ISSN 1694-6286
e-ISSN 1694-9250

Bulletin of the Kyrgyz National Agrarian University

Publisher:
Kyrgyz National Agrarian University Named After K.I. Skryabin

Year of foundation: 2003

Frequency: 4 times a year

State registration:
Registration certificate of the Ministry of Justice of the Kyrgyz Republic
No. 000043 dated 01.12.2003. Re-registered on 11.03.2015, certificate No. 909.

The journal is presented in the following international scientometric databases, repositories and scientific systems:
Russian Science Citation Index (RSCI), Litmaps

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https://knau-bulletin.com/en

ISSN 1694-6286
e-ISSN 1694-9250

Кыргыз улуттук агрардык университетинин Жарчысы

Негиздөөчү:
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети

Негизделген жылы: 2003

Чыгаруунун мезгилдүүлүгү: жылына 4 жолу

Мамлекеттик каттоо:
Кыргыз Республикасынын Юстиция министрлигинин каттоо күбөлүгү
01.12.2003-ж., № 000043, күбөлүк № 909, 11.03.2015 - жылы кайрадан катталган.

Журнал төмөнкү эл аралык илимий-метрикалык маалымат базаларында, репозиторийлерде жана издөө системаларында камтылган:
Орусиянын илимий цитаталар индекси (РИНЦ); Litmaps

Редакциянын дареги:
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
E-mail: info@knau-bulletin.com
https://knau-bulletin.com/ky

ISSN 1694-6286
e-ISSN 1694-9250

Вестник Кыргызского национального аграрного университета

Издатель:
Кыргызский национальный аграрный университет имени К.И. Скрябина

Год основания: 2003

Периодичность выпуска: 4 раза в год

Государственная регистрация:
Регистрационное свидетельство Министерства юстиции Кыргызской Республики
№ 000043 от 01.12.2003. Перерегистрирован 11.03.2015, свидетельство № 909.

Журнал представлен в таких международных наукометрических базах данных, репозиториях и поисковых системах:
Российский индекс научного цитирования (РИНЦ); Litmaps

Адрес редакции:
Кыргызский национальный аграрный университет имени К.И. Скрябина
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https://knau-bulletin.com/ru

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Received: 14.10.2025. Revised: 09.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 577.2

DOI: 10.63621/bknau./1.2026.10

Optimisation of PCR conditions for the detection of infectious bovine rhinotracheitis

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Abstract. The relevance of this study is determined by the need to improve the efficiency of laboratory diagnostics of persistent viral infections in cattle, which are characterised by low pathogen concentrations and difficulty in detection using traditional methods. The aim of the study was to develop and optimise a polymerase chain reaction (PCR) for accurate identification of bovine infectious rhinotracheitis virus based on analysis of the gB gene. Modern methods of molecular biology, genetic engineering, and bioinformatics analysis were used, including the collection, processing, and alignment of nucleotide sequences. During the study, nucleotide sequences of the gB gene of bovine infectious rhinotracheitis virus were collected and analysed, which allowed the identification of its conserved, variable, and polymorphic regions. Based on the results of the analysis, a highly specific pair of primers was designed and synthesised to ensure selective amplification of the target viral genome fragment. DNA of the bovine infectious rhinotracheitis virus was isolated to optimise amplification conditions. Optimal temperature parameters of the polymerase chain reaction and the quantitative composition of reagents were also determined, ensuring high sensitivity and specificity of the method. The results confirmed that the efficiency of diagnostics can

Suggested Citation: Zhaksylyk, S., Sultankulova, K., Boronbaeva, A., Shynybekova, G., & Kozhabergenov, N. (2026). Optimisation of PCR conditions for the detection of infectious bovine rhinotracheitis. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 10-17. doi: 10.63621/bknau./1.2026.10.

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be improved through rational selection of primers and reaction parameters. The practical value of this work is that the obtained data and developed methodological approaches can be used by veterinary diagnostic laboratories and research institutions to improve PCR diagnostics of bovine infectious rhinotracheitis virus

Keywords: primers; BoHV-1; PCR diagnostics; gB gene; reaction optimisation

Introduction

Infectious bovine rhinotracheitis (IBR), caused by Bovine herpesvirus-1 (BoHV-1), is one of the key viral infections of cattle, causing significant economic damage: reduced productivity, reproductive losses, and deterioration of herd health. One of the main problems in controlling BoHV-1 is its ability to establish latent infection: after a clinical or subclinical period, the virus often becomes latent and can be reactivated by stress, immunosuppression or other triggering factors (Ostler & Jones, 2023). In this regard, reliable epidemiological monitoring, timely diagnosis and control measures require the use of modern, sensitive and specific methods for detecting the virus.

In recent years, new studies have emerged that have significantly advanced the methodology for diagnosing BoHV-1 IBR in cattle – not only at the level of serological screening, but also molecular identification of active infection. First, in 2022, a highly sensitive method was developed and verified – digital droplet PCR (ddPCR) for the detection of BoHV-1 in seminal fluid, with a detection threshold of approximately 4.5 DNA copies per reaction, which significantly exceeds the sensitivity of classical qPCR (Yu *et al.*, 2022). This method is particularly relevant in the context of international semen trade control, as well as when it is necessary to detect the virus in asymptomatic, latent carriers. Secondly, a comparative study of various nucleic acid methods conducted by H. Aslim & O. Bulut (2024) showed that both real-time PCR (qPCR) and real-time loop-mediated isothermal amplification (LAMP) have high specificity and sensitivity when analysing nasal swabs; these methods can be used as a more rapid (compared to cultivation) diagnosis of active infection. In addition, according to A. Karabasova *et al.* (2025), a comprehensive approach to diagnosis – a combination of serological and molecular methods – is recommended in a recent study from Kazakhstan, which evaluated the sensitivity and specificity of enzyme-linked immunosorbent assay (ELISA) and qPCR. The authors noted that ELISA remains a reliable tool for mass herd screening (sensitivity ~90%, specificity ~95%), while qPCR detected active infection in only a small proportion of animals, indicating the hidden (latent) nature of the infection in many.

It is also important to consider data from epidemiological studies conducted in recent years, which show that BoHV-1 is still widespread among cattle in various countries. For example, in Colombia, a seroepidemiological study by C. González *et al.* (2025) showed a significant seroprevalence of BoHV-1 among cattle, even in the presence of other bovine respiratory disease complex (BRDC) viruses. In Ireland, as part of the national testing programme, the BoHV-1 status of nearly 190,000 animals was tested: the seropositive rate was 11.4% at the animal level and 48.8% at the farm level; with large herds and active animal rotation considered important risk factors (Brock *et al.*, 2025). Data from D. Barrett *et al.* (2024) confirm significant seroprevalence and co-infection with BVD (bovine viral diarrhoea). In addition, a review of control programmes in Europe shows variability in approaches to the eradication of IBR (infectious bovine rhinotracheitis) (Iscaro *et al.*, 2021). An example of a successful national control programme is presented in Slovakia, where a combination of testing and vaccination has reduced the spread of the virus in herds (Mandelik *et al.*, 2021).

