты с множественной резистентностью к бензилпенициллину и линезолиду. Результаты подчеркивают необходимость регулярного мониторинга *L. monocytogenes* в продуктах животноводства и контроля антибиотикочувствительности для предотвращения распространения резистентных штаммов

Ключевые слова: пищевые патогены; антимикробная устойчивость; продукты животного происхождения; микробиологическая контаминация; риск для здоровья населения; фенотипическая резистентность; мониторинг безопасности пищевых продуктов

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Financing innovative processes in agriculture of the Kyrgyz Republic

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Abstract. Under conditions of limited access to long-term capital and high climate vulnerability, the agricultural sector of the Kyrgyz Republic faces institutional constraints on the adoption of innovations. The aim of the study was to identify and quantitatively assess the relationship between the financing structure and the dynamics of innovation activity in the agricultural sector, as well as to develop a mixed financing model. The empirical base covered official data for 2020-2024. The methodological framework was based on economic and statistical analysis, linear normalisation of indicators, expert assessment of weighting coefficients ($n = 14$), and Spearman's non-parametric correlation analysis. The consistency of expert assessments was confirmed by Kendall's coefficient of concordance ($W = 0.74$). The study proposes an integral index of innovation financing, which includes budget support, long-term bank lending, private investment, funds from international financial organisations, and the investment risk factor. A statistically significant positive relationship was identified between the share of long-term lending and the volume of investment in fixed capital ($\rho = 0.71$; $p < 0.05$), confirming the key role of the temporal structure of capital in shaping the sector's innovation potential. It was shown that increasing the share of long-term lending to 35% can ensure growth in innovation activity depending on the level of private and international capital attraction. A formalised mixed financing model was developed, and scenario modelling of three development trajectories was conducted. The baseline scenario maintained the predominance of short-term lending and ensured growth at the level of 3-4%; the moderate scenario envisaged an increase in the share of long-term loans to 35% while maintaining state support, resulting in growth of 5-6%; whereas the innovative scenario was based on mixed financing with expanded resources and participation of private and international capital, ensuring growth of 7-9%

Keywords: investment mechanisms; agricultural sector; state support; production modernisation; lending

Introduction

The current development of agriculture in the Kyrgyz Republic is characterised by a tension between the need for accelerated technological modernisation and the scarcity of long-term financial resources. Despite the positive trend in the gross value added of the agricultural sector, the structure of investment remains predominantly short-term and focused on maintaining working capital (FAO, 2020). This creates an institutional gap between the needs for innovative renewal and the actual financing mechanisms. In conditions of high climate vulnerability and dependence on seasonal factors, traditional financial instruments prove insufficient to stimulate innovative activity (United Nations, 2023). S.K. Lowder *et al.* (2021) found that over 90% of all farms worldwide are family-run and produce around 80% of the world's food, playing a key role in ensuring food security. At the same time, they demonstrated that land resources are increasingly concentrated in large-scale farms, which creates structural inequality and influences the transformation of agricultural systems. The focus

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of research into the financing of innovation processes in agriculture for the period 2020-2025 is shifting from a description of support instruments to an analysis of institutional constraints and the effectiveness of investment risk allocation. In the studies by L. Klerkx & D. Rose (2020), the focus was on the transformation of agricultural innovation systems in the context of digitalisation; however, financial adaptation mechanisms are primarily examined at the macro level without a quantitative assessment of the impact of individual sources of capital. This creates a methodological gap between institutional theory and financing practice.

F.U. Khan *et al.* (2024) found that in developing countries, agricultural financing is constrained by a complex of interrelated barriers (the sector's riskiness, weak infrastructure, limited access to credit), which operate simultaneously on both the demand and supply sides of financial resources. These constraints reinforce one another, creating a systemic gap in access to finance that cannot be bridged without comprehensive institutional and financial solutions. K. Louhichi *et al.* (2022) considered long-term lending to be a key factor in sustainable agricultural development; however, their work does not propose an integrated model capable of measuring the aggregate impact of various sources of financing on innovation activity. Similarly, analytical reports by the Food and Agriculture Organization of the United Nations (FAO, 2022) and the Organisation for Economic Co-operation and Development (OECD, 2023) emphasised the need for hybrid financial mechanisms, but their conclusions are predominantly normative in nature. A World Bank (2020) study examined blended finance and risk-sharing instruments; however, the empirical models are predominantly focused on large emerging economies. The applicability of these approaches to countries with limited financial market depth, including the Kyrgyz Republic, remains insufficiently explored. C. Yang *et al.* (2024) empirically demonstrated that the development of digital financial instruments (fintech, online lending, mobile payments, etc.) has a positive impact on the agricultural economy's ability to withstand shocks (crises, market fluctuations, climate risks). It is important to note that this effect is not universal – its impact varies depending on the level of market economy development, the status of the region and the structural characteristics of the agricultural sector. M. Hong *et al.* (2022) emphasised in their study that digital inclusive finance contributes to the growth of environmentally oriented productivity in the agricultural sector, primarily through the optimisation of production structures. At the same time, this effect is not uniform and depends on regional and economic conditions. K. Rijswijk *et al.* (2021) emphasised that the effectiveness of digitalisation depends not only on technology, but also on governance, stakeholder accountability and the ability of institutions to adapt to new conditions.

A review of the literature has revealed a lack of quantitative tools for assessing the effectiveness of agricultural innovation financing structures in contexts where access to long-term capital is limited. This research gap highlights the need to develop an integrated model for evaluating blended finance, tailored to the specific national context of the Kyrgyz Republic. Sustainable development of the agricultural sector is achieved through the formation of blended financing models based on the distribution of risks between the state, the banking system and private capital. However, adapting such models to the conditions of the Kyrgyz Republic requires a quantitative assessment of the structure of funding sources and their impact on innovation activity. The aim of the study was to analyse the impact of the structure of funding sources on changes in the level of innovation activity in the agricultural sector, followed by the justification and development of a mixed financing model. The research hypothesis posited that the time structure of capital (the ratio of short-term to long-term financial resources) has a statistically significant impact on the innovation dynamics of the agricultural sector, and that an increase in the share of long-term investment capital accelerates the pace of technological modernisation.

Materials and Methods

This study was empirical and quantitative in nature and was based on a retrospective analysis of data for the period 2020-2024. The subject of the study was the system for financing innovation processes in the agricultural sector of the Kyrgyz Republic. The subject of the study was the relationship between the structure of financial resources and indicators of innovation activity in the agricultural sector. The empirical basis included official data from the World Bank (2021), the National Bank of the Kyrgyz Republic (2024), and the National Statistical Committee of the Kyrgyz Republic (2025a; 2025b). The choice of the 2020-2024 period is due to the availability of complete official statistics for the completed economic cycle, which ensures the comparability of indicators and excludes the influence of preliminary estimates. The analysis included the following indicators:

- the amount of budgetary support (B);
- long-term bank lending (L);
- private investment (P);
- funds from international financial institutions (M);
- investment risk index (R).

The indicator used to measure innovation activity is investment in fixed capital in agriculture, which reflects the scale of technological modernisation and the renewal of production assets. This indicator was chosen due to its regular statistical availability and its alignment with international practice in assessing investment and innovation dynamics in the agricultural sector (FAO, 2022; OECD, 2023). To assess the aggregate impact of funding sources, the IIF was developed:

$$IIF = \alpha B_t + \beta L_t + \gamma P_t + \delta M_t - \theta R_t, \quad (1)$$

where the coefficients α, β, γ, δ, and θ are determined on the basis of expert judgement and are normalised such that $\alpha + \beta + \gamma + \delta + \theta = 1$.

The data were converted to a dimensionless form using linear normalisation:

$$X^{norm} = \frac{X_t - X_{min}}{X_{max} - X_{min}}. \quad (2)$$

To determine the weighting coefficients, an expert assessment was carried out involving representatives from the banking sector, government bodies and the agricultural sector. The degree of consensus among the experts was calculated using Kendall's coefficient of concordance (*W*):

$$W = \frac{12S}{m^2(n^3 - n)}, \quad (3)$$

where *m* is the number of experts, *n* is the number of factors being evaluated, and *S* is the sum of the squares of the deviations of the total ranks from their mean.

The calculation yielded a value of W = 0.74, indicating a high degree of consistency among the expert assessments and allowing the resulting weighting coefficients to be used in further calculations. The expert group comprised 14 specialists with at least 10 years' professional experience in agricultural lending, state support for agriculture and investment analysis. Experts were selected based on criteria of professional competence, participation in investment programmes and managerial experience in accordance with the standards of the Declaration of Helsinki of the World Medical Association (WMA, 2024). To test the research hypothesis regarding the existence of a correlation between the structure of financing and innovative activity, Spearman's non-parametric correlation coefficient (ρ) was used to test the research hypothesis regarding the existence of a correlation between the structure of financing and innovation activity. A correlation analysis was conducted between the share of long-term bank lending in the overall structure of attracted financial resources and the volume of investment in fixed capital in agriculture. A limitation of the study is the small size of the retrospective sample (2020-2024), which reduces the generalisability of the correlation estimates obtained. The level of statistical significance was set at α = 0.05. Calculations were performed using SPSS software. The indicator of investment in fixed capital was also brought to a comparable scale using the linear normalisation method to ensure the accuracy of the comparative analysis. The methodological design of the study enables a quantitative verification of the hypothesis regarding the relationship between the financing structure and the innovative activity of the agricultural sector.

Results and Discussion

In order to test the research hypothesis, an analysis was conducted of trends in investment in fixed capital in the agricultural sector of the Kyrgyz Republic for the period 2020-2024, treated as a quantitative indicator of innovation activity. The results are presented in Table 1.

Table 1. Trends in investment in fixed capital in the Kyrgyz Republic

Year	2020	2021	2022	2023	2024
Investments, million KGS	10,127.10	14,246.10	14,744.80	4,587.00	1,712.90

Source: National Statistical Committee of the Kyrgyz Republic (2025a)

As can be seen from Table 1, investment activity increased between 2020 and 2022: the volume of investment rose from KGS 10,127.1 million to KGS 14,744.8 million (an increase of 45.6%). However, from 2023 onwards, a sharp decline in investment has been recorded – to KGS 4,587.0 million in 2023 and KGS 1,712.9 million in 2024. The cumulative decline compared to the peak value of 2022 amounted to over 80%. The results obtained indicate high volatility in investment dynamics and instability in the financial basis for the modernisation of the agricultural sector. During the study, a structural model for financing innovation processes in agriculture was developed. The general model for financing innovation is presented as follows:

$$F_{innov} = G + B_s + B_t + P + IFI, \quad (4)$$

where G represents state support (subsidies, preferential schemes); B_s represents short-term bank loans; B_t represents long-term bank loans; P represents private investment; IFI represents funds from international financial institutions. Structural coefficient of long-term investment security. To assess the investment orientation of the financial system, the following indicator has been introduced:

$$K_{long} = \frac{B_l}{B_s + B_t}, \quad (5)$$

if $K_{long} < 0.3$ – the system is geared towards working capital; $K_{long} > 0.4$ – the system is geared towards modernisation.

According to official data from the National Bank of the Kyrgyz Republic (2024), the share of long-term loans is approximately 28-29%, hence $K_{long} \approx 0.28$. This indicates a predominance of short-term financing and institutional constraints on innovation. To test the research hypothesis regarding the influence of the capital structure on innovation activity, the Spearman correlation coefficient was calculated between the share of long-term lending (K_{long}) and the volume of investment in fixed capital in agriculture for the period

2020-2024. The calculation of Spearman's coefficient revealed a positive correlation ($\rho = 0.71$), at a statistical significance level of $p < 0.05$, indicating the existence of a robust relationship between the capital structure and investment dynamics in the agricultural sector. The results obtained indicate a positive relationship between the indicators under consideration, which confirms the hypothesis regarding the importance of long-term investment capital for ensuring sustainable innovation dynamics in the agricultural sector. A mixed financing model was developed during the study. The model is based on an analysis of the current structure of credit and budgetary resources channelled into the agricultural sector of the Kyrgyz Republic (National Bank of the Kyrgyz Republic, 2024; National Statistical Committee of the Kyrgyz Republic, 2025b). A comparison of the existing and proposed structures of funding sources is presented in Table 2.

Table 2. A model for the mixed financing of innovation processes in agriculture in the Kyrgyz Republic

Source of funding	Current share, %	Recommended proportion, %
The state	15	20
Banks (short-term loans)	50	30
Banks (long-term loans)	28	35
Private equity	5	10
International financial organisations	2	5

Source: compiled by the author based on data from the National Bank of the Kyrgyz Republic (2024) and the National Statistical Committee of the Kyrgyz Republic (2025b)

The data presented in Table 2 reveal a significant skew in the current financing system towards short-term bank lending, which accounts for as much as 50%. This structure is primarily geared towards supporting working capital and seasonal expenditure, which limits opportunities for technological modernisation and the introduction of innovations. The proposed model envisages increasing the share of long-term loans to 35%, expanding state participation through guarantee and subsidy instruments to 20%, and stimulating private investment and resources from international financial organisations. Such diversification of funding sources is consistent with the principles of sustainable agricultural development and blended finance mechanisms (World Bank, 2021; FAO, 2023). The optimisation function of innovation development can be represented as:

$$I = f(G, B_t, P, IFI), \tag{6}$$

provided that $_{max}I$ when $B_t > B_s$.

The forecast values have been calculated on the basis of the identified correlation and an expert assessment of the sensitivity of investment dynamics to changes in the share of long-term financing. In order to identify potential trajectories for the development of innovation processes in the agricultural sector of the Kyrgyz Republic, expert scenario modelling was carried out, taking into account changes in the structure of financial resources. Three possible development scenarios have been identified:

1. The baseline scenario assumes that the current financing structure will remain in place, with short-term bank loans predominating. In this case, the average annual growth rate of innovation activity is estimated to be between 3% and 4%.

2. The moderate scenario envisages an increase in the share of long-term bank lending to 35%, whilst maintaining the current level of government support. Under these conditions, projected average annual growth could reach 5-6%.

3. This innovation scenario is based on the implementation of a comprehensive blended finance model, which includes the expansion of long-term loans, the strengthening of government guarantees, and increased participation by private capital and international financial institutions. Under this scenario, the expected average annual growth rate of innovation is estimated to be in the range of 7-9%.

The scenario modelling carried out shows that a key factor in accelerating innovation processes is an increase in the share of long-term investment capital within the overall financing structure. The results obtained confirm the hypothesis put forward regarding the influence of the capital's time structure on the innovation dynamics of the agricultural sector. Despite the availability of financial resources, their predominantly short-term nature ($K_{long} \approx 0.28$) limits the scope for technological modernisation. The identified positive correlation between the share of long-term lending and the volume of investment indicates that it is the duration of financial instruments that determines the sustainability of innovation activity. These findings are consistent with the analysis by S. Borrás & J. Edler (2020), which emphasises the importance of long-term capital for the structural modernisation of agricultural systems. Economies with emerging financial markets are characterised by institutional dependence on short-term bank lending, which reduces the sector's investment sustainability. The identified institutional barrier is linked not so much to the volume of financial resources as to their time structure and risk-sharing mechanisms. D. Abebaw & M.G. Haile (2013) also confirmed that participation in agricultural cooperatives has a statistically significant positive impact on the adoption of technologies, in particular the use of fertilisers and pesticides. At the same time, this effect is heterogeneous and depends on household characteristics, as well as on conditions of access to resources and advisory services.

This paper proposes a long-term investment adequacy ratio that enables the assessment of the financial system's focus on the modernisation of the sector. The scenario modelling carried out – for the first time in the context of the Kyrgyz Republic – allows for a quantitative assessment of the impact of changes in capital structure on the pace of innovative development. The results obtained are partly consistent with the findings of M.A. Akudugu (2012), who emphasise the decisive role of long-term lending in ensuring the sustainable transformation of agrarian economies. However, unlike their study, which focused on cross-country analysis, this paper adapts the model to the conditions of a national financial market with limited depth. Similar conclusions are presented in the works of O. Radchenko *et al*. (2023) and J. Barreiro-Hurle *et al*. (2023), where it is demonstrated that extending the maturity of financial instruments reduces investment risks and increases the likelihood of technological innovation adoption. At the same time, an institutional dependence on short-term bank lending has been identified for the Kyrgyz Republic, which exacerbates the seasonal volatility of investment activity. In the analytical review by R. Birner *et al*. (2021) emphasises the need to diversify sources of agricultural financing and expand risk-sharing mechanisms. The mixed financing model developed in this study specifies these recommendations in relation to the capital structure of the Kyrgyz Republic and formalises them in quantitative terms.

Conclusions

An analysis of trends in investment in fixed assets in the agricultural sector of the Kyrgyz Republic for the period 2020-2024 has revealed a high degree of volatility in investment activity. Following a rise in investment in 2020-2022, a sharp decline was recorded in 2023-2024, indicating the instability of the financial basis for the modernisation of the agricultural sector. A structural analysis of financing revealed a marked predominance of short-term bank lending, which directs financial flows primarily towards covering current production costs and the seasonal needs of the agricultural sector. Long-term loans account for only 28-29%, and the calculated long-term investment security ratio ($K_{long} \approx 0.28$) indicates that the financial system is insufficiently geared towards supporting capital-intensive investment projects with long implementation periods. This structure limits the scope for introducing technological innovations, modernising production processes and upgrading the material and technical base, as innovative projects require stable and predictable financial support over a long period. Furthermore, it has been established that the existing financing model creates an institutional gap between the needs of technological modernisation and the actual capacity for investment support, as short-term resources are unable to sustain long-term innovation projects. This increases the agricultural sector's dependence on seasonal factors and heightens its sensitivity to external economic shocks. Scenario modelling has demonstrated that maintaining the current financing structure limits the average annual rate of innovation development to 3-4%. Increasing the share of long-term lending to 35% allows the projected rates to be raised to 5-6%, whilst the implementation of a comprehensive mixed-financing model could raise them to 7-9% per annum. Thus, it has been demonstrated that the key factor in the modernisation of the agricultural sector is not so much the total volume of resources as their temporal structure and the effectiveness of mechanisms for distributing investment risks. Prospects for further research relate to the development of dynamic models for assessing the effectiveness of guarantee instruments, the development of blended finance mechanisms, and the quantitative analysis of investment risks in the agricultural sector.

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Conflict of Interest

None.

References

[1] Abebaw, D., & Haile, M.G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. *Food Policy*, 38, 82-91. doi: 10.1016/j.foodpol.2012.10.003.

[2] Akudugu, M.A. (2012). Estimation of the determinants of credit demand by farmers and supply by rural banks in Ghana's Upper East Region. *Asian Journal of Agriculture and Rural Development*, 2(2), 179-190.

[3] Barreiro-Hurle, J., Dessart, F.J., Rommel, J., Czajkowski, M., Espinosa-Goded, M., Rodriguez-Entrena, M., Thomas, F., & Zagorska, K. (2023). Willing or complying? The delicate interplay between voluntary and mandatory interventions to promote farmers' environmental behavior. *Food Policy*, 120, article number 102481. doi: 10.1016/j.foodpol.2023.102481.

[4] Birner, R., Daum, T., & Pray, C. (2021). Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. *Applied Economic Perspectives and Policy*, 43(4), 1260-1285. doi: 10.1002/aepp.13145.

[5] Borrás, S., & Edler, J. (2020). The roles of the state in the governance of socio-technical systems' transformation. *Research Policy*, 49(5), article number 103971. doi: 10.1016/j.respol.2020.103971.
[6] FAO. (2020). *The state of food and agriculture 2020. Overcoming water challenges in agriculture*. Rome: FAO. doi: 10.4060/cb1447en.
[7] FAO. (2022). *The state of food and agriculture 2022: Leveraging automation in agriculture for transforming agrifood systems*. Rome: FAO. doi: 10.4060/cb9479en.
[8] FAO. (2023). *Agrifood systems transformation and financing for sustainable development*. Rome: FAO. doi: 10.4060/cc7724en.
[9] Hong, M., Tian, M., & Wang, J. (2022). Digital inclusive finance, agricultural industrial structure optimization and agricultural green total factor productivity. *Sustainability*, 14(18), article number 11450. doi: 10.3390/su141811450.
[10] Khan, F.U., Nouman, M., Negrut, L., Abban, J., Cismas, L.M., & Siddiqi, M.F. (2024). Constraints to agricultural finance in underdeveloped and developing countries: A systematic literature review. *International Journal of Agricultural Sustainability*, 22(1), article number 2329388. doi: 10.1080/14735903.2024.2329388.
[11] Klerkx, L., & Rose, D. (2020). Dealing with the game-changing technologies of agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? *Global Food Security*, 24, article number 100347. doi: 10.1016/j.gfs.2019.100347.
[12] Louhichi, K., Ricome, A., & Gomez y Paloma, S. (2022). Impacts of agricultural taxation in Sub-Saharan Africa: Insights from agricultural produce cess in Tanzania. *Agricultural Economics*, 53, 671-686. doi: 10.1111/agec.12704.
[13] Lowder, S.K., Sánchez, M.V., & Bertini, R. (2021). Which farms feed the world and has farmland become more concentrated? *World Development*, 142, article number 105455. doi: 10.1016/j.worlddev.2021.105455.
[14] National Bank of the Kyrgyz Republic. (2024). *Annual report 2023*. Bishkek: National Bank of the Kyrgyz Republic.
[15] National Statistical Committee of the Kyrgyz Republic. (2025a). *Agriculture of the Kyrgyz Republic 2020-2024*. Bishkek: National Statistical Committee of the Kyrgyz Republic.
[16] National Statistical Committee of the Kyrgyz Republic. (2025b). *Investment in fixed capital by economic activity*. Bishkek: National Statistical Committee of the Kyrgyz Republic.
[17] OECD. (2023). *Policies for the future of farming and food in Central Asia*. Paris: OECD Publishing. doi: 10.1787/32810cf6-en.
[18] Radchenko, O., Tkach, L., & Dendebera, O. (2023). Financing innovations in the agricultural industry as a component of the digital development of Ukraine's economy. *Scientific Bulletin of Mukachevo State University Series "Economics"*, 10(4), 54-65. doi: 10.52566/msu-econ4.2023.54.
[19] Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies*, 85, 79-90. doi: 10.1016/j.jrurstud.2021.05.003.
[20] United Nations. (2023). *Financing for sustainable development report 2023*. doi: 10.18356/9789210026116.
[21] WMA. (2024). *WMA Declaration of Helsinki – ethical principles for medical research involving human participants*. Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki/.
[22] World Bank. (2020). *Harvesting prosperity. Technology and productivity growth in agriculture*. Washington, DC: World Bank. doi: 10.1596/978-1-4648-1393-1.
[23] World Bank. (2021). *Global Agriculture and Food Security Program (GAFSP): An update to the board of executive directors of the World Bank*. Washington, DC: World Bank.
[24] Yang, C., Liu, W., & Zhou, J. (2024). The role of digital finance in shaping agricultural economic resilience: Evidence from machine learning. *Agriculture*, 14(10), article number 1834. doi: 10.3390/agriculture14101834.

Айыл чарбасындагы инновациялык процесстерди каржылоо: Кыргыз Республикасынын тажрыйбасы

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Аннотация. Узак мөөнөттүү капиталга жеткиликтүүлүктүн чектелген шарттарында жана климаттык жогорку алсыздыкта Кыргыз Республикасынын айыл чарба тармагы инновацияларды киргизүүдө институционалдык чектөөлөргө дуушар болууда. Изилдөөнүн максаты каржылоо түзүмү менен агрардык сектордогу инновациялык активдүүлүктүн динамикасынын ортосундагы өз ара байланыштарды аныктоо жана сандык баалоо, ошондой эле аралаш каржылоо моделин иштеп чыгуу болуп саналат. Эмпирикалык база 2020-2024-жылдардагы расмий маалыматтарды камтыды. Методологиялык негиз экономикалык-статистикалык талдоого, көрсөткүчтөрдү сызыктуу нормалдаштырууга, салмактык коэффициенттерди эксперттик баалоого ($n = 14$) жана Спирмендин параметрсиз корреляциялык талдоосуна негизделген. Эксперттик баалоолордун шайкештиги Кендаллдын конкордация коэффициенти менен тастыкталды ($W = 0,74$). Изилдөөдө инновациялык каржылоонун интегралдык индекси сунушталып, ал бюджеттик колдоону, узак мөөнөттүү банктык кредиттөөнү, жеке инвестицияларды, эл аралык каржы уюмдарынын каражаттарын жана инвестициялык тобокелдик факторун камтыйт. Узак мөөнөттүү кредиттөөнүн үлүшү менен негизги капиталга инвестициялардын көлөмүнүн ортосунда статистикалык жактан маанилүү оң байланыш аныкталды ($\rho = 0,71$; $p < 0,05$), бул капиталдын убакыттык түзүмүнүн тармактын инновациялык потенциалын калыптандыруудагы негизги ролун ырастайт. Узак мөөнөттүү кредиттөөнүн үлүшүн 35 %га чейин көбөйтүү жеке жана эл аралык капиталды тартуу деңгээлине жараша инновациялык активдүүлүктүн өсүшүн камсыз кыла алаары көрсөтүлдү. Аралаш каржылоонун формалдаштырылган модели иштелип чыгып, өнүгүүнүн үч траекториясы боюнча сценарийлик моделдештирүү жүргүзүлдү. Базалык сценарий кыска мөөнөттүү кредиттөөнүн үстөмдүгүн сактап, 3-4 % деңгээлинде өсүштү камсыз кылды; орточо сценарий мамлекеттик колдоону сактоо шартында узак мөөнөттүү кредиттердин үлүшүн 35 %га чейин жогорулатып, 5-6 % өсүштү болжолдоду; ал эми инновациялык сценарий ресурстарды кеңейтүү жана жеке менен эл аралык капиталдын катышуусу менен аралаш каржылоого негизделип, 7-9 % өсүштү камсыз кылды

Негизги сөздөр: инвестициялык механизмдер; агрардык сектор; мамлекеттик колдоо; өндүрүштү модернизациялоо; кредиттөө

Финансирование инновационных процессов в сельском хозяйстве Кыргызской Республики

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Аннотация. В условиях ограниченного доступа к долгосрочному капиталу и высокой климатической уязвимости сельское хозяйство Кыргызской Республики сталкивается с институциональными ограничениями внедрения инноваций. Цель исследования заключалась в выявлении и количественной оценке взаимосвязи между структурой финансирования и динамикой инновационной активности аграрного сектора с последующей разработкой модели смешанного финансирования. Эмпирическая база охватывала официальные данные за 2020-2024 годы. Методологическая конструкция основана на экономико-статистическом анализе, линейной нормализации показателей, экспертной оценке весовых коэффициентов ($n = 14$) и непараметрическом корреляционном анализе Спирмена. Согласованность экспертных оценок подтверждена коэффициентом конкордации Кендалла ($W=0,74$). В работе предложен интегральный индекс инновационного финансирования, включающий бюджетную поддержку, долгосрочное банковское кредитование, частные инвестиции, средства международных финансовых организаций и фактор инвестиционного риска. Установлена статистически значимая положительная взаимосвязь между долей долгосрочного кредитования и объемом инвестиций в основной капитал ($\rho = 0,71$; $p < 0,05$), что подтверждает ключевую роль временной структуры капитала в формировании инновационного потенциала отрасли. Показано, что увеличение доли долгосрочного кредитования до 35 % может обеспечить рост инновационной активности в зависимости от уровня привлечения частного и международного капитала. Разработана формализованная модель смешанного финансирования и проведено сценарное моделирование трех траекторий развития. Базовый сценарий сохранял преобладание краткосрочного кредитования и обеспечивал рост на уровне 3-4 %, умеренный предусматривал увеличение доли долгосрочных кредитов до 35 % при сохранении господдержки и рост 5-6 %, тогда как инновационный основывался на смешанном финансировании с расширением ресурсов и участием частного и международного капитала, обеспечивая рост 7-9 %

Ключевые слова: инвестиционные механизмы; аграрный сектор; государственная поддержка; модернизация производства; кредитование

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Some monitoring studies of wild animals of the Turkestan Range

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Abstract. The conservation of mountain ecosystem biodiversity in Kyrgyzstan remains one of the priority tasks of modern ecology and nature conservation practice amid increasing anthropogenic pressure, including year-round livestock grazing, poaching and habitat fragmentation. The aim of the study was to analyse the results of monitoring the snow leopard (*Panthera uncia*) population and associated fauna in the Turkestan Range. The work employed remote monitoring methods using 87 Reconyx HC500 camera traps installed in a targeted manner in Sarkent State Nature Park, Surmatash State Nature Reserve and the Leylek Forestry in 2020-2021. Camera traps were placed along animal trails and passes at 2-3 km intervals. Individual identification was carried out by the unique spot pattern by two independent experts. Spatial analysis of the data was performed in ArcGIS and QGIS using a digital elevation model. As a result, 21 snow leopards were identified, including 4 cubs, confirming successful reproduction of the local population. The species demonstrated high ecological plasticity, occupying an altitudinal range from 1,973 to 3,993 m above sea level. A strong positive spatial correlation was revealed between the snow leopard's distribution and the concentration of ungulates (ibex – 120 independent events, 38% of all records). A total of 320 independent events were recorded for 15 mammal and bird species, with ibex, Himalayan snowcock and Tolai hare dominating. Detailed maps of animal distribution and seasonal dynamics of altitudinal

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records were compiled, showing predominance in mid- and high-mountain belts. The analysis confirmed a balanced trophic structure of the ecosystem and the presence of rare protected species (lynx, bearded vulture). The obtained materials are of practical value for the development of snow leopard conservation measures and optimisation of management of specially protected natural areas in the Turkestan Range

Keywords: snow leopard; camera traps; population assessment; altitudinal distribution; trophic relationships; spatial analysis; GIS technologies

Introduction

Biodiversity conservation is one of the key objectives of modern ecology. To assess the status and conservation prospects of species, systematic monitoring is required to track changes in population size and structure, as well as to identify risk factors. Regular monitoring forms the basis for science-based management of conservation activities (Rode *et al.*, 2021). A distinctive feature of the Turkestan Range is the increasing anthropogenic impact associated with year-round grazing of farm animals, poaching and habitat fragmentation. As noted by J. Li *et al.* (2023), these factors lead to a reduction in the snow leopard's food supply and changes in its spatial behaviour, necessitating systematic monitoring studies in this region. Indicator species, which reflect the state of ecosystems, are of particular importance in such studies. Among them, the snow leopard (*Panthera uncia*) occupies a special place, inhabiting high-altitude areas and sitting at the top of the food pyramid. It regulates the populations of other animals and maintains the balance of biodiversity. According to H. Ma *et al.* (2024), its presence serves as a marker of the resilience of mountain ecosystems.

In Kyrgyzstan, the snow leopard has been recognised as the country's national symbol by a decree of President Sadyr Zhaparov (Presidential Decree No. 369, 2023). However, as noted by N.A. Bizhanova *et al.* (2017), the snow leopard is among the least studied large carnivores: its secretive lifestyle, the inaccessibility of its habitats and low population density significantly complicate research into the species. According to E.P. Kashkarov (2017), as recently as 50 years ago there were around 1,500 snow leopards in Kyrgyzstan; however, their numbers have now declined by approximately tenfold. During the Soviet era, the republic was the world's main supplier of snow leopards to zoos. Following independence, the situation regarding the conservation of the species deteriorated repeatedly: in the Sarychat-Ertash Nature Reserve, considered one of the best habitats for the snow leopard in Central Asia, the species was almost completely wiped out three years after the reserve was established, and was subsequently gradually reintroduced. Currently, in the author's view, threats to the snow leopard and other rare species in Kyrgyzstan are once again on the rise.

Monitoring results depend largely on external conditions. According to C. Yang *et al.* (2021), the presence of farm animals makes it difficult to detect signs of snow leopard's activity and reduces the likelihood of sightings, even in areas with favourable terrain and ecology. Livestock grazing not only complicates observations but also reduces available habitats and decreases the animals' daytime activity. Further research in Kyrgyzstan confirms that livestock grazing, poaching and the reduction of the food supply pose serious threats to the conservation of the species and significantly hinder monitoring (NABU, 2025). Against a backdrop of a shortage of natural prey, the intrusion of domestic livestock into hunting grounds may provoke attacks by predators on domestic animals. This risks a retaliatory response from herders and poses an additional threat to the survival of local snow leopard populations. In recent decades, snow leopard research has evolved significantly: from simple descriptive observations, it has moved towards comprehensive interdisciplinary approaches based on modern monitoring and analysis methods (Kuzhlekov *et al.*, 2022). Among the technologies used, camera traps occupy a special place. Their use has proven highly effective in studying the ecology and behaviour of animals inhabiting inaccessible and extreme environments (Dyldaev *et al.*, 2021). Camera traps are recognised as the primary methodological approach for determining the spatial distribution of the snow leopard, its population size, and for tracking migration routes.

NABU Kyrgyzstan (2022) makes a significant contribution to the study of the snow leopard by conducting wildlife monitoring studies across the country. The organisation conducts population surveys of the snow leopard in key areas, including the Turkestan Range. Research into the snow leopard and its prey base in the Turkestan Range began in 2020. According to orographic classification, the Turkestan Range forms part of the Southern Tien Shan; it stretches for 300 km, with a width of 10-15 km in the west and up to 30 km in the east. The highest point is Pyramidal Peak (5,509 m above sea level). The region is characterised by unique natural landscapes and rich species diversity. In recent years, the area has been actively used as year-round pastureland, which in some cases disrupts the food supply. Illegal hunting of wild animals remains an additional threat to the region's biodiversity. The aim of this study was to analyse the results of monitoring surveys of wild animals, including the snow leopard, in the Turkestan Range.

Materials and Methods

The research was conducted within the Sarkent State Nature Park, the Surmatash State Nature Reserve, the Leylek Forestry Enterprise and the adjacent areas of the Turkestan Range. The Sarkent State Nature Park, covering an area of 40,000 hectares, is located in the Leylek district of the Batken region; the Surmatash State Nature Reserve, covering an area of 66,194 hectares, is located in the Kadamzhay district of the same region. The Leylek Forestry covers mountainous forest-meadow, semi-desert and high-altitude nival-glacial zones in the south-western part of Kyrgyzstan, at altitudes ranging from 1,500 to 4,000 metres above sea level. Fieldwork was carried out by staff from specially protected natural areas in collaboration with specialists from the monitoring department of the Nature and Biodiversity Conservation Union (NABU) in 2020-2021, in accordance with generally accepted wildlife monitoring methodologies (Asykulov, 2021). The expedition in the Turkestan Range took place from 4 to 27 July 2021.

The main tool used for remote monitoring was the Reconyx HC500 camera trap (USA) – 87 units in total. Between 12 and 26 September 2020, 43 camera traps were installed within the Sarken National Park and the Leylek Forestry; between 2 and 14 October 2020, a further 44 devices were placed in the Surmatash State Nature Reserve. The cameras operated in photo and video mode with a highly sensitive motion sensor and a 1-minute interval between triggers; the design of the devices allowed them to be used in conditions of low temperatures and precipitation. The average installation altitude was 2,627 metres above sea level, and the average operational period for a single camera trap was approximately 260 days; the total number of trap-days exceeded 22,000. The camera traps were positioned according to a targeted principle – primarily along animal tracks, on mountain passes, at marking points, and in areas showing signs of activity by snow leopards and ungulates. The deployment pattern was non-uniform (not grid-based), due to the complex terrain and the need to cover key habitats. The average distance between stations was 2-3 km; one camera was installed at each station. The total area of the study site was 475,000 ha.

An independent event was defined as the detection of the same species with a time interval of at least 30 minutes between consecutive triggers. Snow leopards were identified by the unique pattern of spots on the animal's body (paws, tail, flanks): an individual "photo-ID" was created for each animal. Identification was carried out independently by two experts; in the event of a discrepancy in assessments, a consensus approach was used; no specialised software was employed. Records of ungulates and other species were compiled using photographic data; the relative density of groups was estimated based on encounter frequency – the number of independent events per 100 trap-days – as well as the activity index (the proportion of species records in the total number of events).

Once the fieldwork was completed, the data underwent initial processing: sorting of photographic material, creation of a database and organisation of the records. For each observation, the date, time, GPS coordinates and absolute elevation above sea level were recorded. Spatial analysis was carried out using ArcGIS and QGIS in the WGS 84 coordinate system (EPSG:4326): observation points were overlaid onto a digital elevation model (DEM) and thematic layers (hydrology, protected area boundaries, landscape structure). Methods of visual analysis and comparison of recording density were used to interpret the spatial distribution; maps were compiled at scales of 1:150,000 and 1:400,000, also using Google Earth Pro. The GPS positioning accuracy of the recording points averaged ±5-10 m. To analyse the seasonal dynamics of the altitudinal distribution of snow leopards, observations were organised by site and plotted on a timeline: the X-axis represented observation dates, the Y-axis represented recording altitude; a separate coloured line was used for each site. All data used as the basis for the spatial analysis were obtained from an internal report by NABU Kyrgyzstan (2021), which is not publicly available but is in the authors' possession. All fieldwork was conducted using exclusively non-invasive observation methods – camera traps and visual counts, – without trapping, tagging or any other physical contact with the animals, in accordance with the principles of humane treatment of wildlife enshrined in the International Union for Conservation of Nature's guidelines on the responsible use of wild animals for research purposes (IUCN, 2012).

Results

Between April 2020 and February 2021, a total of 320 separate sightings of 15 species of mammals and birds were recorded across the three study sites in the Turkestan Range. The spatial distribution of identified snow leopard individuals and the locations of the monitoring stations are shown in Figure 1.

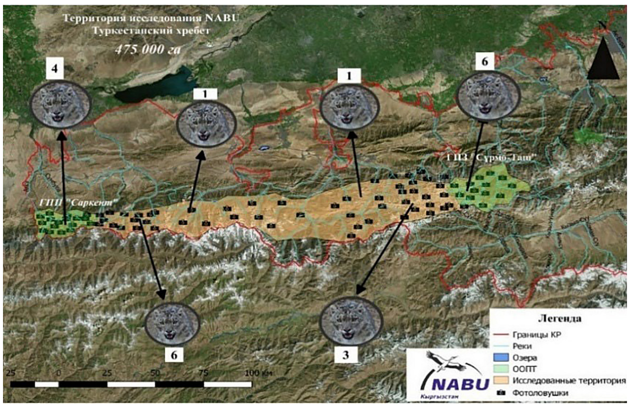

Figure 1. Map showing the locations of camera traps and identified snow leopards

Source: NABU Kyrgyzstan (2021)

The locations of the camera traps are marked on the map with black squares. The circular symbols depicting a snow leopard's head and numbers (1, 2, 3, 4, 6) indicate the uneven distribution of the animals and the varying frequency of their detection within the study area. On the map, the Sarkent State Nature Park is shown on the left, and the Surmatash State Nature Reserve on the right. In the map legend, the borders of the Kyrgyz Republic are marked with a red line, rivers and lakes with blue symbols, specially protected natural areas are highlighted in light green, and the study area is shown in orange.

A total of 17 adults and 4 cubs were identified – making a total of 21 snow leopards. Cubs were recorded in two areas, indicating active reproduction within the local population. Detailed data for each individual, including an individual identification code, the date and time of the first recording, the area and GPS coordinates, are given in Table 1. Four adult individuals have been recorded within the Sarkent State Nature Park, in the Kok-Zoo and Kak-Zhayloo areas. Nine individuals were identified in the Surmatash State Nature Reserve: two adults in the Oiterek section, three adults in Kara-Shoro, two adults and two juveniles in Ak-Zhylga; individuals [SL-876T/H] and [SL-874/H] were recorded simultaneously – 19 January 2021 at 16:56. In the Leylek Forestry, 8 individuals were recorded: 1 adult in the Baul section, 3 adults and 2 cubs at Özgörush, as well as 2 adults with ID tags [SL-1148T/H] and [SL-170T/H], recorded simultaneously at the Toguz-Bulak site. Identification was carried out using the unique pattern of spots on the hind paws – one of the most convenient body parts for recognition, as the paws are most often captured in the frame when the animal crosses a trail. The asymmetry of the pattern (the left and right paws differ) allows for reliable differentiation between individuals. An example of the identification of two individuals – [SL-249T/H] and [SL-651T/H] – in the Kök-Zoo section of the Sarkent State Nature Park is shown in Figure 2.

Table 1. Results of snow leopard surveys in the Sarkent State Nature Park, the Surmatash State Nature Reserve and the Leylek Forestry

Snow leopard facts					
No.	**Personal identification number**	**Date/time**	**Location, area**	**Coordinates GPS**	**Altitude, m above sea level**
Sarkent State Nature Park					
1	[SL-651T/H]	11.02.2021 09:34	Turkestan Range, the Kok Zoo section	N = 39.57791 E = 069.40112	3,993
2	[SL-249T/H]	08.12.2020 12:13	Turkestan Range, the Kok Zoo section	N = 39.66581 E = 69.36504	1,973
3	[SL-1808T/H]	14.12.2020 10:12	Turkestan Range, the Kok Zoo section	N = 39.59085 E = 069.43331	3,138
4	[SL-574T/H]	24.01.2021 13:15	Sarkent State Nature Park (Kak Zhayloo)	N = 39.63851 E = 069.50115	3,464
Surmatash State Nature Reserve					
5	[SL-271T/H]	27.01.2021 13:19	Turkestan Range, Oiterek section (Zhindi Suu)	N = 39.81013 E = 071.96488	2,569
6	[SL-105T/H]	04.02.2021 13:37	Turkestan Range, Oiterek section (Suuk Jailoo)	N = 39.81510 E = 072.08064	2,702
7	[SL-50T/H]	20.10.2020 03:08	Turkestan Range, the Kara-Shoro section (Gozhir)	N = 39.87276 E = 071.68302	2,775
8	[SL-45T/H]	21.11.2020 07:35	Turkestan Range, the Kara-Shoro section (Kara Kazyk)	N = 39.85122 E = 071.55346	2,877
9	[SL-2248T/H]	20.04.2020 09:09	Turkestan Range, the Kara-Shoro section (Marcha)	N = 39.83332 E = 071.58482	2,728
10	[SL-4186T/H]	08.04.2021 08:29	Turkestan Range, the Ak Zhylga section (Chon-Bevet)	N = 39.77898 E = 072.20576	2,543
11	[SL-832T/H]	10.01.2021 10:07	Turkestan Range, the Ak Zhylga section (Ming Zhylky)	N = 39.78860 E = 072.08426	2,420
12	[SL-876T/H]	19.01.2021 16:56	Turkestan Range, the Ak Zhylga section (Chon-Bevet)	N = 39.77898 E = 072.20576	2,543
13	[SL-874/H]	19.01.2021 16:56	Turkestan Range, the Ak Zhylga section (Chon-Bevet)	N = 39.77898 E = 072.20576	2,543
Leylek Forestry					
14	[SL-247T/H]	21.09.2020 16:45	Turkestan Range, Baul (Kashka-Suu)	N = 39.69738 E = 069.83067	3,327
15	[SL-73T/H]	25.09.2020 13:11	Turkestan Range, Özgörüş (Ashat)	N = 39.64954 E = 069.89582	2,836

Table 1. Continued

Snow leopard facts					
No.	Personal identification number	Date/time	Location, area	Coordinates GPS	Altitude, m above sea level
Leylek Forestry					
16	[SL-232T/H]	25.09.2020 12:00	Turkestan Range, Özgörüş (Ak-Zhar)	N = 39.67288 E = 069.89695	2,456
17	[SL-360T/H]	24.09.2020 11:50	Turkestan Range, Özgörüş (Laili)	N = 39.64434 E = 069.85869	2,513
18	[SL-1148T/H]	24.09.2020 12:43	Turkestan Range, Özgörüş (Kyrk-Bulak)	N = 39.64927 E = 069.86926	2,546
19	[SL-170T/H]	24.09.2020 12:43	Turkestan Range, Özgörüş (Kyrk-Bulak)	N = 39.64927 E = 069.86926	2,546
20	[SL-150T/H]	19.09.2020 16:45	Turkestan Range, Toguz-Bulak (Altyn-Beshik)	N = 39.67160 E = 069.64877	3,464
21	[SL-151T/H]	19.09.2020 16:45	Turkestan Range, Toguz-Bulak (Altyn-Beshik)	N = 39.67160 E = 069.64877	3,464

Source: NABU Kyrgyzstan (2021)

Figure 2. Identification of snow leopards by their hind paws (Kök-Zoo area, Sarkent State Nature Park)
Source: NABU Kyrgyzstan (2021)

The highest number of sightings occurred in September 2020 and January 2021. Within the daily cycle, the morning and afternoon hours (09:00-13:00) were predominant, indicating that the animals are primarily active during daylight hours. The snow leopard exhibits a wide ecological range, occupying an altitude range from 1,973 to 3,993 m above sea level. The seasonal dynamics of altitude records for each of the three sites are shown in Figure 3. The Sarkent State Nature Park exhibits the greatest variation in altitude – ranging from 1,973 metres above sea level (December 2020) to 3,993 metres above sea level (February 2021) – reflecting the use of both mid-mountain and high-mountain zones. The Surmatash State Nature Reserve is characterised by a more stable range – 2,420-2,877 m above sea level. Within the Leylek Forestry district, observations are concentrated mainly in the autumn of 2020 and cover altitudes from 2,456 to 3,464 m a.s.l., with several observations coinciding at the highest elevation. Overall, in autumn (September-October) average altitudes (2,400-2,800 m above sea level) predominate, whereas in winter and early spring (January-February) the range expands in both directions. In spring (April), records are again concentrated in the mid-mountain range.