Thus, recent studies show that molecular diagnostic methods (ddPCR, qPCR, LAMP) are becoming increasingly sensitive and accessible for routine use, and their combination with serological tests increases the reliability of detecting both latent and active forms of infection. At the same time, epidemiological data confirm the widespread circulation of BoHV-1 even in the absence of pronounced clinical symptoms, which emphasises the need for constant monitoring, while the standardisation and validation of diagnostic samples remain key elements of effective national control and prevention programmes. The aim of this study was to develop and optimise a PCR method suitable for accurate laboratory identification of IBR virus in cattle and further use in veterinary diagnostics.

Materials and Methods

The work was carried out at the shared-use laboratory at the Research Institute for Biological Safety Problems (Gvardeysky, Kazakhstan) between January and September 2024. The object of study was the DNA of the infectious rhinotracheitis virus from the Aktyubek strain, obtained from the institute's microorganism collection. and engineered plasmid DNA containing a fragment of the gB gene of the BoHV-1 was also used as a positive control (PC). The gB gene was chosen because of its high conservatism among IBR cattle isolates and structural stability. In addition, gB is present in all known subtypes of IBR in cattle, which allows the developed method to effectively detect both classical and circulating field variants of the pathogen (Abukhadra *et al.*, 2022).

Primers were selected for the detection of BoHV-1 with multiple alignment of the nucleotide sequences of the virus genes. The analysis used the sequences of IBR virus isolates obtained from various geographical

regions and presented in the GenBank database (n.d.). Sequence alignment was performed using MEGA version 11 software with the ClustalW algorithm. The specificity of the selected oligonucleotide primers was verified using the BLAST service (n.d.). Virus DNA was extracted from virus-containing material in a biosafety level 2 (BSL-2) laboratory using the innuPREP DNA Mini Kit 2.0 (InnuScreen, Germany) in accordance with the manufacturer's instructions. The quality and concentration of the isolated DNA were assessed using a NanoDrop 2000 spectrophotometer (Thermo Fisher Scientific, USA). For specificity testing experiments, DNA and cDNA samples of the following viruses were also obtained from the institute's collection: cowpox virus strain Cowpox-Cam, bovine nodular dermatitis virus strain Atyrau/KZ/2016, bovine viral diarrhoea virus strain Georgian, bovine parainfluenza-3 virus strain Belarus.

The primers were designed to amplify conservative flanking regions surrounding polymorphic domains, ensuring reliable detection of the target region regardless of sequence variations. The gene site was selected based on analysis of available sequences in GenBank (n.d.) databases and multiple alignment using the ClustalW algorithm, which guarantees specificity and universality of amplification. To ensure high sensitivity and specificity of PCR, optimal primers were selected – short oligonucleotide sequences 20 nucleotides long, complementary to the target sites of the genetic material under study. The sequences of the selected primers are presented in Table 1.

Table 1. Primer sequences for the identification of IBR in cattle

Primer name	5' – 3' sequence	Tm	GC%	Product size, bp
BoHV-1_gB_F	AGCGGCGTCTACCTGACCTA	60	58	133
BoHV-1_gB_R	ACCGCGTAGAGCAGCGAGAA	60	58	

Note: Tm – melting temperature of the DNA fragment; GC% – percentage of GC pairs (proportion of guanine and cytosine in the sequence); bp – base pairs (unit of DNA length)
Source: developed by the authors

To optimise the PCR conditions, a series of experiments were conducted with selected primers. To select the optimal annealing temperature for the primers, gradient PCR was performed at temperatures of 50, 52.5, 55, 57.5, 60, and 62.5°C using the standard composition of the reaction mixture from a commercial kit and a final primer concentration of 400 nM. The Taq polymerase concentration was optimised in the range from 0.5 to 4 units. The standard primer concentrations for PCR are 200-600 nM in the reaction mixture (Lumiprobe, n.d.). During optimisation, concentrations ranging from 50 nM to 1 μM were tested. The recommended concentration of $MgCl_2$ in the reaction mixture is 1-4 mM, but the optimal value is determined experimentally. In the experiments conducted, the range of final $MgCl_2$ concentrations from 0.5 to 6 mM was investigated.

During the studies, the specificity of the selected PCR parameters for detecting BoHV-1 was verified using DNA and cDNA of infectious bovine rhinotracheitis virus, bovine pox virus, bovine nodular dermatitis virus, bovine viral diarrhoea virus, and bovine parainfluenza-3 virus. Constructed plasmid DNA containing a fragment of the gB gene of the BoHV-1 was used as a positive control in the PCR. Deionised water was used as a negative control (NC). To determine the sensitivity of the selected PCR conditions, tenfold dilutions of plasmid DNA carrying a fragment of the gB gene of the infectious bovine rhinotracheitis virus were prepared and used. The range of final concentrations of plasmid DNA with a specific insert in the reaction mixture was from 1 ng to 1 μg. The number of copies of plasmid DNA was calculated based on its length and mass using formula (1):

$$\text{Copies} = \frac{m}{L \times 660} \times 6.022 \times 10^{23}, \quad (1)$$

where m is the amount of DNA (g); L is the length of the plasmid (base pairs); 660 g/mol is the average molecular weight of 1 base pair of double-stranded DNA; 6.022×10^{23} is Avogadro's number.

Results and Discussion

To select the optimal conditions for PCR with the BoHV-1_gB_F and BoHV-1_gB_R primers, experiments were conducted on gradient PCR, enzyme concentration selection, primers, and $MgCl_2$. The results of gradient PCR showed that the selected primers effectively amplified the target region at annealing temperatures of 55-62.5°C. The optimal temperature for further experiments was selected as 57°C, at which no non-specific products were observed. Analysis of the effect of Taq polymerase concentration showed that the most effective amplification of the target product was observed at an enzyme concentration of 1 unit and above. A Taq polymerase concentration of 1 unit was selected for subsequent experiments. Assessment of the effect of primer concentration showed that specific amplification was observed at all concentrations studied, but the most intense formation of amplicons occurred at concentrations of 400 nM and above. In further studies, a final primer concentration of 600 nM was used. Selection of the $MgCl_2$ concentration showed that amplification of the specific product was observed at concentrations of 1.5-6 mM. For further reactions, a concentration of 2.5 mM $MgCl_2$ was selected as providing the best balance of specificity and amplification efficiency. Thus, to optimise the PCR

conditions with the selected primers, experiments were conducted to select the key reaction parameters. The optimal annealing temperature for the BoHV-1_gB_F and BoHV-1_gB_R primers was determined by gradient PCR and was 57°C, at which there were no non-specific products. The concentration of Taq polymerase was selected as 1 unit, which ensured effective amplification. The optimal concentration of primers was 600 nM, and $MgCl_2$ was 2.5 mM. As a result of the studies, the conditions for PCR for the diagnosis of IBR virus in cattle by PCR were optimised. Further studies were conducted to determine the specificity and sensitivity parameters of the primers (Figs. 1, 2). The results of determining the specificity of the developed PCR method for the identification of IBR virus in cattle showed that a specific PCR product with a size of 133 bp is produced only in the BoHV-1 DNA sample and in the positive control, no amplicons were observed in other samples, which confirms the specificity of the developed PCR diagnosis of IBR virus in cattle.