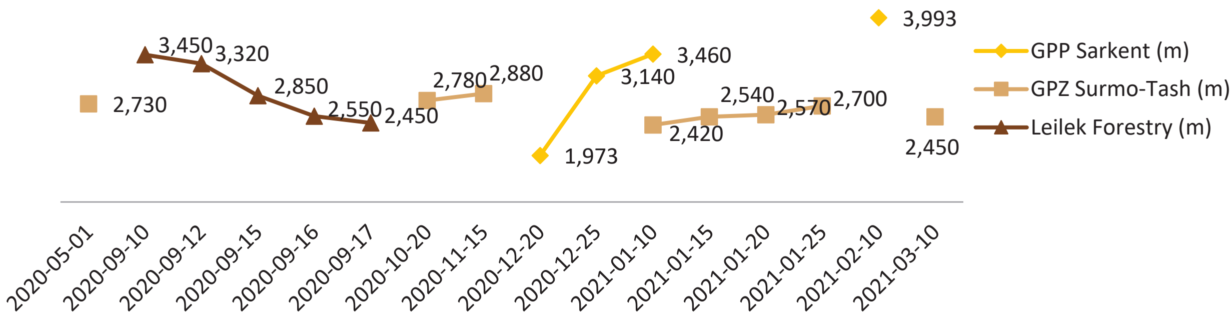

Figure 3. Seasonal dynamics of snow leopard recording altitudes in the Turkestan Range
Source: compiled by the authors

An analysis of spatial distribution revealed a strong positive correlation between the areas where snow leopards and Siberian ibex are concentrated (qualitative estimate: r ≈ 0.7-0.8): areas with a high frequency of ungulate sightings are also characterised by increased snow leopards' activity. A map of wildlife sighting points within the Sarkent State Nature Park, compiled at a scale of 1:150,000 based on GIS analysis, clearly demonstrates this pattern (Fig. 4). Most records occur in the mid-mountain (1,961-2,942 m a.s.l.) and high-mountain (2,942-4,500 m a.s.l.) altitude ranges, which correspond to the main areas of ungulate concentration.

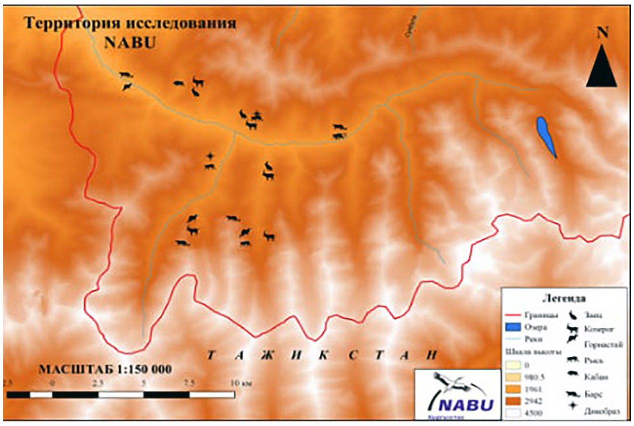

Figure 4. Wildlife observation points within the territory of the Sarkent State Nature Park
Source: NABU Kyrgyzstan (2021)

In addition to the snow leopard, camera traps have recorded the ibex, lynx, wolf, red fox, red marmot, badger, weasel, ermine, Himalayan marmot, rock partridge, sand hare, red pika, wild boar, porcupine, bearded vulture and stone marten. Summary data on encounter frequency are presented in Table 2.

Table 2. Frequency of occurrences and number of independent events by type

Type	Number of independent events	Frequency, %
Siberian ibex	120	38
Himalayan snowcock	75	24
Sand hare	40	13
Snow leopard	20	6
Wolf	15	5
Lynx	8	3
Other types	42	11
Total	320	100

Source: compiled by the authors

The dominant presence of the mountain goat (38% of all records) confirms that there is a sufficient food supply for the snow leopard. High numbers were also recorded for the Himalayan marmot and the sand hare, which form an important part of the ecosystem's trophic structure. Predatory species – the snow leopard, wolf and lynx – were recorded significantly less frequently, which is consistent with their low population density and secretive lifestyle. The presence of rare protected species – the lynx, bearded vulture and stone marten – confirms the ecological stability of the studied area and the functional completeness of its food web.

The research conducted has provided a comprehensive description of the spatial distribution of the snow leopard and associated fauna within the Turkestan Range. It has been established that the population is characterised by low density and uneven distribution, broad ecological flexibility, and close trophic links with ungulates. The data obtained confirm the high conservation potential of the Turkestan Range, but at the same time highlight the need to strengthen conservation measures in the face of increasing anthropogenic pressure.

Discussion

The data obtained on 21 identified snow leopards across the three study sites in the Turkestan Range are generally consistent with the results of similar monitoring studies in other regions (Spitsyn, 2023). However, direct comparison of numerical indicators requires caution: unlike most modern studies, this study did not calculate population density in standardised units (individuals/100 km^2), as the camera trap deployment scheme was uneven and targeted. According to K. Suryawanshi *et al.* (2021), snow leopard density estimates obtained using the spatial capture-recapture (SECR) method vary significantly across regions: from 0.19 individuals/100 km^2 in Himachal Pradesh (India) to over 3 individuals/100 km^2 in several regions of China. The lack of a standardised camera trap deployment scheme in this study prevents the calculation of comparable indices; however, the detailed individual identification and the distribution maps compiled provide a valuable basis for future SECR estimates.

The reproductive success identified in this study – 4 cubs out of 21 recorded individuals – indicates active reproduction within the local population. These findings are consistent with the results of long-term monitoring in the Naryn Nature Reserve (Kyrgyzstan): during four field seasons in the Naryn Nature Reserve, at least five adult snow leopards were identified, and throughout the study period, reproduction was recorded in two females – a total of five cubs and yearlings from three litters were recorded (Rode *et al.*, 2021). Data on reproduction are particularly important for assessing the long-term sustainability of the population: according to O. Johansson *et al.* (2020), snow leopard cubs remain with their mother for up to 20-22 months, which means that the minimum interval between successful litters is at least two years.

The wide recorded altitudinal range of the species – from 1,973 to 3,993 metres above sea level – indicates its high ecological plasticity. A similar pattern is observed in other mountain ranges of Central Asia. The snow leopard's seasonal movements across altitudinal zones are well documented in the literature: GPS tagging in the Mongolian Altai has shown that females' monthly home ranges shrink in summer, whilst males maintain a stable home range size throughout the year; with both sexes preferring steep south-western slopes at high altitudes during the winter (Rosenbaum *et al.*, 2023). The seasonal dynamics observed in this study, in which the majority of autumn records occur at medium altitudes (2,400-2,800 m), whilst both low and maximum elevations are recorded in winter and early spring, are consistent with this pattern: the snow leopard follows the food supply and available habitats depending on the season.

The significant positive spatial correlation identified between the distribution of the snow leopard and the concentration of the ibex (120 independent events, 38% of records) confirms the key role of trophic factors in shaping the spatial structure of the population. This conclusion is supported by a wide range of studies. In a study assessing snow leopard abundance in Himachal Pradesh, K. Suryawanshi *et al.* (2021) demonstrated a significant positive linear relationship between snow leopard density and wild ungulate density ($R^2 = 0.51$, $p = 0.01$); areas with high ungulate density also exhibited higher snow leopard density. A similar pattern was described by S.M. Kachel *et al.* (2022) for the ecosystems of the Mongolian Altai: in Tajikistan – in the Zorkul Nature Reserve – both snow leopards and wolves relied heavily on long-tailed marmots during the summer, although as the population of this species declines in winter, trophic competition between predators may intensify. The spatial interaction of the snow leopard with other predators – the lynx and the wolf – warrants separate consideration. The simultaneous detection of these species by camera traps on the Turkestan Range indicates shared use of the territory. According to S. Kachel *et al.* (2023), snow leopards and wolves exhibit different patterns of spatial use – snow leopards tend to favour steeper slopes and rugged terrain compared to wolves, and it is precisely this topographical separation of space that constitutes the main mechanism of their coexistence. This makes the mapping of habitats and terrain – implemented in this study by overlaying GPS data onto a digital elevation model – a particularly valuable tool for analysing interspecific interactions.

The presence of the bearded vulture (*Gypaetus barbatus*), a rare protected species, underscores the ecological value of the study area. The presence of high-level scavengers alongside an apex predator indicates the functional completeness of the food web. Research by J.S. Alexander *et al.* (2016) in the Qilian Mountains Nature Reserve (China) showed that other large predators – the wolf, lynx, red fox – are regularly encountered, which allows the snow leopard to be regarded as an umbrella species, the presence of which indirectly ensures the protection of the entire predator community. The high frequency of Himalayan snowcock (*Tetraogallus himalayensis*) sightings – 75 independent records, 24% of all records – is significant from the perspective of the snow leopard's trophic ecology. This bird is a common component of its diet in the high-altitude ecosystems of Central Asia. According to data from G.C. Christensen (2020), in the Central Asian part of its range, the Himalayan snowcock may descend to 2,500 m in spring to feed on young vegetation, and then return to higher altitudes, which chronologically correlates with the data obtained in this study on spring sightings of the snow leopard in the mid-mountain zone.

The data obtained confirm the status of the studied areas of the Turkestan Range as a stable snow leopard habitat with high reproduction rates and a functionally complete food web. The predator's identified association with mountain goat populations, seasonal shifts in altitude zones, and coexistence with other large carnivores are fully consistent with the species' pan-areal ecological strategy as an "umbrella" taxon. Despite methodological limitations in calculating population density due to the specific placement of camera traps, the detailed identification of 21 individuals and the mapping of their home ranges form the necessary basis for transitioning to standardised monitoring using the SECR method. This will enable the results of research on the Turkestan Range to be integrated into global assessments of the status of snow leopard populations in Central Asia.

Conclusions

The study confirmed the key role of systematic monitoring in the conservation of biodiversity in Kyrgyzstan's mountain ecosystems. Using the Turkestan Range as a case study, it demonstrated the high effectiveness of remote monitoring methods – particularly camera traps – in studying the snow leopard and associated fauna. Compared to traditional approaches (recording based on signs of activity), this method provides more reliable results, requires less labour and has no negative impact on the animals, although the specific features of the terrain and natural conditions must be taken into account when applying it. In 2020-2021, 87 camera traps were installed in the territories of the Sarkent State Nature Park, the Surmatash State Nature Reserve and the Leylek Forestry, and field research and mapping were carried out. As a result, 21 snow leopards (17 adults and 4 cubs) were identified, indicating reproduction and the relative stability of the population. The use of a unique pattern recognition method enabled the creation of "photo-IDs" for the animals, providing a basis for their further monitoring.

An analysis of altitude distribution (1,973-3,993 m above sea level) revealed the species' ecological plasticity and its adaptation to seasonal changes and the availability of prey. Spatial analysis confirmed the link between the snow leopard's range and the distribution of its prey, as well as overlaps with the ranges of the lynx and the wolf. During the studies, 16 animal species were recorded, including two listed in the Red Data Book, which underscores the importance of conserving this ecosystem. The photo databases and distribution maps created provide a reliable basis for long-term monitoring. However, the study has limitations related to uneven coverage of the territory during the winter period and the inability to accurately calculate population density, which requires the use of more detailed spatial analysis methods in the future. The results obtained confirm the need to continue research into the snow leopard population and the state of its food supply in order to develop effective conservation measures. Livestock grazing and poaching remain key threats, which must be taken into account when formulating conservation policy.

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None.

Conflict of Interest

None.

References

[1] Alexander, J.S., Zhang, C., Shi, K., & Riordan, P. (2016). A granular view of a snow leopard population using camera traps in Central China. *Biological Conservation*, 197, 27-31. doi: 10.1016/j.biocon.2016.02.023.

[2] Asykulov, T. (2021). Study and protection of the snow leopard habitat. *Science, New Technologies and Innovations of Kyrgyzstan*, 4, 112-116.

[3] Bizhanova, N.A., Grachev, Yu.A., Saparov, K.A., & Grachev, A.A. (2017). Distribution, abundance and some features of the ecology of large carnivores in Kazakhstan: Analytical review. *Eurasian Journal of Ecology*, 52(3), 97-107.

[4] Christensen, G.C. (2020). Himalayan snowcock (*Tetraogallus himalayensis*), version 1.0. In S.M. Billerman (Ed.), *Birds of the world*. Ithaca: Cornell Lab. doi: 10.2173/bow.himsno.01.

[5] Decree of the President of the Kyrgyz Republic No. 369 "On Recognition of the Snow Leopard as the National Symbol of the Kyrgyz Republic". (2023, December). Retrieved from https://cbd.minjust.gov.kg/230001468/edition/2820/ru.

[6] Dyldaev, M., Chymyrov, A., Mukabaev, A., & Omurzak uulu, O. (2021). Investigation of the population area of snow leopard in the Central Tian-Shan Mountains. *E3S Web of Conferences*, 227, article number 02002. doi: 10.1051/e3sconf/202122702002.

[7] International Union for Conservation of Nature (IUCN). (2012). *Guidelines for application of IUCN Red List criteria at regional and national levels*. Retrieved from https://portals.iucn.org/library/sites/library/files/documents/RL-2012-002.pdf.

[8] Johansson, O., Ausilio, G., Low, M., Lkhagvajav, P., Weckworth, B., & Sharma, K. (2021). The timing of breeding and independence for snow leopard females and their cubs. *Mammalian Biology*, 101, 173-180. doi: 10.1007/s42991-020-00073-3.

[9] Kachel, S., Bayrakcısmith, R., Kubanychbekov, Z., Kulenbekov, R., McCarthy, T., Weckworth, B., & Wirsing, A. (2023). Ungulate spatiotemporal responses to contrasting predation risk from wolves and snow leopards. *Journal of Animal Ecology*, 92, 142-157. doi: 10.1111/1365-2656.13850.

[10] Kachel, S.M., Karimov, K., & Wirsing, A.J. (2022). Predator niche overlap and partitioning and potential interactions in the mountains of Central Asia. *Journal of Mammalogy*, 103(5), 1019-1029. doi: 10.1093/jmammal/gyac026.

[11] Kashkarov, E.P. (2017). The snow leopard of Kyrgyzstan: National shame or national pride. *Russian Regions: A Look into the Future*, 4(2), 239-263.

[12] Kuzhlekov, A.O., Skopintseva, E.V., & Gulyaev, D.I. (2022). Research and monitoring of the snow leopard in the Altai Republic. In G.Yu. Gulyaev (Ed.), *Scientific research – 2022: IV international scientific and practical conference* (pp. 22-26). Penza: MCNS "Science and Education".

[13] Li, J., Shi, X., He, X., Li, D., Hu, Q., Zhang, Y., & Ran, J. (2023). Free-ranging livestock affected the spatiotemporal behavior of the endangered snow leopard (*Panthera uncia*). *Ecology and Evolution*, 13, article number e9992. doi: 10.1002/ece3.9992.

[14] Ma, H., Qiuying, B., Rong, Z., Zhang, J., Liang, G., Ma, S., Gao, Y., & Chen, S. (2024). Snow leopard (*Panthera uncia*) activity patterns using camera traps in the Qilian Mountain National Park (Qinghai Area), China. *Animals*, 14(18), article number 2680. doi: 10.3390/ani14182680.

[15] NABU Kyrgyzstan. (2021). *Report on the identification of snow leopards from camera trap images*. Bishkek: Monitoring Department of NABU Kyrgyz Republic Branch.

[16] NABU Kyrgyzstan. (2022). *Activity report 2010-2020: Ten years of wildlife protection activities*. Retrieved from https://en.nabu.de/imperia/md/nabu/images/international/asien/kirgistan/220804-nabu-activity-report-kyrgyzstan-en-web.pdf.

[17] Nature and Biodiversity Conservation Union (NABU). (2025). *Upward trend for snow leopards in Kyrgyzstan*. Retrieved from https://en.nabu.de/news/2025/35792.html.

[18] Rode, J., Lambert, C., Marescot, L., Chaix, B., Beesau, J., Bastian, S., Kyrbashev, J., & Cabanat, A.-L. (2021). Population monitoring of snow leopards using camera trapping in Naryn State Nature Reserve, Kyrgyzstan, between 2016 and 2019. *Global Ecology and Conservation*, 31, article number e01850. doi: 10.1016/j.gecco.2021.e01850.

[19] Rosenbaum, B., *et al.* (2023). Seasonal space use and habitat selection of GPS collared snow leopards (*Panthera uncia*) in the Mongolian Altai Range. *PLoS ONE*, 18(1), article number e0280011. doi: 10.1371/journal.pone.0280011.

[20] Spitsyn, S.V. (2023). Results of monitoring the transboundary grouping of snow leopard on the Altai side of the Chikhachev Ridge by the method of camera trap in 2021-2022. *Field Research in the Altai Biosphere Reserve*, 5, 33-57. doi: 10.52245/26867109_2023_5_33.

[21] Suryawanshi, K., *et al.* (2021). Estimating snow leopard and prey populations at large spatial scales. *Ecological Solutions and Evidence*, 2, article number e12115. doi: 10.1002/2688-8319.12115.

[22] Yang, C., Zhang, P., Wu, Y., Dai, Q., Luo, G., Zhou, H., Zhao, D., & Ran, J. (2021). Livestock limits snow leopard's space use by suppressing its prey, blue sheep, at Gongga Mountain, China. *Global Ecology and Conservation*, 2, article number e01728. doi: 10.1016/j.gecco.2021.e01728.

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Аннотация. Кыргызстандагы тоолуу экосистемалардын биоар түрдүүлүгүн сактоо азыркы экология илиминин жана жаратылышты коргоо практикасынын приоритеттүү милдеттеринин бири бойдон калууда. Бул аймакта малды жыл бою жайыттоо, браконьерлик жана жашоо чөйрөлөрүнүн фрагментациясы сыяктуу антропогендик факторлор күч алууда. Изилдөөнүн максаты Түркстан кырка тоосунда ак илбирстин (*Panthera uncia*) популяциясынын жана аны коштогон фаунанын мониторингинин жыйынтыктарын талдоо болгон. Жумушта 2020-2021-жылдары “Саркент” мамлекеттик жаратылыш паркында, “Сүрмө-Таш” мамлекеттик коругунда жана Лейлек токой чарбасында 87 Reconyx HC500 фототузак орнотулган аралыктан мониторинг ыкмалары колдонулган. Фототузактар жаныбарлардын издери боюнча 2-3 км аралыкта максаттуу жайгаштырылган. Жеке идентификация тактардын уникалдуу үлгүсү боюнча эки көз карандысыз эксперт тарабынан жүргүзүлгөн. Маалыматтарды мейкиндик талдоо ArcGIS жана QGIS программаларында рельефтин санариптик моделин колдонуу менен аткарылган. Изилдөө учурунда 21 ак илбирс аныкталган, анын ичинде 4 баласы – бул жергиликтүү популяциянын көбөйүшүн тастыктайт. Түр жогорку экологиялык пластикалуулукту көрсөткөн: деңиз деңгээлинен 1973 метрден 3993 метрге чейинки бийиктик диапазонунда жашайт. Жырткычтын мейкиндик жайгашуусу менен тоо текелеринин (120 окуя, 38 %) топторунун тыгыздыгынын ортосунда күчтүү оң корреляция аныкталган. 15 түр сүт эмүүчү жана канаттуулар боюнча 320 көз карандысыз окуя катталган; басымдуулук тоо текеси, гималай улары жана кумдук коендо. Жаныбарлардын бөлүштүрүлүшү жана бийиктик фиксацияларынын сезондук динамикасынын деталдуу карталары түзүлгөн. Талдоо экосистеманын туруктуу трофикалык түзүмүн жана Кызыл китепке кирген сейрек түрлөрдү (сүлөөсүн, бүркүт-бородач) ырастаган. Алынган материалдар ак илбирсти сактоо чараларын иштеп чыгуу жана Түркстан кырка тоосунун өзгөчө корголуучу жаратылыш аймактарын башкарууну оптималдаштыруу үчүн практикалык мааниге ээ

Негизги сөздөр: ак илбирс; фототузактар; популяцияны баалоо; бийиктик боюнча бөлүштүрүлүш; трофикалык байланыштар; мейкиндик талдоо; ГИС-технологиялар

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Аннотация. Сохранение биоразнообразия горных экосистем Кыргызстана остается одной из приоритетных задач современной экологии и природоохранной практики в условиях усиливающегося антропогенного давления, связанного с круглогодичным выпасом скота, браконьерством и фрагментацией местообитаний. Целью исследования был анализ результатов мониторинга популяции снежного барса (*Panthera uncia*) и сопутствующей фауны на территории Туркестанского хребта. В работе применены методы дистанционного мониторинга с использованием 87 фотоловушек модели Reconyx HC500, установленных целевым образом в Государственном природном парке «Саркент», Государственном природном заповеднике «Сурмө-Таш» и Лейлекском лесном хозяйстве в 2020-2021 годах. Фотоловушки размещались по следам животных на тропах и перевалах с интервалом 2-3 км. Идентификация особей проводилась по уникальному рисунку пятен двумя независимыми экспертами. Пространственный анализ данных выполнялся в программах ArcGIS и QGIS с наложением на цифровую модель рельефа. В результате было идентифицировано 21 особь снежного барса, включая 4 детеныша, что подтвердило успешное воспроизводство локальной популяции. Вид продемонстрировал высокую экологическую пластичность, занимая высотный диапазон от 1973 до 3993 м над уровнем моря. Выявлена выраженная положительная пространственная корреляция между распределением хищника и концентрацией копытных (горный козел – 120 независимых событий, 38 % всех регистраций). Зафиксировано 320 независимых событий по 15 видам млекопитающих и птиц; доминировали горный козел, гималайский улар и заяц-песчаник. Составлены детальные карты распределения животных и сезонной динамики высотных фиксаций, показавшие преобладание регистраций в средне- и высокогорных поясах. Анализ подтвердил устойчивую трофическую структуру экосистемы и присутствие редких охраняемых видов (рысь, бородач). Полученные материалы представляют практическую ценность для разработки мер охраны снежного барса и оптимизации управления особо охраняемыми природными территориями Туркестанского хребта

Ключевые слова: снежный барс; фотоловушки; популяционная оценка; высотное распределение; трофические связи; пространственный анализ; ГИС-технологии

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The influence of meteorological conditions on the development and flowering of saffron (*Crocus sativus* L.) in the Chüy Valley, Kyrgyzstan

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Abstract. Trials and the introduction of saffron (*Crocus sativus* L.) were carried out between 2021 and 2025 with a view to diversifying agricultural production. Saffron is a new crop for Kyrgyzstan and is grown for its stigmas, which are a valuable export-oriented product. The aim of the study was to investigate the structure of the saffron flower, as well as the dynamics of flowering depending on meteorological conditions and agronomic practices (types of mulching). The trials were established in the collection nursery of the Kyrgyz National Agrarian University and on the fields of the "Dyikan" farm. Morphological assessment of the plants was carried out on plots arranged in triplicate. The height and number of leaves per plant, the degree of their overwintering, and the number of flowers were taken into account. Statistical processing and visualisation of the meteorological data and flowering productivity data were performed using MS Excel. The results of the trials showed that saffron flowering occurs on bright sunny days, whereas on rainy or overcast days, the flowers do not open. The duration of the flowering phase ranged from 15 to 30 days, depending on the ambient temperature. This phase was shortest in the year of planting

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(up to 15 days) and relatively longer in the third year of vegetation. The peak of flowering occurred between mid- and late October. Winter covering (mulching) of the saffron plants had a beneficial effect on generative processes, increasing the number of flowers. All types of mulching contributed to more intensive flowering. A significant difference ($p \leqslant 0.04$ for the average number of flowers per plot over 5 years) was found when covering with compost (374), transparent film (419), and paper (533) compared to the control (217). Thus, the main factors positively influencing saffron yield are the formation of a greater number of leaves and intensive flowering of the plants when using mulching materials (paper, film, and compost)

Keywords: introduction; temperature; precipitation; mulching; atrophy

Introduction

Since the 2000s in Uzbekistan and Tajikistan, and from 2021 onwards for the first time in Kyrgyzstan, research into saffron has begun on experimental fields. The results of this study will be the first regarding the adaptation of this new crop for Kyrgyzstan. Saffron (*Crocus sativus* L.) belongs to the large iris family. According to A. Zar (2024), it has been cultivated in the Middle East and Mediterranean countries since the Late Bronze Age. Saffron is grown for its stigmas, which are used as a spice in various dishes. As noted by A. Lambrianidou *et al*. (2021) noted, saffron possesses a wide range of biologically active properties, including antimicrobial, antioxidant and antitumour effects, which makes it promising not only as a spice and aromatic crop but also as a valuable raw material for the pharmaceutical and functional food industries. According to L. Cardone *et al*. (2020), it is one of the most expensive commercial crops in the world, which is why it is called “red gold”. S. Sharma & D. Kumar (2022) stated that saffron stigmas are known as the most expensive spice in the world and for their benefits to human health. The price of 1 kg of stigmas ranges from USD 600 to USD 1,000. The high cost and demand for this golden spice are prompting the scientific community to make efforts towards its large-scale production. According to the article by D. Kothari *et al*. (2021), more than 418 tonnes of saffron were produced annually worldwide across the following areas: in Iran – 108,000 ha, in Afghanistan – 7,557 ha, in India – 3,674 ha, in Greece – 1,000 ha, in Morocco – 850 ha, in Spain – 150 ha, in Italy – 70 ha, and in France – 37 ha, and in small quantities in Central Asian countries.

According to H. Sahabi & F. Moallem Banhangi (2021), the growth, development and yield of saffron depend on climatic factors, specifically average and maximum temperatures. H. Eslamia *et al*. (2024) claimed that in Iran, irrigation following dormancy accelerates and prolongs flowering by 13.5 to 16 days and increases the dry stigma yield of saffron to 7.08 kg/ha. The results of experiments by S. Sudhakar *et al*. (2025) in India showed that high-altitude regions promote the formation of a large number of flowers and an increase in dry stigma yield. Saffron has significant potential for successful cultivation, contributing to the diversification of high-value crops in mountain ecosystems. Modelling by A. Kumar *et al*. (2022) showed that the main environmental variables influencing the adaptation, cultivation and yield of saffron in non-traditional locations and mountainous regions are precipitation and temperature. In Kyrgyzstan, there has been no previous research or experience in saffron cultivation, so all aspects of growing this crop are important. Since the start of the experiments, the main focus has been on the flowering stage. Based on the above, it can be noted that the flowering stage remains poorly studied, including flower structure, flowering dynamics depending on various climatic conditions and agronomic practices (types of mulching, flowering dynamics, etc.). The aim of the study was to assess the influence of meteorological conditions and various types of mulching on the flowering characteristics and productivity of saffron in the Chüy Valley of Kyrgyzstan.

Materials and Methods

The study design corresponded to a single-factor field experiment with three replicates, in which the main factor under investigation was the type of winter cover (mulching) for saffron plants. The experimental trials were established at the collection nursery of the Kyrgyz National Agrarian University and on the premises of the “Dyikan” farm. All observations and records were carried out in accordance with the methods and rules established and approved by the Kyrgyz National Agrarian University. The plot was situated on northern ordinary chernozems at an altitude of 803 metres above sea level. A HANNA HI2002-02 pH meter was used to determine the soil pH, which ranged from 7.5 to 8.0. The humus content was 2.5-2.7% in the topsoil and 0.7-1.3% in the subsoil, as determined using the Tyurin method. The previous crop was winter wheat. The saffron variety ‘Mancha’ was the subject of the study; one of the high-yielding varieties, it was obtained from the company Guerrero Muñoz-Dalfó Pagés, Spain. On 21 September 2021, saffron was planted in the Chüy Valley. In each plot, 8 rows of saffron were planted with a row spacing of 45 cm to a depth of 10 cm. The plot area was 25 m^2. All observations were carried out in the afternoon on 20 marked plants across all experimental treatments, with three replicates. There were 30 plants per m^2. The experimental design included four plot treatments:

1) uncovered (control);
2) covered with compost;

3) covered with polyethylene film;

4) covered with two layers of kraft paper.

The number of leaves per plant, plant height, the degree of spring overwintering, and the number of flowers per plot were recorded. The degree of overwintering was determined by counting plants in rows 2, 4 and 6; 1-metre-long stakes were fixed in each row, and the number of plants before and after overwintering was counted along this section. Flower dissection was carried out according to the method of P. Mahmoudi *et al*. (2025) using medical tweezers and a scalpel manufactured in Russia. A Soptop SZN71 microscope was used to study the structure of the stamens and pollen grains. During the full flowering phase, flower dissection and organ identification were carried out (Fig. 1).

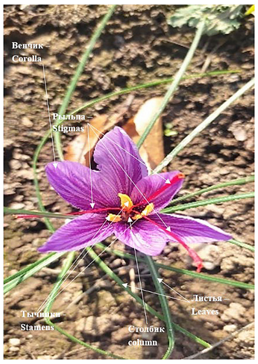

Figure 1. Mature flower

Source: authors' photo

Figure 1 illustrates the main morphological organs of saffron, including the corolla, stigmas, stamens, style, and leaves. Weeds in the plots were removed mechanically. Irrigation was carried out manually along furrows using water from the canal. Annually, the first irrigation took place on 1 September with an irrigation rate of 500 m^3/ha, and the second irrigation followed on 15 September at the same rate. To cover the plants, a two-layer polyethylene film of the M 40 µm × 3 × 100 µm grade and two-layer "A" grade kraft paper with good thermal insulation properties were used. Compost was prepared from fallen leaves from the apple orchard in a concrete pit. The plants were covered when average daily air temperatures turned below zero in November. Flower stigmas were collected by hand using medical tweezers. Stigmas of a dark burgundy colour, without a white base, are considered to be of high quality. A comparative analysis of the average monthly temperature from June to September (diapause) was used to stimulate flowering in October; a gradual transition during the summer is required: ~30°C (2-3 weeks) → ~25°C (1-2 months) → 15-20°C (flowering stage) according to the method of Z. Wang *et al*. (2021). MS Excel was used to process statistical data and create charts. A one-way analysis of variance (ANOVA) was used to examine the effect of mulch. The significance level for the 5-year average flower count was determined at $p \leqslant 0.04$. A correlation analysis (Pearson's correlation coefficient) was conducted to determine the linear relationship between air temperature and the number of flowers. The study was conducted in accordance with the ethical principles set out in the Convention on Biological Diversity (1992).

Results and Discussion

The results of the observations revealed the following phases of saffron: emergence, budding and flowering. The duration of these phases was within one month. The saffron flower consisted of six bright purple petals, with clearly visible longitudinal veins (Fig. 2).

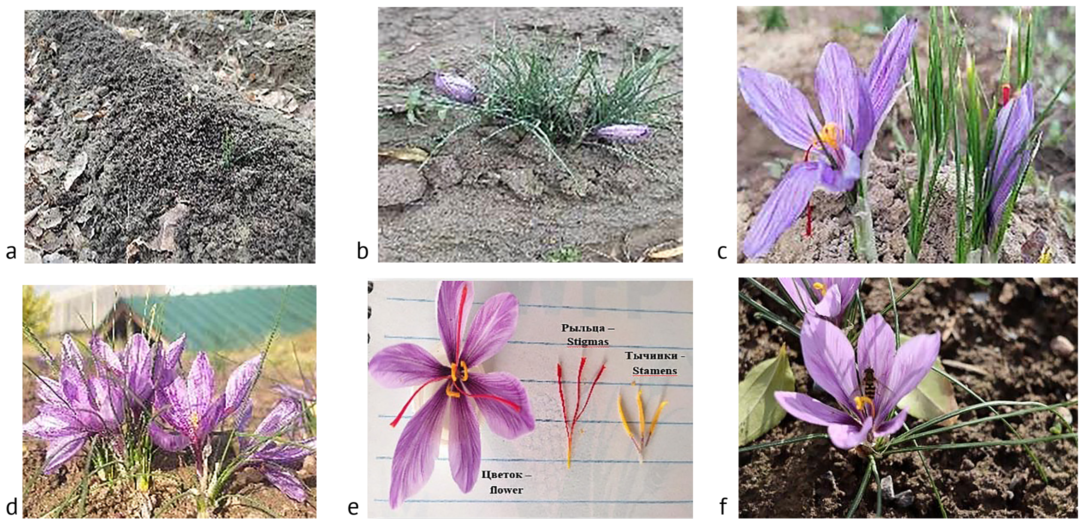

Figure 2. Developmental stages and main parts of the flower

Note: a – germination stage; b – budding stage; c – flowering stage; d – flowering shoot; e – main parts of the flower; f – a fly (*Episyrphus balteatus*) on the flower

Source: authors' photo

Germination occurs 8-10 days after planting the bulbs. The budding phase begins 5-7 days after germination. The flowering phase of an individual flower lasted 5-6 days on average. When the flower opens, the three stigmas are arranged vertically in a single column within the flower. As the petals open fully, the stigmas spread apart and droop downwards in a heliocentric manner. The flowering shoot consists of leaves and flower stalks. At the base of the flower, the stigma forms a column, with three stamens arranged around it. The flower consists of six petals, three stigmas and three stamens. The stamens are bright yellow and elongated-elliptical in shape. The stigmas are burgundy in colour with a slight thickening at the apex and are covered in a sticky liquid. The petals retain their bright colour for 4-5 days and then wilt, turning a pale blue. The saffron flower is pollinated by various groups of pollinators, the most common of which are hymenopteran and lepidopteran insects. As bright sunlight becomes available, the pollen sacs open, and the pollen falls onto the petals and is visible to the naked eye. The opening of the stamens begins at the base, and the pollen grains fall onto the base of the flower's corolla (Fig. 3).

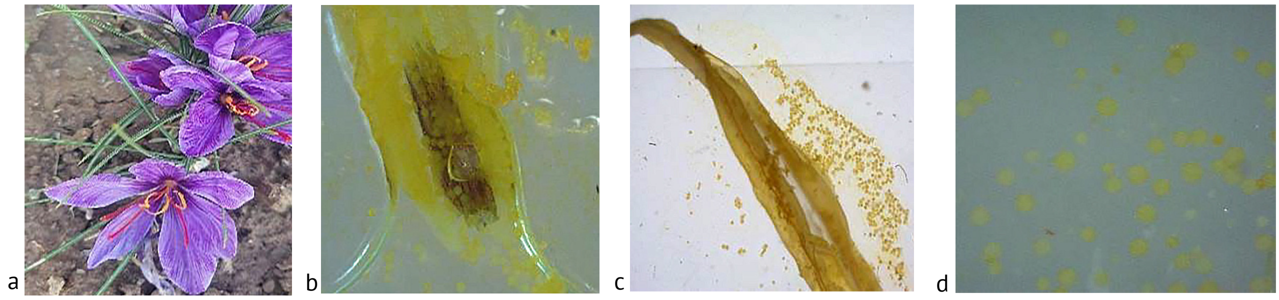

Figure 3. Flower stamens and pollen grains

Note: a – flower and pollen on the petals; b – base of an open anther; c – upper part of an open anther; d – pollen grains

Source: authors' photo

The opening of the pollen sacs begins after the bright rays of the sun have set, which can be seen as a yellow layer at the base of the petals on the inner side. The anther begins to open from its base, with faint cracks. The upper part of the anther opens with the formation of large cracks, accompanied by a profuse release of pollen grains from the anther. The pollen grains are bright yellow in colour, spherical in shape, and show no obvious surface deformities. Most plants complete their growing season in autumn, whereas for saffron, flowering is only just beginning. Purple flowers emerge from the bulbs. In 2021, it took approximately one month from the date of planting to the start of flowering (Fig. 4).

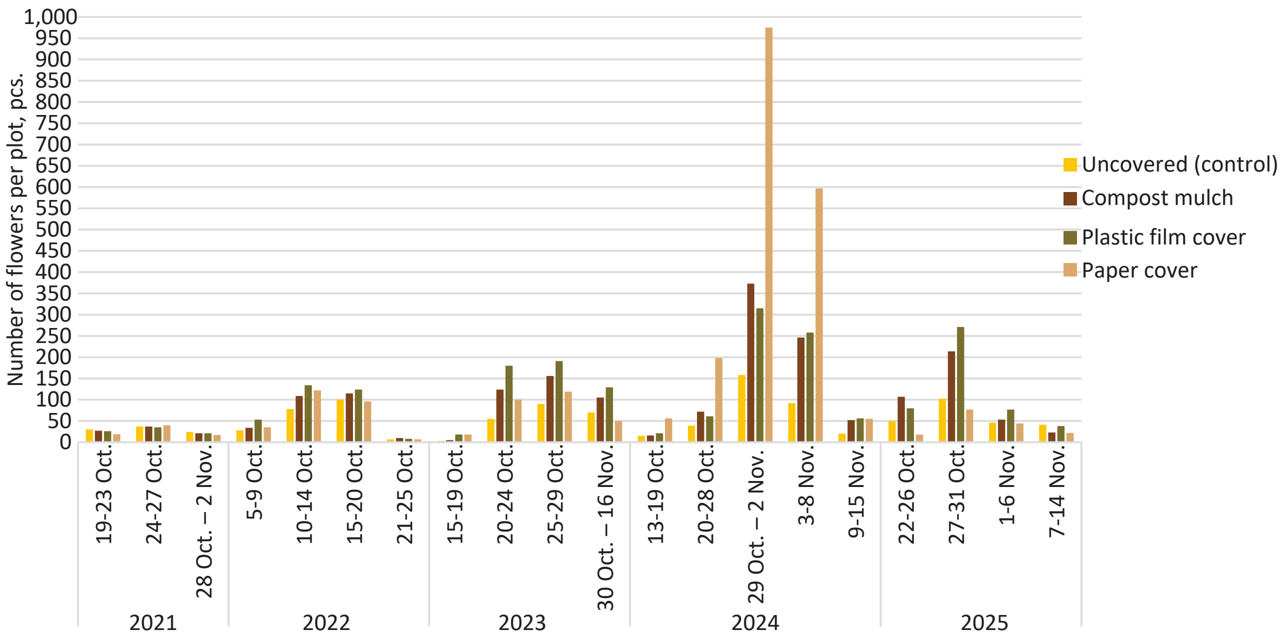

Figure 4. Flowering dynamics of saffron from 2021 to 2025

Source: compiled by the authors

During this period, the bulbs become fully established and shoots emerge above the soil surface, leading to flowering. It should be noted that, in the plants' first year, they were covered with protective materials after flowering to protect them over winter. There was no difference in the onset of flowering across all variants. Flowering peaked between 24 and 27 October. Upon completion of the flowering phase, the transition to winter dormancy began on 2 November. In 2022, flowering began two weeks earlier than in the year of planting. In the variants covered with plastic film and paper, mass flowering began two weeks earlier than in the control. The first flowering peak in the paper-covered treatment occurred on 11 October, five days after flowering began. Five days later, on 16 October, a second peak was observed, with 30 flowers appearing per day. In the other treatments, maximum flowering occurred 10 days after the start of flowering. Plants covered with compost and plastic film stood out for their large number of flowers, producing up to 37-38 flowers per day. A decline in flowering was observed between 15 and 21 October; on 22 October, flowering ceased due to rain, and the end of flowering was noted on 24 October. The duration of the flowering phase in the Chüy Valley of Kyrgyzstan was 20 days. According to A. Khaliq *et al.* (2024), the duration of flowering in Pakistan was 17 days, and in Iran – 16 days, according to H. Eslamia *et al.* (2024). In the Chüy Valley, the duration of saffron flowering was longer than in traditional growing countries due to temperature conditions and the mountainous climate. H. Farrokhi *et al.* (2021) noted that the duration of the flowering period depends on environmental and climatic conditions; as summer maximum temperatures increase, the number of flowers and stigma yield decrease. O. Mykhailenko *et al.* (2020) reported that in the lowland regions of Ukraine, the best saffron yield was obtained in the Kherson region, amounting to 4 kg/ha of dry stigmas. Meanwhile, in Iran, according to H. Pirasteh-Anosheh *et al.* (2023), optimal growing conditions and a sufficient number of warm, sunny days in spring had a positive impact on the subsequent flowering season and on yield, which amounted to 20.8 kg/ha. M. Beyrouthy (2023) calculated that each saffron flower produces three stigmas and, according to his estimate, an average of 150,000 flowers are required to obtain 1 kg of dry saffron stigmas. In 2023, between 15 and 19 October, due to rainy weather, the number of flowers was minimal across all treatments. From 20 October, flowering accelerated, reaching up to 30 flowers per plot in the plastic-covered treatment. The highest flowering productivity was recorded on 24 October at 100 flowers per plot in the plastic-covered treatment, followed by the compost-covered and paper-covered treatments. The lowest saffron flowering productivity was observed in the uncovered variant. A second flush of flowering in all variants occurred between 28 and 30 October. The flowering phase lasted one month, until 16 November.