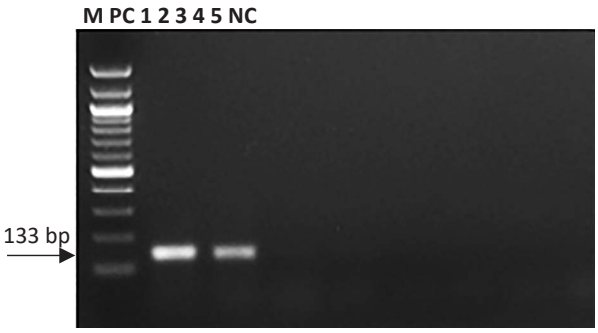

Figure 1. Determination of primer specificity for IBR diagnosis in cattle

Note: M – DNA molecular weight marker; PC – positive control; 1 – DNA of the infectious rhinotracheitis virus strain Aktyubek; 2 – DNA of the nodular dermatitis virus strain Atyrau/KZ/2016; 3 – Cowpox-Cam cowpox virus DNA; 4 – Georgian bovine viral diarrhoea cDNA; 5 – bovine parainfluenza-3 virus strain Belarus cDNA; NC – negative control

Source: authors' development

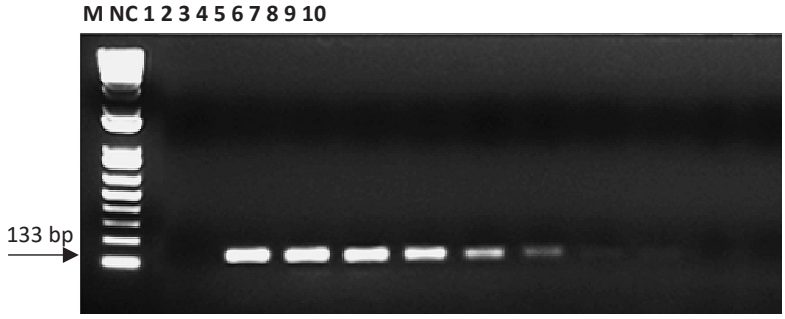

Figure 2. Determination of the sensitivity of selected PCR conditions for the diagnosis of IBR in cattle

Note: M – DNA molecular weight marker; NC – negative control; 1 – 1 ng (nanogram); 2 – 100 pg (picogram); 3 – 10 pg (picogram); 4 – 1 pg (picogram); 5 – 100 fg (femtograms); 6 – 10 fg (femtograms); 7 – 1 fg (femtograms); 8 – 100 ag (attograms); 9 – 10 ag (attograms); 10 – 1 ag (attogram)

Source: authors' development

The selected PCR conditions allow reliable detection of plasmid DNA containing a region of the gB gene of the infectious rhinotracheitis virus of cattle at a concentration of 10 fg, which corresponds to ~1.7×10^3 copies of the DNA molecule, indicating the high sensitivity of the selected PCR method. A conservative region of the gB gene of the infectious rhinotracheitis virus, characterised by high specificity due to the absence of similarity to the gene sequences of other viruses infecting cattle, was used as a target for PCR. Using the designed primers, optimisation of the reaction mixture composition and temperature-time amplification parameters, the developed method for diagnosing IBR in cattle showed high sensitivity and specificity.

The development of PCR-based diagnostic systems for detecting bovine infectious rhinotracheitis virus remains one of the priority tasks of modern veterinary diagnostics due to the high contagiousness of the infection and the difficulty of detecting the virus in its early stages. In this study, the classical PCR method aimed at detecting the gB gene amplicon was optimised, demonstrating high sensitivity and specificity when the reaction is performed manually using standard equipment. These results are consistent with the general trend of increasing the diagnostic efficiency of molecular techniques and are comparable with data in the literature. Current research is mainly focused on qPCR for BoHV-1, which provides even higher analytical sensitivity and quantitative assessment of viral load. In particular, L. Xu *et al.* (2024) described a SYBR Green II qPCR method with a detection limit of approximately 7.8×10^1 copies/μL, which demonstrated good sensitivity and repeatability without cross-amplification with other cattle pathogens. When using this method, the frequency of positive detections in clinical samples was higher than with conventional PCR, confirming the superiority of qPCR in terms of analytical parameters. Similarly, according to Z. Yu *et al.* (2022), ddPCR for the

detection of BoHV-1 in semen demonstrates excellent sensitivity (up to 4.5 copies), especially for latent infections. According to S. Pawar *et al.* (2014), the LAMP assay for semen also provides rapid detection without complex equipment.

In addition to purely technical differences between classical PCR and qPCR, the choice of targets for detection remains important. Evaluation analyses and meta-reviews emphasise that BoHV-1 glycoproteins (gB, gC, gD, gE, etc.) are reliable targets for primer development due to the conservatism of certain gene regions and their widespread use in diagnostics. This choice is also confirmed by a number of international studies, including J. Zhang *et al.* (2025), where g family genes served as the main target for molecular diagnosis of the virus. It is important to note that a number of studies use alternative detection methods that can provide other levels of sensitivity comparable to qPCR. For example, RPA-LFD (recombinant polymerase amplification with lateral flow) for herpesvirus, which provides visual detection of the virus within 30 minutes with a sensitivity of about 1 $TCID_{50}$, which is comparable to sensitive molecular methods and is suitable for rapid diagnosis in the field (Wu *et al.*, 2025). Another example is combined RPA methods for the simultaneous detection of BVDV and BoHV-1, which demonstrate a sensitivity of BoHV-1 of about 10^4 copies/μL, which, according to L. Jiang *et al.* (2024), is slightly inferior to qPCR, but remains high enough for practical diagnosis. As pointed out by P. Horwood & T. Mahony (2011), multiplex approaches, including the simultaneous detection of multiple respiratory viruses, increase the efficiency of screening. Classical PCR for gB remains reliable for regional laboratories, as shown in the article by B. Muylkens *et al.* (2007), where the conservatism of gB is confirmed for the detection of various subtypes.

A comparison of the results indicates that, despite the speed and simplicity of conventional PCR, qPCR and RPA methods have advantages in terms of sensitivity and potential automation, which is important for large diagnostic centres. However, the development of optimised classical PCR methods, as in this study, remains relevant for regional and resource-limited laboratories where access to qPCR equipment is limited. Epidemiological data from different regions confirm the widespread circulation of BoHV-1 and the need for optimised methods (Raaperi *et al.*, 2010; Dias *et al.*, 2013). Thus, the results of this study are consistent with current scientific trends in the molecular diagnosis of infectious bovine rhinotracheitis: increased requirements for sensitivity and specificity, the use of modern analytical platforms, and the analysis of multiplex methods.

Conclusions

In this study, a PCR method for detecting bovine infectious rhinotracheitis virus was optimised, demonstrating high specificity and sensitivity. The optimal reaction parameters include an annealing temperature for the BoHV-1_gB_F and BoHV-1_gB_R primers of 57°C, a Taq polymerase concentration of 1 unit, primers – 600 nM, $MgCl_2$ – 2.5 mM, which ensures effective amplification of the target region without the formation of non-specific products. The specificity of the method was confirmed by testing on a panel of viruses affecting cattle, including nodular dermatitis virus, cowpox virus, viral diarrhoea and parainfluenza-3. A PCR product with a size of 133 bp was formed exclusively in samples of BoHV-1 DNA and the positive control, and was absent in the other samples, which indicates the high specificity of the primers. The sensitivity of the method was 10 fg of plasmid DNA, corresponding to ~1.7×10^3 copies of the molecule, which allows the detection of infection at early stages and ensures reliable diagnosis even at low concentrations of viral material.