In 2024, the flowering phase began, as in the previous year, on 13 October. Flowering proceeded slowly and continued until the end of October. From November, peak flowering was observed in all the variants studied. The maximum number of flowers (1,881 per plot in 2024) was observed in the variant covered with paper. During the overwintering period and subsequently the dormant phase, plants under artificial coverings experienced a favourable combination of light and temperature conditions, which contributed to an increase in flowering shoots. The lowest number of flowers was recorded in the control treatment. Rainy weather in early November had an inhibitory effect on the flowering process. The flowering phase lasted 28 days and continued until 15 November, as in the previous year. In 2025, the flowering phase began on 23 October, somewhat later than in previous years of observation. The delay in flowering was due to rainy weather, during which the flowers do not open. As in previous years of observation, a large number of flowers were noted in the covered plots, with the exception of the paper-covered plot compared to the control. It is possible that in the previous year, following abundant (maximum) flowering, insufficient nutrition and overwintering conditions during the fourth year of life affected the biological processes of flower formation. Overall, the duration of the flowering phase in 2025 was 24 days. The statistical data are presented in Table 1. Based on the cumulative data presented in Table 1, the 5-year average number of flowers per plot demonstrated a statistically significant increase in all mulched variants compared to the control. The highest productivity was observed in the plot covered with kraft paper, yielding an average of 533 flowers. The variants covered with transparent film and compost produced 419 and 374 flowers, respectively, whereas the uncovered control plot showed the lowest productivity with an average of 217 flowers.

Table 1. Number of flowers formed, depending on cover by year

Year/Indicator	No cover	Compost	Plastic film	Paper
2021 total from the plot, pcs.	91	85	81	76
per plant, pcs.	2.2	2.07	1.98	1.85
SD	±3.60	±3.47	±3.25	±3.49
SE	±0.56	±0.54	±0.51	±0.55
2022 total from the plot, pcs.	213	268	319	260
per plant, pcs.	5.20	6.54	7.78	6.34

Table 1. Continued

Year/Indicator	No cover	Compost	Plastic film	Paper
SD	8.16	10.48	11.77	10.03
SE	1.27	1.64	1.84	1.57
2023 total from the plot, pcs.	219	390	518	287
per plant, pcs.	5.34	9.51	12.63	7.00
SD	8.86	17.83	22.18	12.16
SE	1.38	2.78	3.46	1.90
2024 total from the plot, pcs.	324	730	711	1,881
per plant, pcs.	7.90	17.80	17.34	45.88
SD	14.68	35.73	30.72	93.54
SE	2.29	5.58	4.80	14.61
2025 total from the plot, pcs.	239	397	466	161
per plant, pcs.	5.83	9.68	11.37	3.93
SD	10.15	19.54	23.04	7.93
SE	1.58	3.05	3.60	1.24
Total for 5 years, units	1,086	1,870	2095	2,665
per plant over 5 years, pcs.	5.29	9.12	10.22	13
5-year average per plot, pcs.	217	374	419	533

Source: compiled by the authors

Table 1 shows that all mulching methods resulted in a higher number of flowers compared with the control (without cover). There is a significant difference between the use of covering materials as mulch and the control ($p \leq 0.04$). Table 2 presents the results of an analysis of the relationship between air temperature and the intensity of saffron flower formation in different years of the study.

Table 2. Correlation between air temperature and the number of flowers during flowering by year (R^2)

Indicators	2022	2023	2024	2025
Without cover	0.44	0.14	0.16	0.17
Compost	0.53	0.12	0.18	0.19
Film	0.56	0.11	0.17	0.15
Paper	0.50	0.12	0.20	0.01

Source: compiled by the authors

The data in Table 2 indicate that there is a moderate and significant correlation (44-56%) between the second year of the saffron plant's life, air temperature and the number of flowers, and that the number of flowers is influenced by other factors. In the third, fourth and fifth years of the plants' life, the correlation remains positive but insignificant. This is explained by the fact that as the plants age, the size of the bulbs increases and new daughter bulbs appear, thereby increasing the number of flowers. At the same time, the coefficient of determination was higher in the variants covered with compost and plastic film, which create favourable conditions during the plants' winter growth. The data obtained show that the 'Mancha' variety, of the Spanish ecotype, possesses good productive characteristics. Experiments conducted by K. Erden (2025) in the Harran province of Turkey showed that the highest-quality stigmas were obtained from the Greek ecotype of saffron, whilst the highest stigma yield was obtained from the Spanish ecotype of saffron under the conditions of south-eastern Anatolia. Tests on the Indian ecotype of saffron yielded low yields and quality compared to the Greek and Spanish ecotypes. Experiments by S. Sudhakar *et al.* (2025) in India revealed significant differences between locations, with Kantalur-Perumalai showing the highest flower density, yield of fresh flowers and dry stigmas, which is explained by favourable temperature conditions, altitude and soil characteristics and contributes to the diversification of high-value crops in mountain ecosystems. A. Khaliq *et al.* (2024) demonstrated that in Pakistan, the maximum number of flowers (1.35 per plant) was recorded at the Haigala site at a temperature of 26°C. In autumn, it took 30 days for flowering to begin at the Alisojal site, and the flowering period lasted 17 days. According to Z. Wang *et al.* (2021), the following principles of saffron cultivation apply: a two-stage method of saffron cultivation; saffron flowers best when warm, moderate and cool temperatures alternate; high temperatures during the dormancy period are necessary for the onset of saffron flowering; optimal temperatures promote early flower formation and shorten the flowering period. The influence of mulch types and meteorological factors on saffron flowering. Studies were also conducted to investigate the relationship between the flowering phase and meteorological indicators such as air temperature and precipitation (Fig. 5).

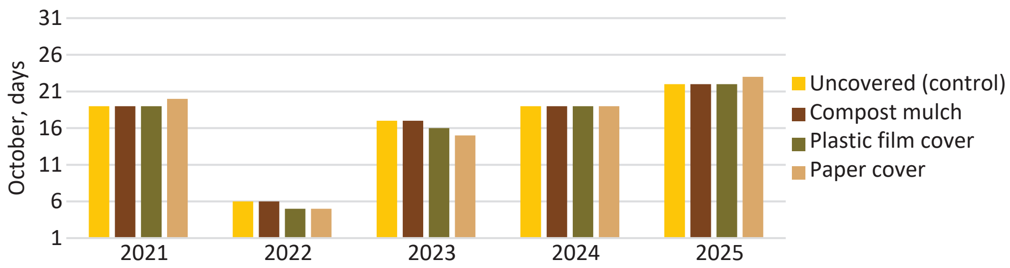

Figure 5. The onset of saffron flowering depending on the type of cover by year

Source: compiled by the authors

No use of mulch is observed at the time of the first saffron flower's emergence; the first flowers appear in October across all plots, with a variation of up to two days. An analysis of monthly average temperatures and precipitation in the Chüy Valley for the period 2021-2025 allows an assessment of the conditions for saffron cultivation, based on the incubation temperature regime proposed by Z. Wang *et al.* (2021). Temperature conditions (monthly averages) during the diapause and flowering periods of saffron are shown in Table 3.

Table 3. Average monthly temperature conditions during saffron dormancy and flowering

Year	June (°C)	July (°C)	August (°C)	October (°C)	Average temperature during dormancy and flowering (°C)	The effect of temperature on plant development
	30	30	25	15-20		Model by Z. Wang *et al.* (2021)
2021	17.6	21.2	18.4	14.5	17.93	Unfavourable: temperatures too low for initiation (below 25-30°C)
2022	17.8	19.9	16.4	15.1	17.30	Unfavourable: risk of daughter bulb atrophy and reduced flower count due to cool temperatures during dormancy
2023	25.8	26.6	24.9	18.4	23.93	Optimal: temperatures in July-August (25-26°C) and September (18.4°C) are close to the ideal pattern
2024	25.6	26.5	26.2	17.2	23.88	Favourable: steady warming in summer and a gradual decline in September
2025	26.4	28.1	25.7	9.6	22.45	Risky: high summer temperatures are favourable, but a sharp drop in September to 9.6°C could halt development

Source: compiled by the authors based on data from Kyrgyzhydromet (n.d.), Bishkek

The data in Table 3 show that conditions during the period 2023-2025 were favourable and better align with the model proposed by Z. Wang *et al.* (2021) (high summer temperatures stimulate bud set). In 2021-2022, temperatures were relatively low for effective shoot and root system development. Thus, the model proposed by Z. Wang *et al.* (2021) does not fully correspond to the actual temperature conditions and flower formation. This is due to the need for further research in various regions of Kyrgyzstan. Other researchers believe that the optimal temperature for shoot growth (23-25°C) was also optimal for flower bud formation (Molina *et al.*, 2004). In studies, the optimal temperature for the diapause and initiation of saffron flowering was 25-27°C. The results of studies by A. Khaliq *et al.* (2024) in Pakistan showed that the maximum number of flowers (1.35 per plant), fresh flower weight (29.03 mg/plant), stigma length (1.21 cm), fresh stigma weight (8.97 mg/plant) and stigma yield (8.60 mg/pot) were recorded at the Haigala site (loamy soil) at a temperature of 26°C. Z. Wang *et al.* (2021) reported that unsuitable incubation temperatures, such as a constant temperature of 15°C or 25°C, lead to a failure to flower, interruption of flowering and atrophy, respectively. Consequently, incubation of tubers at a higher temperature (around 30°C) for 2-3 weeks, followed by transfer to a suitable temperature (around 25°C) for 1-2 months and, finally, transfer to a lower temperature (around 15-20°C) for flowering, constitutes a suitable temperature regime for stimulating flowering, resulting in saffron entering the full flowering stage in early October. Research by D. Gao *et al.* (2023) showed that the number of flowers, the proportion of daily flowering, and dry weight were significantly correlated ($p \leq 0.01$) with the total daily integral of sunlight intensity. According to K. Kour *et al.* (2022), corm size has the greatest influence on saffron growth. In percentage terms, the priority of corm size as a variable is 34%, followed by water availability (27%), as well as temperature and mineral nutrients (24% and 17% respectively). In this regard, Table 4 presents the results of an analysis of meteorological conditions during the dormancy period and factors contributing to the initiation of saffron flowering.

Table 4. Precipitation, mm

Month	Year				
	2021	2022	2023	2024	2025
January	14.4	17	29.8	25	25
February	33.3	20.7	42.2	29	94
March	69.1	112.7	91.2	110	59
April	33.5	65.4	53.1	27	93
May	38	128.6	18.9	8	61
June	28	32.3	2.8	11	19
July	27.6	39.8	17.4	9	5
August	19.1	23.4	19.2	6	1
September	1.8	1.7	24.3	23	18
October	46.7	44.8	38.9	55	20
November	33.7	58.5	64.5	38	21
December	15.3	17.1	60.3	29	51
Total precipitation	360.5	562	462.6	370	467

Source: compiled by the authors based on data from Kyrgyzhydromet (n.d.), Bishkek

The data in Table 4 show that September 2021 was extremely dry (1.8 mm), which, combined with cooler temperatures, may have delayed the start of the growing season, despite moderate rainfall in October (46.7 mm). 2022: a very wet November (58.5 mm) following a dry autumn may have promoted leaf growth, but not flowering itself. In 2023, balanced rainfall (September 24.3 mm, October 38.9 mm, November 64.5 mm) created the best conditions for soil moisture during the flowering period. In 2024, October was the wettest (55 mm), which was favourable for the active flowering phase that began after a warm summer. In 2025, there was a moisture deficit in October (20 mm) and rainfall in November (21 mm) compared to previous years, which caused a delay in the start and end of flowering. Meanwhile, Iranian researchers H. Sahabi & F. Moallem Banhangi (2021) noted that in the provinces of Khorasan Razavi and South Khorasan there was a negligible difference in three climatic parameters, namely summer precipitation, temperature and hours of sunshine, which cannot be the cause of lower saffron quality; rather, saffron quality can be significantly improved through other factors, such as better planning and management. According to T. Pashayev & İ. Mammadov (2019), saffron, due to its biological characteristics, is highly adaptable to various climatic conditions and can be successfully cultivated at different altitudes above sea level, as well as with variations in the timing and depth of bulb planting. The authors note that these characteristics of the crop ensure high profitability and economic efficiency of its cultivation. Based on the results obtained by T. Ali *et al.* (2025), the following conditions must be taken into account for the effective cultivation of saffron in non-traditional regions: altitude above sea level (>600 m), soil texture, air temperature during flowering (October-November) not exceeding 17°C, and precipitation levels prior to flowering.

Conclusions

The weather conditions in 2023 and 2024 were most favourable for the resumption of flowering in October, as the temperature regime during dormancy provided the necessary "incubation" for the tubers (25-26°C), and autumn rainfall was sufficient to sustain physiological processes. In 2025, despite ideal dormancy conditions, a sharp drop in temperature in September and a dry autumn may have had a negative impact on flower formation. The best results for the resumption and completion of the full flowering cycle in October were observed in 2023 and 2024. In these years, the following sequence was observed: bulbs warmed to above 25°C in July-August, a gentle drop in temperature in September to 17-18°C, and sufficient rainfall (38-55 mm) in October to maintain soil moisture. Forecasting the saffron harvest in Kyrgyzstan is complicated by the fact that key agronomic practices have not yet been studied: planting dates and rates, irrigation regimes, testing of other varieties under a sharply continental climate, and other factors that may influence the growth and development of saffron. Winter protection of saffron plants had a beneficial effect on the flowering process, increasing the number of flowers – the marketable yield of this crop. The flowering phase lasted up to 30 days. Abundant (maximum) flowering lasted for 10 days. Prospects for further research involve studying the influence of various irrigation regimes, planting dates and saffron variety characteristics on flowering processes and crop yield in different regions of Kyrgyzstan. The adaptation mechanisms of saffron to changing climatic conditions and the effectiveness of various agronomic practices in its cultivation also require further study.

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Conflict of Interest

None.

References

[1] Ali, T., Mansotra, R., Sharma, S., Bhagat N., & Vakhlu J. (2025). Saffron yield and quality response under varying altitude, climate, and soil properties in the Pir Panjal range in North-Western Himalayas. *Journal of Soil Science and Plant Nutrition*, 25, 1885-1900. doi: 10.1007/s42729-025-02243-z.

[2] Beyrouthy, M. (2023). *Effect of plastic nets on saffron growth*. (Master's thesis, American University of Beirut, Beirut, Lebanon). doi: 10.13140/RG.2.2.17399.43686.

[3] Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., & Candido, V. (2020). Saffron (*Crocus sativus* L.), the king of spices: An overview. *Scientia Horticulturae*, 272, article number 109560. doi: 10.1016/j.scienta.2020.109560.

[4] Convention on Biological Diversity. (1992, May). Retrieved from https://www.cbd.int/doc/legal/cbd-en.pdf.

[5] Erden, K. (2025). Determination of yield and quality characteristics of some saffron (*Crocus sativus* L.) ecotypes in Southeastern Anatolian conditions. *International Journal of Research – Granthaalayah*, 13(2), 89-96. doi: 10.29121/granthaalayah.v13.i2.2025.5959.

[6] Eslami, H., Salehi-Arjmand, H., Shahhoseini, R., Akramian, M., & Mirmazloum, I. (2024). The phytochemical and morpho-physiological response of saffron (*Crocus sativus*) to different summer irrigation regimes. *Journal of Medicinal Plants and By-Products*, 3, 519-526. doi: 10.22034/jmpb.2024.364190.1629.

[7] Farrokhi, H., Asgharzadeh, A., & Samadi M.K. (2021). Yield and qualitative and biochemical characteristics of saffron (*Crocus sativus* L.) cultivated in different soil, water, and climate conditions. *Italian Journal of Agrometeorology*, 2, 43-55. doi: 10.36253/ijam-1216.

[8] Gao, D., Ji, X., Yuan, Q., Pei, W., Zhang, X., Li, F., & Han, Q. (2023). Effects of total daily light integral from blue and broad-band red LEDs on flowering of saffron (*Crocus sativus* L.). *Scientific Reports,* 13, article number 7175. doi: 10.1038/s41598-023-34424-0.

[9] Khaliq, A., Sarfraz, M., Tahir, M.M., Awan, S.I., Zafar, M., Shehzad, M., Shaheen, A., & Iqbal, A. (2024). Growth, yield and quality of saffron in response to different soil textures and temperature regimes. *Soil and Environment*, 43(2), 278-289. doi: 10.25252/SE/2024/243380.

[10] Kothari, D., Thakur, M., Joshi, R., Kumar, A., & Kumar, R. (2021). Agro-climatic suitability evaluation for saffron production in areas of Western Himalaya. *Frontiers in Plant Science*, 12, article number 657819. doi: 10.3389/fpls.2021.657819.

[11] Kour, K., Gupta, D., Gupta, K., Juneja, S., Kaur, M., Alharbi, A.H., & Lee, H.-N. (2022). Controlling agronomic variables of saffron crop using IoT for sustainable agriculture. *Sustainability*, 14(9), article number 5607. doi: 10.3390/su14095607.

[12] Kumar, A., Devi, M., Kumar, R., & Kumar, S. (2022). Introduction of high-value *Crocus sativus* (saffron) cultivation in non-traditional regions of India through ecological modelling. *Scientific Reports*, 12, article number 11925. doi: 10.1038/s41598-022-15907-y.

[13] Kyrgyzhydromet. (n.d.). Retrieved from https://meteo.kg/ru/.

[14] Lambrianidou, A., Koutsougianni, F., Papapostolou, I., & Dimas, K. (2021). Recent advances on the anticancer properties of saffron (Crocus sativus L.) and its major constituents. *Molecules*, 26(1), article number 86. doi: 10.3390/molecules26010086.

[15] Mahmoudi, P., Moieni, A., Khayam Nekouei M., Mardi M., & Hosseini Salekdeh, G. (2025). Induction of stigma-like structures in saffron (*Crocus sativus* L.): Exploring factors and metabolite analysis. *PLoS ONE*, 20(1), article number e0317186. doi: 10.1371/journal.pone.0317186.

[16] Molina, R.V., García-Luis, A., Coll, V., Ferrer, C., Valero, M., Navarro, Y., & Guardiola, J.L. (2004). Flower formation in the saffron crocus (*Crocus sativus* L.): The role of temperature. *Acta Horticulturae*, 650, 39-47. doi: 10.17660/ActaHortic.2004.650.2.

[17] Mykhailenko, O., Desenko, V., Ivanauskas, L., & Georgiyants, V. (2020). Standard operating procedure of Ukrainian saffron cultivation according to with good agricultural and collection practices to assure quality and traceability. *Industrial Crops and Products*, 151, article number 112376. doi: 10.1016/j.indcrop.2020.112376.

[18] Pashayev, T., & Mammadov, İ. (2019). The studying of bioecological features of saffron (*Crocus sativus* L.) in Nakhchivan Autonomous Republic. *Bulletin of Science and Practice*, 5(3), 22-26. doi: 10.33619/2414-2948/40/02.

[19] Pirasteh-Anosheh, H., Babaie-Zarch, M.J., Nasrabadi, M., Parnian, A., Alavi-Siney, S.M., Beyrami, H., Kaveh, H., Hashemi, S.E., Durrer, U., McDonald, K., & Race, M. (2023). Climate and management factors influence saffron yield in different environments. *Agrosystems, Geosciences & Environment*, 6, article number e20418. doi: 10.1002/agg2.20418.

[20] Sahabi, H., & Moallem Banhangi, F. (2021). Evaluation of the effects of climatic parameters on flowering behaviour and yield of saffron (*Crocus sativus* L.) in Razavi and South Khorasan provinces. *Saffron Agronomy and Technology*, 9(4), 357-373. doi: 10.22048/jsat.2021.283088.1423.

[21] Sharma, S., & Kumar, D. (2022). Chemical composition and biological uses of *Crocus sativus* L. (saffron). In M.H. Masoodi & M.U. Rehman (Eds.), *Edible plants in health and diseases* (pp. 249-277). Singapore: Springer. doi: 10.1007/978-981-16-4959-2_7.
[22] Sudhakar, S., Yadav, V., Sharma, C., Paul, M., Jattan, P., Choudhary, S., Dansena, V., & Pradhan, R. (2025). Agro climatic suitability assessment for saffron (*Crocus sativus* L.) cultivation in the serene hills of Idukki, Kerala, India. *International Journal of Advanced Biochemistry Research*, 9(12), 1033-1036. doi: 10.33545/26174693.2025.v9.i12Sm.6657.
[23] Wang, Z., Li, X., Xu, J., Yang, Z., & Zhang, Y. (2021). Effects of ambient temperature on flower initiation and flowering in saffron (*Crocus sativus* L.). *Scientia Horticulturae*, 279, article number 109859. doi: 10.1016/j.scienta.2020.109859.
[24] Zar, A. (2024). *The 10 best saffron in the world: A 2024 guide to the finest red gold*. Retrieved from https://saffronice.com/blogs/saffron-value-heritage/10-best-saffron-in-the-world-2024.

Кыргызстандын Чүй өрөөнүндө шафрандын (*Crocus sativus* L.) өнүгүшүнө жана гүлдөшүнө метеорологиялык шарттардын таасири

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Аннотация. Өндүрүштү диверсификациялоо максатында 2021-2025-жылдары эгилме шафранды (*Crocus sativus* L.) сыноо жана интродукциялоо иштери жүргүзүлдү. Шафран Кыргызстан үчүн жаңы өсүмдүк болуп саналат жана экспортко багытталган продукция болгон гүлдүн мамычасын алуу үчүн өстүрүлөт. Изилдөөнүн максаты шафран гүлүнүн түзүлүшүн, ар кандай метеорологиялык шарттарга жана агротехникалык ыкмаларга (мульчалоо түрлөрүнө) жараша гүлдөө динамикасын изилдөө болгон. Эксперименттик тажрыйбалар Кыргыз улуттук агрардык университетинин коллекциялык питомнигинде жана “Дыйкан” фермердик чарбасынын талаасында жүргүзүлгөн. Өсүмдүктөрдүн морфологиялык баалоосу үч жолку кайталануу менен жайгаштырылган аянтчаларда жүргүзүлгөн. Өсүмдүктүн бийиктиги, жалбырактарынын саны, кыштоодон өтүү деңгээли жана гүлдөрүнүн саны эсепке алынган. Статистикалык эсептөөлөрдү жүргүзүү жана алынган маалыматтарды визуалдаштыруу үчүн метеорологиялык маалыматтар жана шафран гүлдөрүнүн саны боюнча MS Excel компьютердик программасы колдонулган. Изилдөөлөрдүн жыйынтыгында шафран ачык күн тийген күндөрү гүлдөп, жаанчыл жана булуттуу күндөрү гүлдөрү ачылбагандыгы аныкталган. Шафрандын гүлдөө фазасы айлана-чөйрөнүн температурасына жараша 15-30 күнгө созулган. Гүлдөө фазасынын эң кыска мөөнөтү отургузулган жылы байкалган – 15 күнгө чейин, ал эми жашоо циклинин үчүнчү жылында салыштырмалуу узагыраак болгон. Гүлдөрдүн эң көп саны октябрь айынын ортосунан аягына чейин байкалган. Шафран өсүмдүктөрүн кышында жабуу гүлдөө процессине оң таасирин тийгизип, гүлдөрдүн санын көбөйткөн. Мульчалоонун бардык түрлөрү шафранда гүлдөрдүн көбүрөөк пайда болушуна өбөлгө түзгөн. Компост (374 даана), тунук пленка (419 даана) жана кагаз (533 даана) менен жабууда контролго (217 даана) салыштырмалуу олуттуу айырмачылык байкалган ($p \leqslant 0{,}04$, 5 жылдагы бир аянтчадагы гүлдөрдүн орточо саны). Шафрандын түшүмдүүлүгүнө таасир эткен негизги көрсөткүчтөр мульча – компост жана пленка колдонулганда өсүмдүктөгү жалбырактардын жана гүлдөрдүн санынын көбөйүшү болгон

Негизги сөздөр: интродукция; температура; жаан-чачын; мульчалоо; атрофия

Влияние метеорологических условий на развитие и цветение шафрана (*Crocus sativus* L.) в Чуйской долине Кыргызстана

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Аннотация. В период с 2021 по 2025 год проводились испытания и интродукция шафрана посевного (*Crocus sativus* L.) с целью диверсификации сельскохозяйственного производства. Шафран является новой культурой для Кыргызстана и выращивается ради получения рылец – ценной экспортно-ориентированной продукции. Целью работы было изучение строения цветка шафрана, а также динамики цветения в зависимости от метеорологических условий и агротехнических приемов (вариантов мульчирования). Опыты были заложены в коллекционном питомнике Кыргызского национального аграрного университета и на полях фермерского хозяйства «Дыйкан». Морфологическая оценка растений проводилась на делянках в трехкратной повторности. Учитывались высота и количество листьев на растении, степень их перезимовки и количество цветков. Статистическая обработка и визуализация метеорологических данных, а также данных по продуктивности цветения выполнялись с помощью программы MS Excel. По результатам испытаний установлено, что цветение шафрана происходит в яркие солнечные дни, тогда как в дождливую и пасмурную погоду цветки не раскрываются. Длительность фазы цветения составляла 15-30 дней в зависимости от температуры окружающей среды. Наиболее короткой эта фаза была в год посадки (до 15 дней), а относительно удлиненной – на третий год вегетации. Пик цветения приходился на период с середины до конца октября. Зимнее укрытие (мульчирование) растений оказало благоприятное воздействие на генеративные процессы, увеличивая количество цветков. Все типы мульчирования способствовали более интенсивному цветению. Выявлена существенная разница ($p \leqslant 0{,}04$ по среднему количеству цветков на делянке за 5 лет) при укрытии компостом (374 шт.), прозрачной пленкой (419 шт.) и бумагой (533 шт.) по сравнению с контролем (217 шт.). Таким образом, основными факторами, положительно влияющими на урожайность шафрана, являются формирование большего количества листьев и интенсивное цветение растений при использовании мульчирующих материалов (бумаги, пленки и компоста)

Ключевые слова: интродукция; температура; осадки; мульчирование; атрофия

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State policy for supporting beef cattle farming in the Republic of Kazakhstan: Mechanisms of subsidisation and concessional lending using Abai region as an example

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Abstract. This study aimed to evaluate the effectiveness of state policies supporting beef cattle farming in Kazakhstan by analysing the interaction between subsidies and concessional lending at a regional level. A combination of institutional, comparative and empirical-statistical analysis was employed to interpret the dynamics of production indicators, investment activity and budgetary parameters over time. It was found that the institutional configuration of state support has become multi-level, with a formal division of powers between central and regional authorities. The financing structure in the Abai region was found to be characterised by the predominance of financial instruments (KZT 7.8 billion) over direct forms of support (KZT 4.8 billion), indicating a policy shift towards stimulating investment activity. An empirical analysis of livestock numbers and production structure revealed a preference for an extensive development model, evidenced by the quicker growth in livestock numbers (with cattle numbers rising by 2.4%) compared to output growth (with meat production rising by 2.7%). However, access to credit remains uneven as collateral requirements limit the participation of small producers in financing programmes. This contributes to the strengthening of structural differentiation within the sector: agricultural holdings account for 55% of meat production, while households account for only 15%. Generalising the obtained results showed that state policy effectiveness is determined not only by financing volume, but also by support instrument coherence, institutional integration level, and accessibility to different producer categories. The practical significance of the results lies in their potential use in revising access criteria for small producers in subsidy programmes, including lowering project capacity requirements, and in adjusting budget planning in the agricultural sector by synchronising payments with production cycles

Keywords: budget transfers; deferred obligations; extensive model; investment projects; cluster model; digitalisation of the agricultural sector

Introduction

This study was conducted to assess the effectiveness of state policy in supporting beef cattle farming in the Republic of Kazakhstan, particularly in combining subsidy- and credit-based support mechanisms. Despite increased public expenditure on the agro-industrial complex and financing of subsidy programmes, production performance in the sector remains uneven, and access to financial instruments is characterised by pronounced regional disparities (Siximbayeva *et al.*, 2025). The Abai region is representative for analysing state policy in the livestock sector as it accounts for around 8% of the national total output of livestock products and the share of livestock farming in the region's gross output exceeds 55%, indicating specialisation and pasture potential (Kazhieva *et al.*, 2024). A. Yesbolova *et al.* (2025) established that small farms have

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limited access to credit resources due to their collateral base being so small. Meanwhile, 4.4 million tonnes of milk out of a total of 6.4 million tonnes are produced by private subsidiary farms. The authors also found that large agricultural enterprises received the majority of subsidies and concessional loans, with milk production increasing by 36.8% over five years. This intensified the structural asymmetry of the agricultural sector and uneven regional development. P. Shevchenko *et al.* (2024) demonstrated that using imported breeding lines results in higher productivity, with an average live weight of 518 kg – 19% higher than the breed standard – compared to local genotypes. However, the feasibility of implementing these innovations is contingent upon access to subsidised lending for the purchase of breeding animals and breeding services.

Kazakhstan's production systems remain highly dependent on pasture resources, while intensification is constrained by a shortage of arable land and limited access to financial support instruments, as argued in the work of S. Robinson & M. Petrick (2024). Based on a survey of 250 farms, the authors established that only 32.8% of respondents have access exclusively to rural pastures, 12.4% hold two 49-year state lease agreements, a 1% increase in access to arable land raises the self-production of concentrated feed by 5.2%, and credit-constrained farmers are 43% more likely to use mobile grazing and move their livestock 28 km further. B.R. Hankerson (2025) showed that only about 50% of Kazakhstan's suitable pasture lands are used in the production process, which indicates a reserve for the extensive expansion of the sector. At the same time, the author identified a link between grazing intensity and the degradation of land resources, emphasising the need to integrate environmental criteria into state subsidy mechanisms. The institutional dimension of the issue is examined in a study by J. Yin & J. Guo (2026). It was found that technological backwardness, infrastructural constraints and an unstable regulatory environment all contribute to the ineffectiveness of agricultural policy. Climate risks, together with imperfect financial instruments, increase production instability and limit investment activity. R. Yegemberdiyev *et al.* (2024) found that beef cattle farming competitiveness requires subsidies to be integrated with long-term credit instruments, as imports exceed exports by USD 292.3 million despite production increasing by 57% between 2018 and 2022. The authors emphasised that structural modernisation depends on coherent budgetary support, investment policy and export strategy.

G. Mussina *et al.* (2025) proved, based on a survey of farmers from 2020 to 2024, that entrepreneurial activity is only possible for individuals with a risk-aversion coefficient $rr(w) \leqslant 2$ in the absence of subsidies. However, subsidies of KZT 30,000 per head of cattle and KZT 4,500 per centner of milk enable farmers with rr(w) up to 4 to participate. At the same time, the region's crop production has a relative economic advantage over livestock farming. This means that beef cattle farming can only develop through state subsidies. Building on this, S. Wang *et al.* (2026) surveyed 420 farmers and demonstrated that risk-tolerant farmers implement environmentally sustainable practices with a coefficient of 0.101 and $p < 0.01$. Furthermore, multidimensional contextual factors – such as internal attitudes, resource potential and social legitimacy – reinforce the positive impact of risk preferences on the intention to switch to organic production. An analysis of agricultural production in Kazakhstan from 2017 to 2024, conducted by S. Sarbassova *et al.* (2025), confirmed the positive impact of subsidies on production dynamics. KZT 1 billion in subsidies generates an additional KZT 17.49 billion in output ($p = 0.0085$). However, the study also revealed a dependence on climatic factors, with production falling to KZT 7,576.5 billion in 2023 after peaking at KZT 9,481.2 billion. Meanwhile, access to credit resources was found to have a statistically insignificant effect, with a coefficient of -1.06 and $p = 0.6874$. This indicates the need for improved monitoring of state programmes. E. Bukin *et al.* (2025) proved that transferring pastures into private use leads to their intensified use and the degradation of vegetation cover, creating additional risks for producers who rely on subsidy support. The negative effects of privatisation were stronger for individual farmers, with a decline in the normalised difference vegetation index of 1.4-1.9%, than for agricultural enterprises. Spillover effects on neighbouring, non-privatised plots worsened vegetation conditions by a further 1.3-1.8%.

However, existing studies have not examined budget execution and the structure of livestock numbers at the regional level simultaneously. This study aimed to determine the effectiveness of state policy in supporting beef cattle farming in the Republic of Kazakhstan by analysing the interaction between subsidy mechanisms and concessional lending, using the Abai region as a case study. To achieve this, the following objectives were addressed: establishing the institutional structure and functional features of state support instruments, assessing their impact on investment activity and production indicators in the sector, and identifying structural constraints and imbalances affecting the effectiveness of agricultural policy implementation.

Materials and Methods

The study covered the period from 2014 to 2025 to analyse the transformation of state support mechanisms for livestock farming, changes in the institutional architecture of Kazakhstan's agricultural policy and current empirical data and budgetary parameters of medium-term planning for 2026-2028. The spatial focus was limited to the Republic of Kazakhstan, with Abai region being examined in detail as a representative case of the regional implementation of state support instruments. The region was chosen because its pasture farming structure corresponded to national average indicators, subsidy programmes were available, and investment projects were being implemented in beef livestock farming. The research methodology combined legal and regulatory analysis with elements of institutional modelling, legal systematisation and content analysis of regulatory acts. This approach enabled the identification of subsidy allocation mechanisms, the functional links between state institutions, and the structure of support instruments for the agricultural sector. The material basis consisted of regulatory acts concerning subsidy policy and support for livestock farming: These included the Order of the Minister of Agriculture of the Republic of Kazakhstan No. 3-2/615 (2014), the Order of the Acting Minister of Agriculture of the Republic of Kazakhstan No. 317 (2018), the Order of the Minister of Agriculture of the Republic of Kazakhstan No. 108 (2019) and the Order of the Minister of Agriculture of the Republic of Kazakhstan No. 107 (2020). The analysis aimed to assess the mechanisms of investment subsidisation, support for breeding, lending and processing development.

To evaluate the financial stability of the state support system, the method of comparing planned and actual budget execution indicators was employed. The analysis examined the volumes of subsidy financing, the level of budgetary debt and the existence of deferred state obligations to agricultural producers. Data from the Atameken National Chamber of Entrepreneurs (The outstanding subsidy..., 2026) and international analytical materials from the Food and Agriculture Organization of the United Nations (FAO) (2023) were used as sources. A functional and comparative analysis of macro-credit and microcredit programmes was used to study credit instruments. This covered loan terms, interest rates, collateral requirements and interest-rate compensation mechanisms for different producer categories, based on the budget lending programme (Order of the Minister of Agriculture of the Republic of Kazakhstan No. 322, 2023) and interest-rate subsidy mechanisms for loans and leasing operations (Order of the Deputy Prime Minister of the Republic of Kazakhstan – Minister of Agriculture of the Republic of Kazakhstan No. 436, 2018).

Budget policy dynamics were analysed using a macroeconomic approach, incorporating official statistical and forecast indicators from the Kazinform International News Agency (Nurmaganbetova, 2025), Agrosearch (Around 2 trillion..., 2026) and the World Bank (Trading Economics, n.d.). This included total public expenditure, agribusiness allocation volumes, and the proportion of transfers and subsidies within expenditure structures. The analysis period covered 2023-2028, enabling the combination of actual data with medium-term budget planning forecasts. The methodology for analysing regional development programmes was based on a case-study approach, with Abai region serving as the analytical unit. Materials used included official reports on the implementation of development programmes from Baibolsyn.kz (A sheep farming..., 2026) and Kazakhstan's Agribusiness (50 billion tenge..., 2026). The analysis assessed the sectoral specialisation of the region, the scale of financing, the development of infrastructure facilities, and the integration of production and processing components within agro-industrial chains. The empirical study of livestock development was based on descriptive statistical analysis of secondary data without econometric modelling. Sources included ElDala.kz (Breeding cattle numbers..., 2026), Qazinform (Mergalym, 2026) and FAO (2023). Structural analysis was applied to evaluate changes in livestock numbers and meat production. The study covered cattle, small ruminant and horse numbers, meat production and investment in fixed capital in the agro-industrial complex. Investment activity was analysed through a comparative dynamic comparison, examining the relationship between state support and investment volumes without providing a quantitative assessment of its strength.

A comparative analysis of livestock development models was carried out using typologisation, based on materials from the United States Department of Agriculture Foreign Agricultural Service (2022), the Agrarian Credit Corporation JSC (n.d.), OECD & FAO (2023). The intensive, extensive and cluster-based development models were compared according to the following criteria: productivity; production structure; investment; institutional support; and chain integration. At the same time, constraints relating to personnel, technology, biosecurity and digitalisation were considered as contextual factors that indirectly affect the effectiveness of state support instruments, rather than being evaluated directly in terms of the effectiveness of subsidy and credit policy. The study's limitations are related to the absence of micro-level data on individual farms, the inability to verify budget data at the level of individual payments, and the limited comparability of regional statistical indicators with those of other Kazakhstani regions.

Results

State policy for supporting beef cattle farming in the Republic of Kazakhstan

This policy is implemented through a multi-level governance system. At the national level, the rules for subsidisation, lending and budgetary parameters are defined, and at the regional level, these are put into practice in accordance with territorial specialisation. In the Abai region, this involves adapting support mechanisms to the pasture-based farming model and the structure of livestock production. This division of functions corresponds to the "policy design-policy delivery" model, which is typical of countries with territorially differentiated agricultural production (López-García *et al.*, 2024). In 2025, the total volume of state support for the agricultural sector in the Abai region was KZT 15.1 billion. Of this, KZT 7.8 billion was allocated to financial instruments, KZT 4.8 billion to livestock support and KZT 2.5 billion to crop production (The agricultural sector..., 2025). Thus, lending mechanisms and interest-rate compensation prevailed in the regional financing structure, corresponding to the general trend of Kazakhstan's agricultural policy shifting towards investment-based support instruments (Gebeyehu & Bedemo, 2024). At the same time, however, signs of budgetary instability were recorded in the region. Subsidy arrears owed to agricultural producers in the region for 2024-2025 reached KZT 2 billion (The outstanding subsidy..., 2026). This indicates a mismatch between the approved volumes of support and the actual capacity of budget financing. In international practice, irregularity in subsidy payments is regarded as a factor that reduces the predictability of investment activity among agricultural producers (FAO, 2023).

One of the support instruments at the national level is Order of the Minister of Agriculture of the Republic of Kazakhstan No. 322 (2023), which allows local executive bodies to borrow from the budget for up to 10 years at an annual interest rate of 1%. This programme is intended for large-scale investment projects, including dairy farms with a minimum of 400 head of cattle, feedlots with a minimum of 5,000 head of cattle, meat-processing enterprises, greenhouse complexes and irrigation facilities. Meanwhile, Kazakhstan operates the "Auyl Amanaty" microcredit programme, which supports small-scale farming. For livestock farming, the programme provides loans of up to 2,500 monthly calculation index (MCI) for a term of up to seven years at an interest rate of up to 2.5% (Kazakhstan stimulates agricultural..., 2025). Unlike macro-lending, this programme supports private subsidiary farms, cooperatives and the self-employed. However, access to financial instruments in Kazakhstan remains uneven. Large agricultural enterprises have advantages due to their access to collateral and ability to develop investment projects. In contrast, small producers are hindered by the requirements relating to formalising their activities and joining cooperatives. In the Abai region, this is reflected in the concentration of large investment projects around the regional programme for forming a meat cluster, combining state support with infrastructure and processing development (Implementation of the President's instructions..., 2026).

In 2025, the full volume of state support allocated to the Abai region, amounting to KZT 15.1 billion, was utilised (15.1 billion tenge..., 2025). At the same time, a programme to develop sheep farming in the region from 2026 to 2030 was approved, with KZT 50 billion of financing from the national budget. The programme envisaged the implementation of nine investment projects in the agro-industrial complex, with a total value of KZT 23.1 billion. The expected investment volume in the sector is projected to rise to KZT 78.2 billion (50 billion tenge..., 2026). While these indicators characterise the Abai region specifically, the nationwide trend lies in the expansion of state budgetary participation in Kazakhstan's agricultural sector. In this context, systematising the regulatory legal acts presented in Table 1 makes it possible to identify the main state support mechanisms and record their structural limitations at the regional level.

Table 1. Systematisation of regulatory and legal mechanisms for subsidising Kazakhstan's agro-industrial complex and their institutional characteristics

Regulatory legal act	Functional area	Implementation mechanism	Limitations of application
Order of the Acting Minister of Agriculture of the Republic of Kazakhstan No. 317 (2018)	Investment subsidies	Partial reimbursement of capital expenditure on the creation and modernisation of facilities: farms, processing, infrastructure	Forms the long-term investment base of the sector; however, due to requirements concerning the minimum capacity of projects, it is in practice oriented towards large agricultural formations, which limits the participation of small producers
Order of the Minister of Agriculture of the Republic of Kazakhstan No. 108 (2019)	Breeding livestock farming	Compensation of expenses for the purchase of breeding animals, breeding services, and artificial insemination	Ensures the genetic modernisation of the sector, but under the conditions of Abai region, the low share of breeding stock reduces the multiplier effect of the instrument
Order of the Minister of Agriculture of the Republic of Kazakhstan No. 3-2/615 (2014)	Processing of agricultural products	Reimbursement of expenses incurred by processing enterprises for the purchase of raw materials	Institutionally aimed at developing added value; however, actual financing of this area in the region remains minimal, indicating a gap in the "production-processing" chain
Order of the Deputy Prime Minister of the Republic of Kazakhstan – Minister of Agriculture of the Republic of Kazakhstan No. 436 (2018)	Lending and leasing	Subsidisation of part of the interest rate on loans and leasing operations	The most system-forming mechanism, ensuring the attraction of private capital; in 2025, it accumulated the main share of financial support resources
Order of the Minister of Agriculture of the Republic of Kazakhstan No. 107 (2020)	Crop production: feed base	Compensation of expenses for seeds, fertilisers, and plant protection products	Has an indirect impact on beef cattle farming through the formation of the feed base, but the volume of financing does not correspond to the needs of intensive development of the sector

Note: Ministry of Agriculture refers to the Ministry of Agriculture of the Republic of Kazakhstan
Source: compiled by the author

The analysis revealed that the regulatory system is fragmented, with each instrument functioning autonomously and lacking an integrated coordination framework. This makes it difficult to achieve synergy between the stages of agricultural production. In particular, support for primary production, such as livestock farming, is not accompanied by sufficient incentives for processing. This is evident from the low proportion of financing allocated to this area within the regional expenditure structure. A defining feature of the institutional model is the prevalence of compensatory mechanisms. While reimbursement of expenses already incurred reduces the risk of budgetary funds being misused, it creates an entry barrier for small farms that do not have sufficient working capital. This partly explains why access to investment subsidies is concentrated among large agricultural formations. Institutional weakness is reflected in the insufficient integration of the vertical value chain.