The developed PCR method is an effective tool for rapid diagnosis of IBR in cattle, combining accuracy, sensitivity and reproducibility. Prospects for further research include the introduction of real-time quantitative PCR to assess viral load using fluorescent probes, which will not only detect the presence of the virus but also determine its concentration in biological material. Expansion of the tested panel of strains from different geographical regions is necessary to verify the universality of the method and its applicability to a variety of field isolates. Integration of the developed PCR diagnostics with other molecular and serological approaches will create a basis for comprehensive monitoring of infections in cattle. An important direction is to validate the method on an expanded set of clinical samples obtained from animals with different clinical statuses and from different farms, which will allow assessing the practical effectiveness of the developed methodology in the context of surveillance and prevention of IBR in cattle.

Acknowledgements

The authors would like to thank the staff of the Laboratory of Molecular Biology and Genetic Engineering for their assistance in conducting the study.

Funding

This work was carried out within the framework of the PCF: "Improvement of biological safety measures in Kazakhstan: Countering dangerous and particularly dangerous infections" (IRN BR2180004/0223).

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Abukhadra, B.A., Mosad, S.M., & El-Rahman, S.A. (2022). Molecular identification of bovine alpha herpesvirus subtype 1.1 in field isolates in Egypt by phylogenetic analysis of glycoprotein B gene. *Advances in Animal and Veterinary Sciences*, 10(8), 1739-1746. doi: 10.17582/journal.aavs/2022/10.8.1739.1746.

[2] Aslim, H.P., & Bulut, O. (2024). Detection of BoHV-1 – comparative evaluation of real time PCR, real time LAMP and subtyping. *Acta Scientiae Veterinariae*, 52(1), article number 1954. doi: 10.22456/1679-9216.139938.
[3] Barrett, D., Lane, E., Lozano, J.M., O'Keeffe, K., & Byrne, A.W. (2024). Bovine herpes virus type 1 (BoHV-1) seroprevalence, risk factor and bovine viral diarrhoea (BVD) co-infection analysis from Ireland. *Scientific Reports*, 14(1), article number 867. doi: 10.1038/s41598-023-50433-5.
[4] BLAST. (n.d.). Retrieved from https://blast.ncbi.nlm.nih.gov/Blast.cgi.
[5] Brock, J., Guelbenzu-Gonzalo, M., Lozano, J.M., Lane, E.A., Gunn, M., Brady, S., Thulke, H.H., & Graham, D.A. (2025). Prevalence and risk factors for bovine herpesvirus type 1 (BoHV-1) infection in Irish beef herds: Results from the National Beef Welfare Scheme 2023. *Irish Veterinary Journal*, 78, article number 22. doi: 10.1186/s13620-025-00308-0.
[6] Dias, J.A., Alfieri, A.A., Ferreira-Neto, J.S., Gonçalves, V.S., & Muller, E.E. (2013). Seroprevalence and risk factors of bovine herpesvirus 1 infection in cattle herds in the state of Paraná, Brazil. *Transboundary and Emerging Diseases*, 60(1), 39-47. doi: 10.1111/j.1865-1682.2012.01316.x.
[7] GenBank. (n.d.). Retrieved from https://www.ncbi.nlm.nih.gov/genbank/.
[8] González, C.B., Briñez, K., Tobón, J.C., Sanjuanelo Corredor, D.W., Bauermann, F.V., & Guzmán Barragán, B.L. (2025). Cross-sectional seroprevalence study of bovine herpesvirus 1, bovine respiratory syncytial virus, and parainfluenza virus 3 in cattle from Villavicencio, Colombia. *BMC Veterinary Research*, 21, article number 24. doi: 10.1186/s12917-024-04461-6.
[9] Horwood, P.F., & Mahony, T.J. (2011). Multiplex real-time RT-PCR detection of three viruses associated with the bovine respiratory disease complex. *Journal of Virological Methods*, 171(2), 360-363. doi: 10.1016/j.jviromet.2010.11.020.
[10] Iscaro, C., Cambiotti, V., Petrini, S., & Feliziani, F. (2021). Control programs for infectious bovine rhinotracheitis (IBR) in European countries: An overview. *Animal Health Research Reviews*, 22(2), 136-146. doi: 10.1017/S1466252321000116.
[11] Jiang, L., Zhang, G., Wang, P., Niu, X., Liu, Q., Zhang, S., Gao, W., & Li, Y. (2024). Simultaneous detection of bovine viral diarrhea virus (BVDV) and bovine herpesvirus 1 (BoHV-1) using recombinase polymerase amplification. *Scientific Reports*, 14, article number 10169. doi: 10.1038/s41598-024-56869-7.
[12] Karabasova, A., Turkeev, M.K., Tulepov, B.S., Lesov, B.E., Akshalova, P.B., Tujmebaeva, K.Zh., Akylbaj, A.K., Kanatbaev, S.G., & Kajmoldina, S.E. (2025). Analysis of serological and molecular genetic methods for the diagnosis of infectious rhinotracheitis in cattle in Kazakhstan. *Science and Education*, 1(78), 172-186. doi: 10.52578/2305-9397-2025-1-1-172-186.
[13] Lumiprobe. (n.d.). *DNA amplification with ProbeMaster® UNI PCR/qPCR reaction mixture, 5x*. Retrieved from https://ru.lumiprobe.com/protocols/pcr-qpcr-master-mix-5x?utm_source.
[14] Mandelik, R., Bires, J., Ozsvari, L., Hodnik, J.J., & Vilcek, S. (2021). Infectious bovine rhinotracheitis control program in Slovakia. *Frontiers in Veterinary Science*, 8, article number 675521. doi: 10.3389/fvets.2021.675521.
[15] Muylkens, B., Thiry, J., KIBRen, P., Schynts, F., & Thiry, E. (2007). Bovine herpesvirus 1 infection and infectious bovine rhinotracheitis. *Veterinary Research*, 38(2), 181-209. doi: 10.1051/vetres:2006059.
[16] Ostler, J.B., & Jones, C. (2023). The bovine herpesvirus 1 latency-reactivation cycle, a chronic problem in the cattle industry. *Viruses*, 15(2), article number 552. doi: 10.3390/v15020552.
[17] Pawar, S.S., Meshram, C.D., Singh, N.K., Sonwane, A.A., Saini, M., Rautmare, S.S., Muglikar, D.M., Mishra, B.P., & Gupta, P.K. (2014). Rapid detection of bovine herpesvirus 1 in bovine semen by loop-mediated isothermal amplification (LAMP) assay. *Archives of Virology*, 159(4), 641-648. doi: 10.1007/s00705-013-1869-2.
[18] Raaperi, K., Nurmoja, I., Orro, T., & Viltrop, A. (2010). Seroepidemiology of bovine herpesvirus 1 (BHV1) infection among Estonian dairy herds and risk factors for the spread within herds. *Preventive Veterinary Medicine*, 96(1-2), 74-81. doi: 10.1016/j.prevetmed.2010.06.001.
[19] Wu, Y., Zhang, W., Yi, C., He, K., Hu, C., Ye, G., & Zhang, A. (2025). Rapid, sensitive, and visible RPA-LFD assay for BoHV-1 and BoHV-5. *Microbiology Spectrum*, 4, 13(3), article number e0089524. doi: 10.1128/spectrum.00895-24.
[20] Xu, L., *et al.* (2024). Establishment of a real-time fluorescent quantitative PCR detection method and phylogenetic analysis of BoAHV-1. *BMC Veterinary Research*, 20, article number 180. doi: 10.1186/s12917-024-04025-8.
[21] Yu, Z., Zhao, Z., Chen, L., Yan, H., Cui, Q., Ju, X., Yong, Y., Liu, X., Ma, X., & Zhang, G. (2022). Development of a droplet digital PCR assay to detect bovine alphaherpesvirus 1 in bovine semen. *BMC Veterinary Research*, 18, article number 125. doi: 10.1186/s12917-022-03235-2.
[22] Zhang, J., Cao, J., Cao, L., Zhang, C., Gong, L., Kang, X., Li, D., & Zhang, Y. (2025). Research progress on the diagnostic techniques and vaccine development of bovine herpesvirus types 1. *Frontiers in Veterinary Science*, 12, article number 1703336. doi: 10.3389/fvets.2025.1703336.