Of the analysed documents, four out of five provide for mechanisms of partial reimbursement of expenses. However, only Order of the Deputy Prime Minister of the Republic of Kazakhstan – Minister of Agriculture of the Republic of Kazakhstan No. 436 (2018) and signed by the Deputy Prime Minister, focuses on subsidising interest rates on loans and leasing. The main target groups for support are medium and large-scale agricultural enterprises, as Order of the Acting Minister of Agriculture of the Republic of Kazakhstan No. 317 (2018) establishes minimum capacity parameters for investment projects to qualify for compensation for capital expenditure. Lending mechanisms, however, require collateral. Order of the Minister of Agriculture of the Republic of Kazakhstan No. 108 (2019) is aimed at farms engaged in breeding livestock; however, the effectiveness of this instrument in the Abai region is limited by the low proportion of breeding stock in the herd. The analysis also revealed an imbalance in support for production versus processing. For example, Order of the Minister of Agriculture of the Republic of Kazakhstan No. 3-2/615 (2014) formally provides for the compensation of processing enterprises' expenses for raw material purchases, yet actual financing in this area remains minimal compared to lending programmes and investment subsidies. Meanwhile, Order of the Minister of Agriculture of the Republic of Kazakhstan No. 107 (2020) has only an indirect impact on beef cattle farming since it aims to support the feed base by compensating for expenses incurred in the purchase of seeds, fertilisers and plant protection products. Overall, it can be concluded that the regulatory system supporting Kazakhstan's agro-industrial complex primarily focuses on stimulating capital investment and lending activity. However, mechanisms for integrating production, processing and sales remain underdeveloped.

The dynamics of state support for the complex in the period 2026-2028 are characterised by an increase in national-level budgetary expenditure. According to official government forecasts, total public expenditure is expected to rise from KZT 27.7 trillion in 2026 to KZT 29.8 trillion in 2028 (Nurmaganbetova, 2025). Approximately KZT 2 trillion is earmarked for supporting agribusiness within Kazakhstan's agricultural policy for 2026-2028, primarily through concessional lending and financial intermediation mechanisms (Around 2 trillion..., 2026). According to the World Bank, transfers and subsidies accounted for over 69% of public expenditure in 2023, indicating the significant role of budgetary financing in state economic policy (Trading Economics, n.d.). Consequently, there is a clear shift in emphasis at the national level from direct subsidisation towards financial support instruments.

At the national level, the financing structure of Kazakhstan's agro-industrial complex is dominated by credit mechanisms, but the distribution of funds between individual sectors remains uneven. For example, KZT 44 billion was allocated in 2025 to support the processing of agro-industrial products, accounting for just 4.4% of the KZT 1 trillion total state support for the agro-industrial complex (Baiterek National Holding..., 2025). This indicates a concentration of resources in primary production and financial stimulation, with the processing segment receiving a smaller share of financing. The article did not apply correlation or regression models, meaning the presented data can record structural ratios and trends, but cannot prove the direct causal impact of individual support instruments on production outcomes.

The Abai region is characterised by a distinct regional configuration of state support. New and regionally adapted programmes for the development of beef cattle farming are being formed in Abai region in the context of the broader transformation of Kazakhstan's agricultural policy, which is gradually shifting from universal support instruments to territorially differentiated models. This transformation is driven by the need to consider the natural resource specialisation of regions, which is particularly relevant in the east of the country, where pasture resources, livestock farming traditions and the potential for export-oriented production are combined (Tkacheva *et al.*, 2024). In 2025, the region fully utilised the allocated financing volume of KZT 15.1 billion (15.1 billion tenge..., 2025). At the same time, KZT 50 billion in budgetary funds was approved for the development of sheep farming in the region for 2026-2030. In 2025, the implementation of nine investment projects in the agro-industrial complex with a total value of KZT 23.1 billion was planned (50 billion tenge..., 2026).

Unlike national programmes, which have universal support mechanisms, the regional initiatives of the Abai region are sectorally and territorially specialised. The regional "Igilik" programme focuses on developing sheep farming and renewing the genetics of livestock (A sheep farming..., 2026). As part of the sheep farming development programme for 2026-2030, the aim is to increase the number of sheep from 1.2 million to 2.3 million (50 billion tenge…, 2026). These figures specifically characterise the target parameters of the Abai region's regional programme, rather than the nationwide dynamics of livestock farming in Kazakhstan. Here, state support is combined with the region's territorial specialisation, whereby some agricultural land is used as pasture. Another area of regional policy is the development of processing infrastructure. In the Zhanasemey District, a project for a meat-processing complex with an annual production capacity of 11.4 thousand tonnes and a total investment volume of KZT 7.7 billion is underway (Serdalina, 2025). The project also provides for the formation of feedlots with a capacity of up to 40 thousand head of livestock. These data characterise a local investment project in the Abai region and cannot be extrapolated to the entire Kazakhstani agricultural sector. Nevertheless, they demonstrate that regional policy is oriented towards integrating production and processing within individual territorial clusters.

A comparison of national and regional programmes reveals differences in their functional purpose. At the national level, the main emphasis is on financial stimulation through subsidies and loans, whereas in the Abai region, support is supplemented by specific investment projects and production specialisation. The "Igilik" programme for developing sheep farming, and the construction of the meat-processing complex are mutually complementary, as they cover breeding, increasing livestock numbers and processing products. However, the available data does not provide sufficient evidence to suggest that a fully formed cluster has been established, as no formalised assessment of the effectiveness of intersectoral integration has been conducted. The personnel component remains an additional limitation. Abai region's regional programmes up to 2028 include measures to train specialists and expand employment in the processing sector (A new level…, 2026). This indicates that staffing provision has been incorporated into regional agricultural policy. Nevertheless, the materials presented demonstrate institutional and investment modernisation, although they do not confirm the direct impact of individual programmes on changes in productivity or production efficiency due to the absence of formal statistical modelling.

Empirical assessment of the effectiveness of state support in the Abai region

In Kazakhstan, the structure of livestock farming is linked to natural resource conditions: pastures account for 83.8% of agricultural land, and part of the territory belongs to semi-arid zones where sheep and goats are better adapted to the conditions than cattle (Yerseitova *et al.*, 2018). However, the current system of support for Kazakhstan's agro-industrial complex lacks separate mechanisms exclusively aimed at developing beef cattle farming, thus preserving the advantage of less capital-intensive farming methods. Nationally, the cattle population in Kazakhstan reached 8.2 million in 2025, while the sheep and goat population stood at 20.6 million, and the horse population at 4.6 million. Meat production reached 1.2 million tonnes (Mergalym, 2026). The ratio of livestock population growth to meat production indicates that the increase in livestock numbers is not accompanied by a proportional increase in output. An economic assessment of the state of livestock farming in Kazakhstan shows that overcoming this imbalance requires the creation of integrated production structures, namely meat hubs, to ensure a link between small producers and processing enterprises (Abdikerimova *et al.*, 2024). The discrepancy between livestock numbers and production clarifies the impact of state policy: an increase in the resource base is not accompanied by a proportional increase in output. This suggests that financial instruments are not aligned with production efficiency requirements. The territorial structure of livestock farming in Kazakhstan remains uneven. Regions with developed pasture farming and access to infrastructure typically have higher indicators of livestock concentration. According to FAO (2023), over half of Kazakhstan's land is used for pasture. Under these conditions, large farms have better access to winter pastures, credit resources and subsidy programmes than small producers, who are involved in the support system to a lesser extent.

The current livestock structure in the Abai region is characterised by the dominance of small ruminants, with a population of over 1.17 million compared to 752,500 cattle and 405,900 horses (Breeding cattle numbers…, 2026). A comparison between investment activity and production indicators is particularly indicative for the region. In 2024, investment in fixed capital in the region's agro-industrial complex exceeded KZT 43.2 billion, and a minimum level of KZT 48 billion was planned for 2025 (Mamyrkhanova, 2024). Meanwhile, the national increase in meat production was 2.7% (Mergalym, 2026). This suggests that subsidisation maintains production volumes, while lending stimulates capital investment and drives structural transformation. Analytically, this distinguishes the functional roles of state support instruments. Subsidies stabilise production in the short term and reduce operational risks, but they do not incentivise technological change. Conversely, lending establishes the investment framework for development, enabling the renewal of fixed assets and expansion of production capacity. Accordingly, credit mechanisms act as the channel through which state policy influences the sector's long-term dynamics. However, the presented indicators cannot be interpreted solely as the result of state policy. The development of livestock farming is also influenced by natural-resource factors and external demand for meat products, including from Central Asian countries and China (OECD & FAO, 2023). Therefore, within this study, state support is considered as one of the factors in the development of the sector, rather than as the sole cause of changes in production indicators.

The Abai region is characterised by a combination of extensive and partially integrated production models. The target parameters of state policy, particularly the aim to increase the average live weight of cattle from 336 kg to 400 kg (United States Department of Agriculture Foreign Agricultural Service, 2022), indicate a shift towards intensified production. However, the actual indicators suggest that an extensive development model is predominant. In 2025, cattle numbers in Kazakhstan grew by 2.4%, while meat production increased by only 2.7% (Mergalym, 2026). This does not demonstrate an increase in productivity per head. This is further evidenced by the continued high proportion of small farms in the production structure and the prevalence of pasture-based farming, which results in lower average daily weight gains compared to intensive feedlot systems. Under these conditions, the target of 400 kg remains primarily a strategic benchmark, as intensification is limited in practice by producers' uneven access to breeding material, compound feed resources and investment in feedlot infrastructure.

The structure of meat production in Kazakhstan, where agricultural holdings account for approximately 55% of output, individual farms for 30%, and households for 15% (Daribayeva *et al.*, 2025), reflects the partial concentration of production in large economic structures. This indicator was used as an empirical indicator of the formation of cluster elements, as it demonstrates the presence of vertical integration only in part of the production chains. At the same time, the profitability level of agricultural holdings, at 18-22%, indicates the higher efficiency of capitalised structures compared with small-scale forms of farming, which confirms the influence of the investment component of state support. The models of beef cattle development are specified through actual indicators in Table 2.

Table 2. Comparative characteristics of beef livestock development models

Criterion	Intensive elements	Extensive elements	Cluster elements
Productivity	Average live weight of cattle: 336 → 400 kg (target benchmark)	Growth in meat production: 2.7% with higher growth rates in livestock numbers	Profitability of agricultural holdings: 18-22%
Production structure	Share of capitalised farms: ~55%	Share of households: ~15%	Integrated production: agricultural holdings + farmers: ~55% + 30%
Investment	Investment in the agro-industrial complex: over KZT 43.2 billion in 2024	Low capitalisation of small farms	Processing investment projects: KZT 7.7 billion meat-processing plant
Institutional support	Access to loans at 1-2.5%	Limited access to financing	State programmes + infrastructure projects
Chain integration	Partial modernisation	Absence of processing among small farms	Processing capacity: 11.4 thousand tonnes per year

Note: cattle refer to bovine livestock

Source: compiled by the author based on United States Department of Agriculture Foreign Agricultural Service (2022), FAO (2023), Order of the Minister of Agriculture of the Republic of Kazakhstan No. 322 (2023), M. Mamyrkhanova (2024), A. Daribayeva *et al.* (2025), United Nations Development Programme (2025), O. Sushchenko *et al.* (2026), N. Mergalym (2026), Agrarian Credit Corporation JSC (n.d.)

Analysis of the presented indicators shows that the Abai region has not transitioned to an intensive or cluster-based model. Instead, a combination of different types of development is evident, with extensive characteristics remaining dominant. This is reflected in livestock numbers growing faster than production, which indicates the limited impact of subsidies on productivity. At the same time, credit instruments facilitate the formation of individual cluster elements by financing processing and infrastructure. The impact of these instruments is localised and concentrated in the segment of large farms, which explains the asymmetry in the sector's development. Thus, state support creates a mixed model in which subsidisation maintains the existing production structure while concessional lending creates the conditions for its transformation. However, without systemic integration, these effects are partial.

The effectiveness of state support for beef livestock production in the Abai region is limited by structural constraints primarily relating to financing, access to credit resources and technological modernisation. At the national level, budgetary support for producers accounted for 4.9% of gross farm receipts in 2021-2023, which is lower than the average for OECD (2024) monitoring countries (9%) and OECD countries (14%). This indicates the limited scale of direct support for Kazakhstan's agricultural sector compared to international practice. At the same time, the predominance of subsidies linked to capital expenditure and resource provision increases producers' dependence on regular budget financing. In cases of delayed payments or incomplete financing, this complicates the implementation of investment projects and reduces the predictability of production planning.

Another limitation is uneven access to financial instruments. Large agricultural enterprises are better able to attract concessional loans due to their access to collateral and their ability to prepare investment projects, whereas small farms remain outside the system of long-term lending. Consequently, state support is characterised by differential coverage of different categories of producers, exacerbating the structural polarisation of the sector. Technological constraints also directly affect the effectiveness of support instruments. According to sectoral reviews, around 80% of agricultural machinery in Kazakhstan has exceeded its standard service life (International Trade Administration, n.d.). This reduces effectiveness even where access to subsidies or credit resources is available, since some farms operate with outdated materials and technology. Partial subsidisation of machinery renewal does not compensate for the extent of accumulated technological depreciation. Personnel constraints are mainly national in character. It is estimated that there is a shortage of approximately 6.5 thousand agricultural specialists in Kazakhstan, while only around 28% of these specialists have the relevant professional qualifications (Kazakhstan's agricultural sector…, 2025). This restricts the implementation of production and management practices, thereby reducing the effectiveness of modernisation programmes and concessional lending.

The analysis showed that the effectiveness of state support depends on two factors: the volume of financing and the coherence between financial instruments and the production capacities of farms. While subsidy mechanisms primarily support ongoing operations and reduce short-term costs, there was insufficient evidence in this study to demonstrate a direct link with increased productivity or technological modernisation. Conversely, credit instruments in the Abai region are associated with the implementation of investment projects in processing and the expansion of production infrastructure. This is reflected in increased capital investment and the development of individual cluster elements. The results obtained suggest that the model of state support for beef cattle farming in Kazakhstan can be characterised as partially integrated. At the national level, financial, technological and personnel constraints persist, reducing the effectiveness of subsidy policy. In the Abai region, however, concessional lending is mainly used for investment projects and infrastructure development. However, access to these mechanisms remains uneven depending on the size of the farm.

Discussion

The analysis confirmed that state support for beef livestock farming in Kazakhstan varies in effectiveness depending on the instruments used, production structure, and producers' level of integration into the financial system of the sector. The study established that the total volume of state support in the Abai region in 2025 amounted to KZT 15.1 billion. Of this, KZT 7.8 billion was allocated to financial instruments, KZT 4.8 billion to livestock farming and KZT 2.5 billion to crop production. At the same time, subsidy arrears for 2024-2025 totalled KZT 2 billion. This indicates a concentration of support in the financial and credit segment combined with an insufficient stable budgetary provision. Meanwhile, the cattle population in Kazakhstan increased by 2.4% to reach 8.2 million head in 2025, while meat production increased by only 2.7% to reach 1.2 million tonnes. The ratio identified between livestock growth and production growth does not suggest increased sectoral productivity; rather, it reflects the preservation of extensive development. These results are partly consistent with those of D. Matakbayev & S. Shauyenov (2025), who found that genetic improvement of the herd can increase average daily weight gain by 12-18%, depending on breed and feeding system, in their study of Kazakhstani livestock farming. The present study also found that state policy is oriented towards breeding: target parameters envisage an increase in the average live weight of cattle from 336 kg to 400 kg. However, actual results in the Abai region demonstrated slower intensification. Despite the increase in livestock numbers, no faster growth in meat production was recorded. This suggests that breeding programmes largely function in isolation from the modernisation of fattening and processing systems. In addition, the structure of meat production in Kazakhstan remains uneven. According to a recent study, agricultural holdings accounted for around 55% of meat production, while individual farms and households accounted for 30% and 15%, respectively. This level of concentration in production is consistent with the findings of D. Matakbayev & S. Shauyenov (2025), who discovered that large integrated farms exhibit productivity metrics that are 20-25% higher than those of smaller producers, thanks to their use of breeding and technological tools. A similar trend was observed in the Abai region, where large producers had better access to concessional lending and investment programmes.

Comparing the results with those of the study by S.M. Yessengaliyeva *et al.* (2021) revealed the importance of technological modernisation in improving sector efficiency. The authors found that introducing resource-saving technologies could reduce production costs by 15-20% and increase labour productivity by almost a third. The present study found that around 80% of agricultural machinery in Kazakhstan has exceeded its standard service life, limiting the potential for large-scale modernisation. Nevertheless, investment in fixed capital in the Abai region's agro-industrial complex exceeded KZT 43.2 billion in 2024, with plans to reach no less than KZT 48 billion in 2025. While this indicates growth in investment activity, it does not confirm an automatic transition to an intensive production model since technological renewal is concentrated mainly in large farms.

Comparing the results with those of the study by K. Džermeikaitė *et al.* (2023) revealed the technological gap between the potential of precision livestock farming and the current state of the sector. The authors found that using automated monitoring systems and digital feed control systems could increase herd productivity by 10-15% and reduce feed losses by up to 12%. The present study found that such technologies are only applied fragmentarily in the Abai region, mainly in large agricultural formations. The main limitation was found not to be a technological deficit per se, but rather uneven access to credit resources and the high costs of modernisation for small farms. This clarifies that technological modernisation in Kazakhstan depends not only on producers' innovative activity, but also on the structure of state support.

Comparing the results with those of the study by G. Gongal *et al.* (2022) clarified the functional role of veterinary infrastructure in the state support system for beef livestock farming. These authors emphasise that the effectiveness of veterinary control depends on the system's capacity for an early response and coordination. In an international context, this is associated with reducing economic losses from epizootics by 25-40%. However, the present study found that the development of the veterinary system in Kazakhstan is mainly taking place through institutional and infrastructural strengthening without a clearly traceable link to increased productivity in beef cattle farming in the Abai region. This analysis supports a key analytical conclusion: in the study by G. Gongal *et al.*, veterinary infrastructure is integrated into a risk management model where it contributes to economic efficiency, whereas in Kazakhstan it primarily serves to reduce epizootic risks and ensure basic production stability. Therefore, the difference lies not in the existence of infrastructure, but in the extent to which it is integrated into the sector's production and economic outcomes.

Comparing the results with those of the study by A. Gabriel & M. Gandorfer (2023) revealed different levels of institutional use of digital tools in the agricultural sector. In their work, these authors consider digitalisation to be a factor in improving the efficiency of the production process in the agricultural sectors of EU countries. However, the present study found no evidence to suggest that digitalisation is an independent factor in increasing the productivity of beef cattle farming in Kazakhstan, particularly in the Abai region. The results obtained provide a clear distinction between the functions of digital tools: in European models, they are integrated into production and management processes, whereas in Kazakhstan, their use is mainly limited to administrative and accounting functions related to the provision of public services. Accordingly, in the examined context, digitalisation does not transform the production structure of the sector, but rather plays an auxiliary role in ensuring the functioning of the state regulatory system.

Comparing the results with those of D.R.K. Saikanth *et al.* (2023) revealed the environmental dimension of the sector's development. The authors found that the extensive use of pastures without controlling grazing pressure could reduce land productivity by 18-30% in the long term. The present study found that pastures account for 83.8% of Kazakhstan's agricultural land and that the pasture-based production model dominates in the Abai region. While this ensures the sector's adaptation to natural and climatic conditions, it also maintains the extensive nature of development. The increase in livestock numbers outpaced the modernisation of fattening and processing systems, indicating limited production intensity.

A comparative analysis with the study by S. Tokenova *et al.* (2025) confirmed the existence of institutionally determined restrictions on small-scale farming access to state financial support instruments, as evidenced by regulatory and administrative participation requirements for lending and subsidisation programmes. The present study empirically clarified these provisions by identifying structural unevenness in the distribution of support, whereby entities with a higher level of capitalisation and institutional capacity systematically accumulate advantages. Even the existence of specialised microcredit instruments was found to be insufficient to eliminate basic barriers to access, as the requirements for cooperation and formalisation of economic activity act as a selective mechanism for allocating resources. Generalising the results obtained led to the conclusion that state policy for developing beef cattle farming in the Republic of Kazakhstan is only partially effective: while it expands the sector's production and investment potential, it simultaneously reproduces institutional asymmetry in access to support, limiting inclusiveness and reducing the systemic effect of implemented measures.

Conclusions

The study found that the institutional configuration of state support for beef cattle farming in the Republic of Kazakhstan, using the Abai region as an example, is multi-level, with a formal division of functions between the central government and the regional government. The total volume of financing in the Abai region reached KZT 15.1 billion in 2025. The share of financial instruments (KZT 7.8 billion) exceeded that of direct support for livestock farming (KZT 4.8 billion). This demonstrated a shift in policy emphasis from compensatory mechanisms to stimulating investment activity. This resulted in the identification of accumulated deferred subsidy obligations to agricultural producers in the Abai region for 2024-2025, totalling KZT 2 billion as of February 2026. This proved the existence of a gap between budget planning and the state's actual fiscal capacity. Systematising regulatory legal acts revealed the fragmented nature of the regulatory system, where each subsidy instrument operates autonomously without an integration framework. Meanwhile, support for processing remains minimal against the backdrop of compensation for capital expenditure dominating, which, in practice, favours large agricultural enterprises.