Ири мүйүздүү малдын инфекциялык ринотрахеитин аныктоо үчүн ПЧР коюунун параметрлерин оптималдаштыруу

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Аннотация. Бул иликтөөнүн актуалдуулугу малдын узакка созулган вирустук инфекцияларын лабораториялык диагностиканы жогорулатуу зарылдыгында турат, анткени бул инфекциялардын учурунда оору жараткан агенттин концентрациясы аз болуп, аны салттуу ыкмалар менен аныктоо кыйынчылык жаратат. Изилдөөнүн максаты – ири мүйүздүү малдын инфекциялык ринотрахеити вирусун так идентификациялоо үчүн gB генинин анализине негизделген полимеразалык чынжыр реакциясын (ПЧР) оптималдаштыруу. Ишти аткарууда молекулярдык биологиянын заманбап ыкмалары, гендик инженерия жана биоинформатика колдонулду, анын ичинде нуклеотиддик секвенциялардын жыйноосу, иштетилиши жана салыштырылышы. Изилдөө учурунда ири мүйүздүү малдын инфекциялык ринотрахеити вирусунун gB генинин нуклеотиддик секвенциялары жыйналып, анализденди, натыйжада анын консервативдик, вариабелдүү жана полиморфтук аймактары аныкталды. Анализдин негизинде жогорку спецификалык таасири бар праймерлерди синтездөө жана иштеп чыгуу жүргүзүлүп, вирус геномунун максаттуу фрагментин амплификациялоого мүмкүндүк берилди. Иш учурунда ири мүйүздүү малдын инфекциялык ринотрахеити вирусунун ДНКсын бөлүп алуу жүргүзүлүп, амплификация шарттарын оптималдаштыруу үчүн негиз түзүлдү. Ошондой эле полимеразалык чынжыр реакциясынын температуралык параметрлери жана реагенттердин сандык курамы оптималдаштырылып, методдун жогорку сезгичтиги жана спецификтиги камсыздалды. Изилдөө натыйжалары праймерлерди жана реакция параметрлерин рационалдуу тандоо аркылуу диагностиканын эффективдүүлүгүн жогорулатууга мүмкүнчүлүк берерин көрсөттү. Практикалык мааниси – алынган маалыматтар жана иштелип чыккан методикалык ыкмалар ветеринардык диагностикалык лабораториялар жана илимий-изилдөө мекемелер тарабынан ири мүйүздүү малдын инфекциялык ринотрахеити вирусунун ПЦР-диагностикасын өркүндөтүү үчүн колдонулушу мүмкүн

Негизги сөздөр: праймерлер; BoHV-1; ПЧР-диагностика; gB гени; реакцияны оптималдаштыруу

Оптимизация параметров постановки ПЦР для выявления инфекционного ринотрахеита крупного рогатого скота

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Аннотация. Актуальность данной работы определяется необходимостью повышения эффективности лабораторной диагностики персистирующих вирусных инфекций крупного рогатого скота, для которых характерны низкие концентрации возбудителя и затрудненность его выявления традиционными методами. Цель исследования заключалась в разработке и оптимизации полимеразной цепной реакции (ПЦР) для точной идентификации вируса инфекционного ринотрахеита крупного рогатого скота на основе анализа гена gB. Для выполнения работы использованы современные методы молекулярной биологии, генной инженерии и биоинформатического анализа, включая сбор, обработку и выравнивание нуклеотидных последовательностей. В ходе исследования были собраны и проанализированы нуклеотидные последовательности гена gB вируса инфекционного ринотрахеита крупного рогатого скота, что позволило выявить его консервативные, вариабельные и полиморфные участки. На основании результатов анализа была разработана и синтезирована высокоспецифичная пара праймеров, обеспечивающая селективное амплифицирование целевого фрагмента генома вируса. В ходе работы было проведено выделение ДНК вируса инфекционного ринотрахеита крупного рогатого скота, необходимое для оптимизации условий амплификации. Также установлены оптимальные температурные параметры полимеразной цепной реакции и подобран количественный состав реагентов, обеспечивающие высокую чувствительность и специфичность метода. Результаты исследования подтвердили возможность повышения эффективности диагностики путем рационального подбора праймеров и параметров реакции. Практическая ценность работы заключается в том, что полученные данные и разработанные методические подходы могут быть использованы ветеринарными диагностическими лабораториями и научно-исследовательскими учреждениями для совершенствования ПЦР-диагностики вируса инфекционного ринотрахеита крупного рогатого скота

Ключевые слова: праймеры; BoHV-1; ПЦР-диагностика; gB ген; оптимизация реакции

Received: 01.11.2025. Revised: 13.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 633.358:613

DOI: 10.63621/bknau./1.2026.18

Amino acid composition of chickpea (*Cicer arietinum* L.) varieties cultivated in the Kyrgyz Republic

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Abstract. Chickpeas (*Cicer arietinum* L.) are an important source of plant protein, but data on the biochemical composition of varieties cultivated in the Kyrgyz Republic are limited. The aim of the study was to determine the amino acid composition of the grains of three chickpea varieties ('Kyrgyz Local', 'Uzbekistan 32' and 'Yulduz') grown in the republic in order to assess their nutritional value. Average samples were selected according to the ISTA methodology from the 2024 harvest. Amino acid analysis was performed by high-performance liquid chromatography (HPLC) after acid hydrolysis with pre-column derivatisation with phenylisothiocyanate. The study revealed significant varietal differences in the content of individual amino acids. The highest methionine content was recorded in the 'Kyrgyz Local' variety (0.85 g/100 g), followed by 'Yulduz' (0.80 g/100 g) and 'Uzbekistan 32' (0.72 g/100 g). The lysine content ranged from 0.09 g/100 g ('Yulduz') to 0.14 g/100 g ('Kyrgyz Local'). The dominant amino acids in all samples were aspartic acid (2.74-3.69 g/100 g) and cystine (1.53-2.70 g/100 g). The 'Yulduz' variety showed the highest histidine content (1.62 g/100 g), while 'Uzbekistan 32' had the highest tyrosine content (0.65 g/100 g). The results confirm the status of chickpeas as a valuable source of plant protein with a favourable amino acid profile and can be used in the development of balanced diets and functional foods in the Kyrgyz Republic

Keywords: biochemical profile; protein; high-performance liquid chromatography; lysine; methionine; arginine

Suggested Citation: Batyrbasheva, Zh., Asanaliev, A., Imanaliev, A., & Sultanbaeva, V. (2026). Amino acid composition of chickpea (*Cicer arietinum* L.) varieties cultivated in the Kyrgyz Republic. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 18-27. doi: 10.63621/bknau./1.2026.18.