The study found that the number of small ruminants in the Abai region exceeds 1.17 million, while the cattle population amounts to 752,500. It also found that the rate of livestock growth outpaces meat production growth, indicating the persistence of an extensive model and productivity problems. The outcome was the identification of asymmetric effectiveness of instruments: credit mechanisms demonstrated greater transformative capacity than subsidies, but access to them was uneven due to collateral requirements, intensifying the structural polarisation of the sector. The implementation of investment projects such as the construction of a 11.4-thousand-tonne-per-year meat-processing complex in Zhanasemey District with an investment of KZT 7.7 billion indicates the positive impact of credit instruments on investment activity. However, agricultural holdings account for only 55% of meat production, suggesting that this impact is mainly limited to large-scale producers.

The level of budgetary support in the structure of gross farm receipts was only 4.9%, while the wear of agricultural machinery exceeded 80%, which, together with a shortage of 6.5 thousand specialists, forms systemic constraints on the transition to intensive production. The analysis identified five types of systemic limitations in state policy in Abai region: an investment-production gap, where KZT 43.2 billion in investment generated only a 2.7% increase in meat production; uneven access to financial instruments due to collateral requirements; a personnel deficit, with 6.5 thousand vacancies and only 28% of specialists having relevant professional education; technological ageing, with 80% of machinery exceeding its standard service life; and a disproportion between support for production and support for processing, with only 4.4% of the agro-industrial complex budget allocated to processing while capacity utilisation stands at 37.6%. Prospects for further research lie in developing an adjusted model of inter-budgetary relations that would eliminate the gap between declared support volumes and actual financing at the regional level.

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References

[1] 15.1 billion tenge in subsidies have been allocated to support agricultural producers in the Abai region. (2025). Retrieved from https://ortcom.kz/ru/novosti/1762849116.

[2] 50 billion tenge will be allocated over 5 years for the sheep farming development program in the Abai region. (2026). Retrieved from https://eldala.kz/novosti/zhivotnovodstvo/24202-na-programmu-razvitiya-ovcevodstva-v-oblasti-abay-vydelyat-50-mlrd-tenge.

[3] A new level of agricultural development: Transition to a progressive agroeconomy launched on the President's instructions. (2026). Retrieved from https://surli.cc/ajxxbq.

[4] A sheep farming development program will be adopted in the Abai region. (2026). Retrieved from https://baibolsyn.kz/ru/novosti/programmu-razvitiya-ovcevodstva-primut-v-oblasti-abaj/.

[5] Abdikerimova, G., Yesbolova, A., Moldabekov, B., Kulanova, D., & Seidakhmetov, M. (2024). Economic assessment of the state of livestock industry in Kazakhstan: Prerequisites for the creation of a meat hub. *Agricultural and Resource Economics: International Scientific E-Journal*, 10(1), 29-45. doi: 10.51599/are.2024.10.01.02.

[6] Agrarian Credit Corporation JSC. (n.d.). *Annual report 2021*. Retrieved from https://agrocredit.kz/upload/iblock/48a/tdlgoaitwlgy81tuxfvhyezz0bvq93iv.pdf.

[7] Around 2 trillion tenge to be allocated for agribusiness support in Kazakhstan in 2026-2028. (2026). Retrieved from https://agrosearch.kz/en/news/na-podderzku-agrobiznesa-v-kazaxstane-napravyat-okolo-2-trln-tenge-v-2026-2028-godax.

[8] Baiterek National Holding plans to allocate 1 trillion tenge to support farmers. (2025). Retrieved from https://baiterek.gov.kz/ru/pr/news/1-trln-tenge-planiruet-napravit-ao-nukh-bayterek-na-podderzhku-agrariev.

[9] Breeding cattle numbers are growing in the Abai region. (2026). Retrieved from https://eldala.kz/novosti/zhivotnovodstvo/24127-pogolove-plemennogo-skota-rastet-v-oblasti-abay.

[10] Bukin, E., Robinson, S., & Petrick, M. (2025). The effects of land privatization on pasture productivity in south-eastern Kazakhstan. *Land Use Policy*, 158, article number 107741. doi: 10.1016/j.landusepol.2025.107741.

[11] Daribayeva, A., Alina, G., Nurgaliyeva, A., Ukubassova, G., & Tursumbayeva, M. (2025). Kazakhstan's meat market: Analysis of production, consumption, and export. *Scientific Horizons*, 28(5), 90-101. doi: 10.48077/scihor5.2025.90.

[12] Džermeikaitė, K., Bačėninaitė, D., & Antanaitis, R. (2023). Innovations in cattle farming: Application of innovative technologies and sensors in the diagnosis of diseases. *Animals*, 13(5), article number 780. doi: 10.3390/ani13050780.

[13] Food and Agriculture Organization of the United Nations (FAO). (2023). *Elaboration of the state programme 2022-2026 (Including the concept) of agro-industrial development – TCP/KAZ/3801*. Retrieved from https://openknowledge.fao.org/handle/20.500.14283/cc8533en.
[14] Gabriel, A., & Gandorfer, M. (2023). Adoption of digital technologies in agriculture – an inventory in a European small-scale farming region. *Precision Agriculture*, 24, 68-91. doi: 10.1007/s11119-022-09931-1.
[15] Gebeyehu, L., & Bedemo, A. (2024). How agricultural credit and subsidies impact agricultural productivity in Ethiopia: Empirical evidence using ARDL model. *Cogent Food & Agriculture*, 10(1), article number 2329118. doi: 10.1080/23311932.2024.2329118.
[16] Gongal, G., Rahman, H., Thakuri, K.C., & Vijayalakshmy, K. (2022). An overview of transboundary animal diseases of viral origin in South Asia: What needs to be done? *Veterinary Sciences*, 9(11), article number 586. doi: 10.3390/vetsci9110586.
[17] Hankerson, B.R. (2025). *Pasture, grazing, and meat production in Kazakhstan – current state and future opportunities*. (Doctoral dissertation, Humboldt University of Berlin, Berlin, Germany). doi: 10.18452/34649.
[18] Implementation of the President's instructions: Abai region strengthens industrial, agricultural, and transport-logistics potential. (2026). Retrieved from https://surl.li/mlrpiw.
[19] International Trade Administration. (n.d.). *Kazakhstan – agricultural sector*. Retrieved from https://www.trade.gov/country-commercial-guides/kazakhstan-agricultural-sector.
[20] Kazakhstan stimulates agricultural cooperation. (2025). Retrieved from https://surl.li/dxexzb.
[21] Kazakhstan's agricultural sector faces acute shortage of specialists. (2025). Retrieved from https://dairynews.today/news/v-kazakhstane-agrarnyy-sektor-ispytyvaet-ostruyu-nekhvatku-spetsialistov.html.
[22] Kazhieva, Zh., Barchak, M., & Zamanbekova, A. (2024). Small and medium-sized entities in livestock sector of the Republic of Kazakhstan: Factors of increasing production volumes. *Problems of AgriMarket*, 2, 137-148. doi: 10.46666/2024-2.2708-9991.11.
[23] López-García, D., Cruz-Maceín, J.L., & DiPaula, M. (2024). Agri vs. food? Perceptions of local policymakers on agri-food policies from a multilevel approach. *Frontiers in Sustainable Food Systems*, 8, article number 1399746. doi: 10.3389/fsufs.2024.1399746.
[24] Mamyrkhanova, M. (2024). *Criminalization of assault, eviction of the aggressor: A deputy spoke about new amendments prepared by the Majilis*. Retrieved from https://www.zakon.kz/sobytiia/6421855-kriminalizatsiya-poboev-vyselenie-agressora-deputat-rasskazal-o-novykh-popravkakh-podgotovlennykh-mazhilisom.html.
[25] Matakbayev, D., & Shauyenov, S. (2025). Improving feed efficiency in Kazakh white-headed cattle: The role of residual feed intake, growth, and dry matter intake. *Scientific Horizons*, 28(6), 9-22. doi: 10.48077/scihor6.2025.09.
[26] Mergalym, N. (2026). *Big push ahead for Kazakhstan's cattle numbers*. Retrieved from https://qazinform.com/news/big-push-ahead-for-kazakhstans-cattle-numbers-3671b9.
[27] Mussina, G., Kussaiynov, T., Kadrinov, M., Sarsembayeva, G., & Assilov, B. (2025). Searching for a risk-efficient production structure on crop-livestock farms. *International Journal of Business Information Systems*, 50(8), 22-37. doi: 10.1504/IJBIS.2025.151328.
[28] Nurmaganbetova, Zh. (2025). *Kazakh Government presents 2026-2028 economic growth forecast*. Retrieved from https://qazinform.com/news/kazakh-government-presents-2026-2028-economic-growth-forecast-b80a06.
[29] Order of the Acting Minister of Agriculture of the Republic of Kazakhstan No. 317 "On Approval of the Rules for Subsidizing the Reimbursement of Part of the Expenses Incurred by an Entity in the Agro-Industrial Complex for Investment Investments". (2018, July). Retrieved from https://prg.kz/document/?doc_id=31769410.
[30] Order of the Deputy Prime Minister of the Republic of Kazakhstan – Minister of Agriculture of the Republic of Kazakhstan No. 436 "On Approval of the Rules for Subsidizing Interest Rates for Lending to Entities in the Agro-Industrial Complex, as well as Leasing for the Purchase of Farm Animals, Machinery and Technological Equipment". (2018, October). Retrieved from https://prg.kz/document/?doc_id=37925596.
[31] Order of the Minister of Agriculture of the Republic of Kazakhstan No. 3-2/615 "On Approval of the Rules for Subsidizing the Costs of Processing Enterprises for the Purchase of Agricultural Products for the Production of Deep Processing Products". (2014, November). Retrieved from https://prg.kz/document/?doc_id=31658375.
[32] Order of the Minister of Agriculture of the Republic of Kazakhstan No. 108 "On Approval of the Rules for Subsidizing the Development of Livestock Breeding, Increasing the Productivity and Quality of Livestock Products". (2019, March). Retrieved from https://prg.kz/document/?doc_id=32302766.
[33] Order of the Minister of Agriculture of the Republic of Kazakhstan No. 107 "On Approval of the Rules for Subsidizing the Increase in Yield and Quality of Crop Products". (2020, March). Retrieved from https://prg.kz/document/?doc_id=33097375.
[34] Order of the Minister of Agriculture of the Republic of Kazakhstan No. 322 "On Approval of the Rules for Lending to Projects in the Agro-Industrial Complex". (2023, August). Retrieved from https://surl.li/ttmlbm.

[35] Organisation for Economic Co-operation and Development & Food and Agriculture Organization of the United Nations (OECD & FAO). (2023). *OECD-FAO agricultural outlook 2023-2032*. doi: 10.1787/08801ab7-en.
[36] Organisation for Economic Co-operation and Development (OECD). (2024). *Agricultural policy monitoring and evaluation 2024: Innovation for sustainable productivity growth*. doi: 10.1787/74da57ed-en.
[37] Robinson, S., & Petrick, M. (2024). Land access and feeding strategies in post-Soviet livestock husbandry: Evidence from a rangeland system in Kazakhstan. *Agricultural Systems*, 219, article number 104011. doi: 10.1016/j.agsy.2024.104011.
[38] Saikanth, D.R.K., Supria, Singh, B.V., Rai, A.K., Rana, S.R., Sachan, D.S., & Singh, B. (2023). Advancing sustainable agriculture: A comprehensive review for optimizing food production and environmental conservation. *International Journal of Plant & Soil Science*, 35(16), 417-425. doi: 10.9734/ijpss/2023/v35i163169.
[39] Sarbassova, S., Aimurzina, B., & Mataibaeva, G. (2025). Effectiveness of agricultural subsidies in Kazakhstan as a factor of inclusive development. *Economic Series of the Bulletin of L.N. Gumilyov ENU*, 3, 205-226. doi: 10.32523/2789-4320-2025-3-205-226.
[40] Serdalina, A. (2025). *Construction of a meat processing complex has begun in the Abai region*. Retrieved from https://www.inform.kz/ru/stroitelstvo-myasopererabativayushego-kompleksa-nachalos-v-oblasti-abay-65cace.
[41] Shevchenko, P., Miciński, J., & Brel-Kisseleva, I. (2024). Evaluation of Aberdeen angus breeding bulls in the northern region of the Republic of Kazakhstan. *Animals*, 14(6), article number 894. doi: 10.3390/ani14060894.
[42] Siximbayeva, G., Shayakhmetova, K., Yernazarova, U., & Ruzanov, R. (2025). Efficiency of agriculture subsidies in Kazakhstan. *Central European Journal of Public Policy*, 19(1), 22-37. doi: 10.2478/cejpp-2025-0003.
[43] Sushchenko, O., Tireuov, K., Stoyanova-Asenova, S., Tymkovan, V., & Kozubova, N. (2026). Socio-economic drivers of sustainable agrobusiness development: Implications for responsible SME practices. In M. Petrova (Ed.), *Reshaping socially responsible business practices in small and medium enterprises* (pp. 245-284). Hershey: IGI Global Scientific Publishing. doi: 10.4018/979-8-3373-3805-7.ch008.
[44] The agricultural sector in Abai region is developing steadily. (2025). Retrieved from https://massaget.kz/news/abay-oblysyinda-auyil-sharuashyilyigyi-salasyi-turaktyi-131617/.
[45] The outstanding subsidy arrears to farmers in the Abai region are promised to be repaid in the spring. (2026). Retrieved from https://surl.li/jrfydf.
[46] Tkacheva, A., Saginova, S., Karimbergenova, M., Taipov, T., & Saparova, G. (2024). Problems and prospects for the development of cluster structuring in the economy of Kazakhstan's agricultural sector: Theory and practice. *Economies*, 12(7), article number 185. doi: 10.3390/economies12070185.
[47] Tokenova, S., Mussina, R., Zhenskhan, D., Kadrinov, M., & Orynbekova, G. (2025). The present state of development of agricultural cooperatives in Kazakhstan: Problems and Prospects. *International Journal of Innovative Research and Scientific Studies*, 8(6), 113-127. doi: 10.53894/ijirss.v8i6.9512.
[48] Trading Economics. (n.d.). *Kazakhstan – subsidies and other transfers (% of expense)*. Retrieved from https://tradingeconomics.com/kazakhstan/subsidies-and-other-transfers-percent-of-expense-wb-data.html.
[49] United Nations Development Programme. (2025). *The first biennial transparency report of the Republic of Kazakhstan*. Retrieved from https://surl.li/epyltb.
[50] United States Department of Agriculture Foreign Agricultural Service. (2022). *Kazakhstan finalizes national agricultural sector development project plan 2021-2025*. Retrieved from https://surl.li/brxujt.
[51] Wang, S., Dulatbay, Y., Sun, P., Yessengaliyeva, S., Ling, T.J., Kozhayeva, A., Sugirbay, A., Begeyeva, M., & Nartay, B. (2026). The role of risk preferences in transitioning to organic livestock farming: Evidence from Kazakhstan. *International Journal of Agriculture and Biosciences*, 15(1), 354-363. doi: 10.47278/journal.ijab/2025.191.
[52] Yegemberdiyev, R., Yessirkepova, A., Baineyeva, P., Kamalov, A., & Orazova, B. (2024). Mechanisms for improving the economic efficiency of livestock development in the Republic of Kazakhstan. *International Journal on Food System Dynamics*, 15(3), 316-328. doi: 10.18461/ijfsd.v15i3.K9.
[53] Yerseitova, A., Issakova, S., Jakisheva, L., Nauryzbekova, A., & Moldasheva, A. (2018). Efficiency of using agricultural land in Kazakhstan. *Entrepreneurship and Sustainability Issues*, 6(2), 558-576. doi: 10.9770/jesi.2018.6.2(7).
[54] Yesbolova, A., Abdikerimova, G., Kuashbay, S., Sadykbekova, A., & Bigeldieva, Z. (2025). Analysis of the current state of dairy cattle breeding in the Republic of Kazakhstan. *E3S Web of Conferences*, 614, article number 03029. doi: 10.1051/e3sconf/202561403029.
[55] Yessengaliyeva, S.M., Mansurova, M.A., Makhmudov, A.D., & Fedorchenko, L.V. (2021). Current state and development trends of livestock in the Republic of Kazakhstan. *Economics: The Strategy and Practice*, 16(2), 134-144. doi: 10.51176/1997-9967-2021-2-134-144.
[56] Yin, J., & Guo, J. (2026). Sci-tech finance to improve agricultural production efficiency: Empirical evidence from pilot policies. *Sustainability*, 18(10), article number 4910. doi: 10.3390/su18104910.

Казакстан Республикасында эт багытындагы мал чарбасын колдоо боюнча мамлекеттик саясат: Абай аймагынын мисалында субсидиялоо жана жеңилдетилген насыя берүү механизмдери

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Аннотация. Бул изилдөө Казакстанда эт багытындагы уй чарбасын колдоого багытталган мамлекеттик саясаттын натыйжалуулугун субсидиялар менен жеңилдетилген насыялоонун регионалдык деңгээлдеги өз ара байланышын талдоо аркылуу баалоону максат кылды. Өндүрүш көрсөткүчтөрүнүн, инвестициялык активдүүлүктүн жана бюджеттик параметрлердин убакыт бою динамикасын түшүндүрүү үчүн институционалдык, салыштырмалуу жана эмпирикалык-статистикалык анализдердин айкалышы колдонулду. Нәтижелер көрсөткөндөй, мамлекеттик колдоонун институционалдык түзүмү көп деңгээлдүү болуп, борбордук жана регионалдык бийлик органдарынын ортосунда ыйгарым укуктардын расмий бөлүнүшү пайда болгон. Абай аймагындагы каржылоо структурасы түздөн-түз колдоонун (4,8 млрд теңге) ордуна каржылык инструменттердин (7,8 млрд теңге) үстөмдүгү менен мүнөздөлгөнү аныкталды, бул инвестициялык активдүүлүктү стимулдаштырууга багытталган саясаттын өзгөрүшүн көрсөтөт. Малдын саны жана өндүрүш структурасына эмпирикалык анализ кеңири өнүгүү моделине артыкчылык берилишин көрсөттү, бул малдын санынын ылдамыраак өсүшү (сиырлардын саны 2,4 %га өсүп) менен, ал эми продукция өсүшү (эт өндүрүшү 2,7 %га өсүп) ортосундагы айырмачылык аркылуу далилденди. Бирок насыя алуу мүмкүнчүлүгү бирдей эмес бойдон калууда, анткени кепилдик талаптары чакан өндүрүүчүлөрдүн каржылоо программаларына катышуусун чектейт. Бул сектор ичиндеги структуралык ажырымдын бекемделишине өбөлгө түзөт: айыл чарба чарбалары эт өндүрүшүнүн 55 %ын түзсө, үй чарбалар болгону 15 %ын гана түзөт. Алынган натыйжаларды жалпылоо мамлекеттик саясаттын натыйжалуулугу каржылоо көлөмү менен гана эмес, колдоо куралдарынын шайкештиги, институционалдык интеграция деңгээли жана ар кандай өндүрүүчү категорияларына жеткиликтүүлүк менен да аныкталарын көрсөттү. Натыйжалардын практикалык маанилүүлүгү кичи өндүрүүчүлөр үчүн субсидия программаларындагы катышуу критерийлерин кайра карап чыгууда, анын ичинде долбоордун кубаттуулук талаптарын төмөндөтүүдө жана айыл чарба тармагында төлөмдөрдү өндүрүш циклдерине шайкеш келтирип бюджетти пландоону жөнгө салууда колдонуу мүмкүнчүлүгүндө жатат

Негизги сөздөр: бюджеттик трансферттер; кийинкиге калтырылган милдеттенмелер; экстенсивдүү модель; инвестициялык долбоорлор; кластердик модель; айыл чарба тармагын санариптештирүү

Государственная политика поддержки животноводства в Республике Казахстан: механизмы субсидирования и льготного кредитования на примере Абайской области

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Аннотация. Целью данного исследования была оценка эффективности государственной политики поддержки мясного скотоводства в Казахстане путем анализа взаимодействия субсидий и льготного кредитования на региональном уровне. Для интерпретации динамики производственных показателей, инвестиционной активности и бюджетных параметров во времени был использован комплекс институционального, сравнительного и эмпирико-статистического анализа. Было установлено, что институциональная структура государственной поддержки приобрела многоуровневый характер с формальным разделением полномочий между центральными и региональными органами власти. Установлено, что структура финансирования в Абайской области характеризуется преобладанием финансовых инструментов (7,8 млрд тенге) над прямыми формами поддержки (4,8 млрд тенге), что свидетельствует о сдвиге в политике в сторону стимулирования инвестиционной деятельности. Эмпирический анализ поголовья скота и структуры производства выявил предпочтение экстенсивной модели развития, о чем свидетельствует более быстрый рост поголовья (на 2,4 %) по сравнению с ростом объемов производства (на 2,7 %). Однако доступ к кредитам остается неравномерным, поскольку требования к залогу ограничивают участие мелких производителей в программах финансирования. Это способствует усилению структурной дифференциации внутри сектора: на долю сельскохозяйственных предприятий приходится 55 % производства мяса, в то время как на долю домохозяйств – лишь 15 %. Обобщение полученных результатов показало, что эффективность государственной политики определяется не только объемом финансирования, но и согласованностью инструментов поддержки, уровнем институциональной интеграции и доступностью для различных категорий производителей. Практическая значимость результатов заключается в их потенциальном использовании при пересмотре критериев доступа мелких производителей к программам субсидирования, включая снижение требований к мощностям проектов, а также при корректировке бюджетного планирования в агропромышленном комплексе путем синхронизации выплат с производственными циклами

Ключевые слова: бюджетные трансферты; отложенные обязательства; экстенсивная модель; инвестиционные проекты; кластерная модель; цифровизация сельскохозяйственного сектора

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