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Introduction

With the growing pressure on global agroecosystems and the worsening food security problem, the transition to sustainable food sources is becoming strategically important. Plant proteins play a key role in the formation of healthy, balanced and environmentally responsible diets. Legumes, with their high nutritional value and nitrogen-fixing ability, are a cornerstone in addressing these challenges. According to J. Aschemann-Witzel *et al.* (2021), global demand for plant protein has increased significantly over the past decade due to consumer concerns about the adverse effects of animal-based diets on health and the environment. In the context of a growing shortage of complete protein, legumes are becoming strategically important for food security. According to FAOSTAT (n.d.), global production of chickpeas (*Cicer arietinum* L.) reached 15.9 million tonnes in 2021, making it the third most important legume crop after beans and peas.

Chickpea proteins are highly digestible and have a balanced amino acid composition, making them a promising alternative to animal proteins. The essential amino acid index of chickpeas is 76 on the DIAAS scale, and the crop is characterised by a high content of lysine, an amino acid that is deficient in cereals (Yeasmen & Orsat, 2025). As noted by W. Xu *et al.* (2024), compared to soy protein, chickpea protein has lower allergenicity, better solubility and foaming properties. The amino acid profile of chickpeas varies significantly depending on the variety and growing conditions. Studies of genotypes with different protein contents have shown that the amino acid composition of chickpeas exceeds the WHO recommended values for all essential amino acids and is comparable to that of complete protein sources (Grewal *et al.*, 2023).

In addition to its nutritional value, chickpea is a soil-improving crop due to its ability to fix atmospheric nitrogen through symbiosis with nodule bacteria, which is especially important for cereal crops in crop rotation (Liu *et al.*, 2020). According to S. Salaria *et al.* (2023), increasing the protein content in chickpea seeds has been identified as a priority area for research in crop breeding and genetics. In the Kyrgyz Republic, chickpeas traditionally have the status of a vegetable crop. According to unpublished data from the Ministry of Water Resources… (n.d.) and NSCKR (n.d.), the area sown with chickpeas in Kyrgyzstan in 2024 reached 1,472 hectares with a yield of 15.4 centners per hectare, which puts the crop in second place among legumes after common beans. The main cultivation areas are concentrated in the Osh and Jalal-Abad regions, where mainly locally selected varieties, two selected varieties of Kyrgyz origin ('Rafat' and 'Saira') and the introduced variety 'Uzbekistan 32' are cultivated. However, information on the biochemical composition of the grain of local varieties is extremely limited. E. Torutaeva *et al.* (2014) and A. Asanaliev *et al.* (2017) reported only on the mineral composition and productivity of various chickpea varieties, while data on the amino acid composition are lacking. The aim of this study was to determine the amino acid composition of three chickpea varieties cultivated in the Kyrgyz Republic in order to assess their nutritional value and potential for use in functional foods.

Literature Review

The biochemical composition of chickpea proteins is characterised by a significant variety of fractions and high nutritional value. Chickpea proteins, like pea proteins, are mainly represented by albumins and globulins, which account for up to 97% of their mass (Dhaliwal *et al.*, 2021). A detailed analysis of protein fractions shows that chickpea proteins contain globulins (56 g/100 g), albumins (12 g/100 g), glutelins (18 g/100 g), prolamins (3 g/100 g) and residual proteins. According to Y. Chang *et al.* (2011), chickpea proteins have a higher content of glutelins than other legumes, which determines their unique functional properties. According to A. Olagunju *et al.* (2018), an important advantage of legume proteins is their hypoallergenicity compared to other plant proteins. To isolate chickpea protein fractions, it is preferable to use salt solutions at a concentration of 0.5-3.0 mol·L^{-1}, which ensures effective extraction while preserving the native properties of the protein. Legume proteins have a wide range of techno- and biofunctional applications comparable to those of animal and dairy proteins, providing numerous health benefits (Glusac *et al.*, 2020).

The amino acid profile of chickpeas is of particular interest in terms of nutritional value. Legumes have significant potential in terms of eliminating protein deficiency, as they are a source of essential amino acids. As noted by I. Pankina & L. Borisova (2016), unlike cereal proteins, legume proteins contain higher amounts of essential amino acids, including threonine, isoleucine, leucine, valine, phenylalanine, lysine, and tryptophan. Among them, lysine plays an important role, participating in various biochemical processes in the bodies of animals and humans and often being a limiting amino acid in cereal crops. Chickpeas are cultivated worldwide as a legume rich not only in protein but also in vitamins, carbohydrates, polyphenols, fatty acids, fibre and flavonoids (Patil *et al.*, 2024). Chickpea grains contain antioxidants that can be included in various concentrates and have a positive effect on the body's immunity. Due to its abundance of essential amino acids, especially lysine, and high digestibility, chickpeas are considered a promising substitute for animal proteins. A comparative analysis of the functional properties of various plant proteins shows the advantages of chickpea protein. Chickpeas are highly valued as a source of protein due to their high digestibility, biological value and balanced amino acid composition. However, it should be noted

that chickpeas have limitations in terms of their content of sulphur-containing amino acids, including methionine and cysteine (Koul *et al.*, 2022). Despite this limitation, chickpeas are an attractive source of protein for the development of protein-enriched ingredients and functional foods (Yeasmen & Orsat, 2025).

According to F. Roy *et al.* (2010), in the modern context, the number of hungry people in the world continues to grow, reaching one third of the Earth's population, with a significant portion of the population experiencing a deficiency of complete protein. Concerns about high cholesterol levels in food, food allergies, high prices for animal products, and the negative environmental impact of their production have led to a significant increase in interest in alternative sources of protein (Zotikov, 2016). In this regard, plant proteins, in particular chickpea protein, have gained considerable popularity in the food industry as an environmentally sustainable and cost-effective source of high-quality protein. The urgency of solving the problem of providing the population with complete protein determines the need for a comprehensive analysis of the chickpea raw material base, including a detailed study of the amino acid composition of different varieties. Amino acid analysis of chickpea grains cultivated in different regions is of considerable scientific and practical interest for optimising the production of functional foods and developing balanced diets.

Materials and Methods

The study was conducted in 2024-2025 at the Kyrgyz State Technical University named after I. Razzakov and the Kyrgyz National Agrarian University named after K.I. Skryabin. The objects of the study were three varieties of chickpea (*Cicer arietinum* L.): 'Kyrgyz Local', 'Yulduz' and 'Uzbekistan 32'. The varieties were grown on northern foothill grey soils with natural moisture. For chickpea cultivation, autumn ploughing was carried out to a depth of 20 cm, and no mineral fertilisers were applied during ploughing. When sowing in rows, simple granulated superphosphate was applied at a dose of P_{20} per 1 ha of active ingredient. Sowing was carried out at the end of April 2024 with row spacing of 45 cm and a sowing rate of 0.4 million viable seeds per hectare. All operations were carried out in strict accordance with the Convention on Biological Diversity (1992).

Harvesting was carried out in the third decade of August 2024 when full biological ripeness was reached. Average grain samples weighing 1 kg from each variety were selected in accordance with ISTA (n.d.) methods from the 2024 harvest. Prior to analysis, the grain samples were stored in a dry, ventilated room at a temperature of 18-20°C and a relative humidity of no more than 60%. The moisture content of the grain was 10-11%. The dry matter content was determined by weighting the grain in an oven according to GOST 31640-2012 (2020). The amino acid composition was studied in 2025 in the analytical laboratory of the Kyrgyz State Technical University named after I. Razzakov. The total amino acid content in the samples was determined by high-performance liquid chromatography (HPLC) after preliminary acid hydrolysis. Hydrolysis of a 100 mg sample was carried out in 6 M HCl at 110°C for 13 hours in sealed glass ampoules in a nitrogen atmosphere to prevent oxidation. The amino acid derivatisation process was carried out using phenylisothiocyanate (PITC). After hydrolysis, 1,000 µl of the sample was dried under vacuum. Then, 150 µl of 0.1 mol NaOH, 50 µl of deionised water and 350 µl of PITC reagent (propanol/PITC/TEA [8:1:1, v/v/v]) were added and kept at room temperature for 30 minutes for the reaction to proceed. PITC was removed in a nitrogen atmosphere, and the derivatised sample was redissolved in 1.5 mL of water. The sample was filtered through a syringe filter (0.45 µm) and injected into the HPLC system in a volume of 10 µl. Two mobile phases were used for the separation of amino acid derivatives by HPLC. Mobile phase A consisted of 99% HPLC-grade acetonitrile and 1% acetic acid, while mobile phase B consisted of 99.9% HPLC-grade water, 0.1% acetic acid, and 0.1 mol sodium acetate. All buffers were filtered through a 0.2 µm pore size filter and degassed.

Chromatographic separation was performed using a Shimadzu Prominence LC-20 system (Shimadzu Corporation, Japan) equipped with a UV detector (SPD-20A) and a fluorescence detector (RF-10AXL). The HPLC system was equipped with a binary pump (LC-20AD), an autosampler (SIL-20AC), a degasser (DGU-20A5) and a column thermostat (CTO-20A), controlled by LCSolution software. Samples and standards were separated on a Thermo Hypersil GOLD C18 (150 mm × 4 mm, 5 µm) HPLC column manufactured by Thermo Fisher Scientific (USA, distributor – India branch). UV detection was performed at a wavelength of 254 nm. The mobile phase flow rate was 0.8 mL/min. The total HPLC analysis time for the separation of derivatised amino acids in a single sample was 43 minutes. The column temperature was maintained at 40°C.

Standard solutions of 18 amino acids were used to calibrate the system: L-aspartic acid (Asp), L-glutamic acid (Glu), L-serine (Ser), L-asparagine (Asn), L-histidine (His), L-arginine (Arg), L-threonine (Thr), L-alanine (Ala), L-proline (Pro), L-cysteine (Cys), L-tyrosine (Tyr), L-valine (Val), L-methionine (Met), L-cystine (Cystine), L-isoleucine (Ile), L-leucine (Leu), L-phenylalanine (Phe) and L-lysine (Lys), purchased from Titan Biotech Ltd (India, Delhi, Netaji Subhash Place). All amino acids were commercially available, pure and of pharmaceutical grade (purity ⩾99%). Each amino acid was accurately weighed and dissolved in 0.1 mol HCl to prepare a stock solution with a concentration of 1 mg/mL. Each 1 mL standard solution was evaporated under vacuum and derivatised using the method described above. Five calibration solutions were prepared by serial dilution at the following concentrations for each amino acid: 1, 10, 25, 50

and 100.0 µg/mL. Calibration curves were constructed using the least squares method, with a correlation coefficient of at least 0.998 for all amino acids.

The quantitative content of amino acids in the samples was calculated based on the peak areas and calibration curves, expressing the results in g/100 g of absolutely dry matter. All analyses were performed in triplicate. Statistical data processing was carried out by determining the arithmetic mean values and standard deviations. Statistical analysis was performed using Microsoft Excel 2019 and Statistica 10.0 software. Differences between varieties were considered significant at a significance level of $p < 0.05$.

Results and Discussion

The results of the study to determine the amino acid composition of the 'Yulduz' chickpea variety are presented in Table 1 and Figure 1.

Table 1. Amino acid composition of 'Yulduz' chickpea grains

Amino acids	Retention time, min	Peak area	Concentration in the initial sample, µg/mL	Content, g/100 g dry matter
Aspartic acid	8.599	5,211,277	3,686.17	3.69
Glutamic acid	9.375	1,518,458	757.92	0.76
Serine	10.226	1,258,646	421.67	0.42
Asparagine	10.595	1,303,993	697.76	0.70
Histidine	11.729	3,678,498	1,616.81	1.62
Arginine	12.429	333,678	289.22	0.29
Threonine	12.655	820,705	327.74	0.33
Alanine	13.060	1,074,865	305.68	0.31
Proline	13.413	1,886,110	266.57	0.27
Cysteine	14.684	462,755	53.45	0.05
Tyrosine	16.029	467,679	247.70	0.25
Valine	17.111	478,938	262.30	0.26
Methionine	17.511	1,438,629	795.33	0.80
Cystine	18.010	2,079,349	2,704.21	2.70
Isoleucine	19.019	646,529	215.29	0.22
Leucine	19.474	644,791	374.56	0.37
Phenylalanine	20.136	563,213	308.01	0.31
Lysine	20.962	219,758	93.05	0.09

Source: compiled by the authors

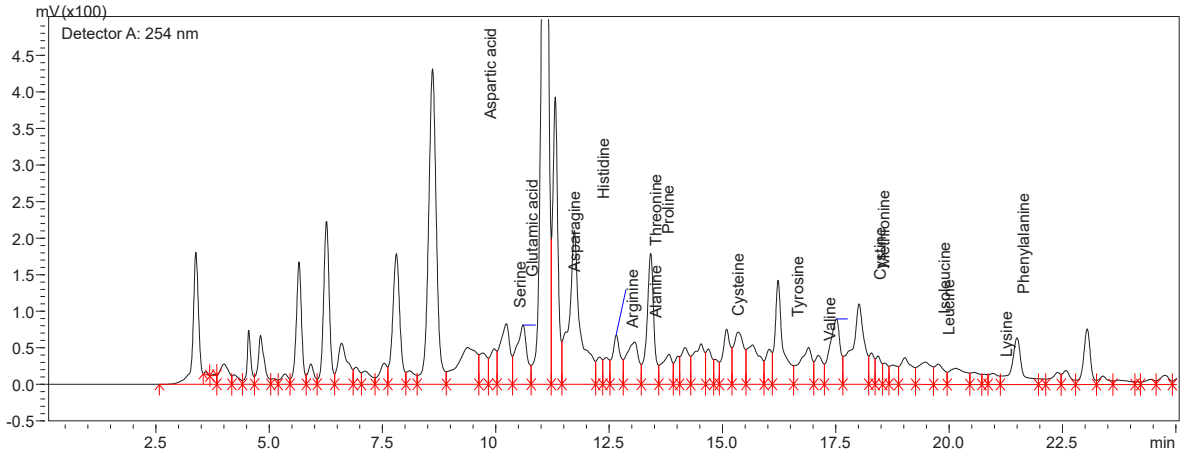

Figure 1. Amino acid composition of the 'Yulduz' variety of chickpeas

Source: authors' development

Table 1 and Figure 1 show that the 'Yulduz' variety has the highest amino acid potential. The grains of this variety are clearly dominated by aspartic acid (3.69 g/100 g) and cystine (2.70 g/100 g), which have the highest values among all three varieties. The high content of glutamic and aspartic acids, as well as histidine, is characteristic of the protein of the 'Yulduz' chickpea variety: the histidine content (1.62 g/100g) is the highest among all three varieties. This variety has an average arginine content. Essential amino acids: methionine (0.80 g/100 g), which is often a limiting amino acid in legumes, has a high value in this variety compared to other essential acids in this table. The lysine content in chickpea protein (0.09 g/100 g) is low. The amino acid composition of the protein of the 'Kyrgyz Local' variety is shown in Table 2 and Figure 2.

Table 2. Amino acid composition of the grain of the 'Kyrgyz Local' variety

Amino acids	Retention time, min	Peak area	Concentration in the initial sample, µg/mL	Content, g/100 g dry matter
Aspartic acid	8.545	4,782,908	3,383.17	3.38
Glutamic acid	9.332	1,563,239	780.27	0.78
Serine	10.174	1,349,914	452.24	0.45
Asparagine	10.545	1,089,511	582.99	0.58
Histidine	11.715	2,425,717	1,066.18	1.07
Arginine	12.364	489,249	424.07	0.42
Threonine	12.604	646,977	258.36	0.26
Alanine	13.023	913,005	259.65	0.26
Proline	13.492	1,770,832	250.28	0.25
Cysteine	14.525	1,008,567	116.48	0.12
Tyrosine	16.163	896,952	475.06	0.48
Valine	17.112	437,404	239.55	0.24
Methionine	17.443	1,537,509	850.00	0.85
Cystine	17.973	1,796,575	2,336.46	2.34
Isoleucine	19.311	543,864	181.10	0.18
Leucine	19.572	366,164	212.70	0.21
Phenylalanine	20.173	424,961	232.40	0.23
Lysine	20.965	320,051	135.52	0.14

Source: compiled by the authors

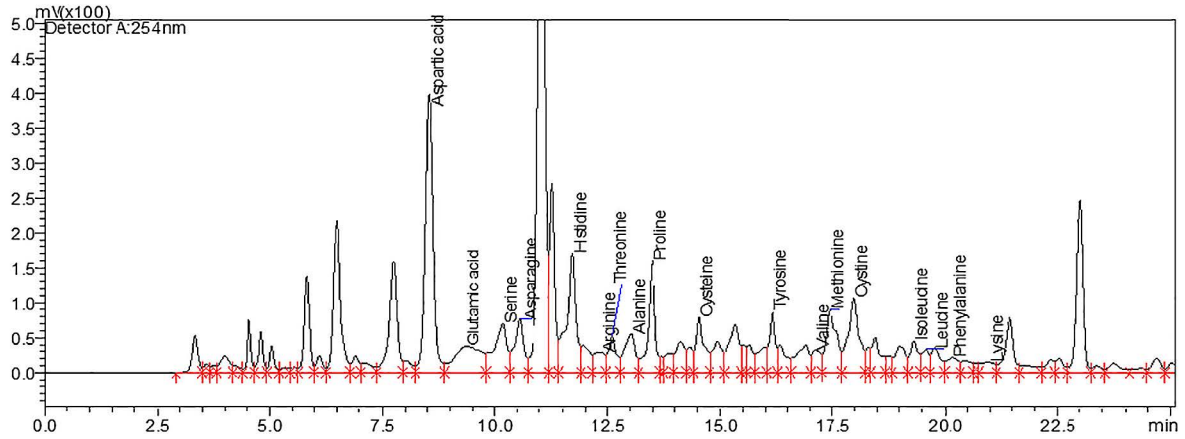

Figure 2. Amino acid composition of 'Kyrgyz Local' variety

Source: authors' development

The data in Table 2 and Figure 2 show that the 'Kyrgyz Local' variety also has high amino acid potential, especially in terms of the content of the essential amino acid methionine. The highest concentrations in the 'Kyrgyz Local' variety are found in aspartic acid (3.38 g/100 g) and cystine (2.34 g/100 g). This variety has the highest content of methionine (0.85 g/100 g) and glutamic acid (0.78 g/100 g) among the three varieties analysed. The arginine content (0.42 g/100 g) is also the highest of the three varieties. The lysine content (0.14 g/100 g) in this sample is higher than in the 'Yulduz' variety, but lower than in 'Uzbekistan 32'. The 'Kyrgyz Local' variety has a high histidine content (1.07 g/100 g) compared to other amino acids in this sample. The amino acid composition of the 'Uzbekistan 32' variety is shown in Table 3 and Figure 3.

Table 3. Amino acid composition of chickpeas of the 'Uzbekistan 32' variety

Amino acids	Retention time, min	Peak area	Concentration in the initial sample, µg/mL	Content, g/100 g dry matter
Aspartic acid	8.534	387,466	2,740.73	2.74
Glutamic acid	9.417	400,186	199.75	0.20
Serine	10.171	1,294,343	433.63	0.43
Asparagine	10.538	870,848	465.98	0.47
Histidine	11.709	1,600,926	703.66	0.70
Arginine	12.253	386,484	334.99	0.33
Threonine	12.567	642,637	256.63	0.26
Alanine	13.286	201,351	57.26	0.06

Table 3. Continued

Amino acids	Retention time, min	Peak area	Concentration in the initial sample, µg/mL	Content, g/100 g dry matter
Proline	13.591	1,446,738	204.47	0.20
Cysteine	14.542	723,982	83.62	0.08
Tyrosine	16.103	1,219,768	646.03	0.65
Valine	16.918	371,809	203.63	0.20
Methionine	17.417	1,296,070	716.52	0.72
Cystine	17.938	1,174,374	1,527.28	1.53
Isoleucine	19.312	550,471	183.30	0.18
Leucine	19.539	325,470	189.06	0.19
Phenylalanine	20.182	388,121	212.26	0.21
Lysine	20.916	308,119	130.47	0.13

Source: compiled by the authors

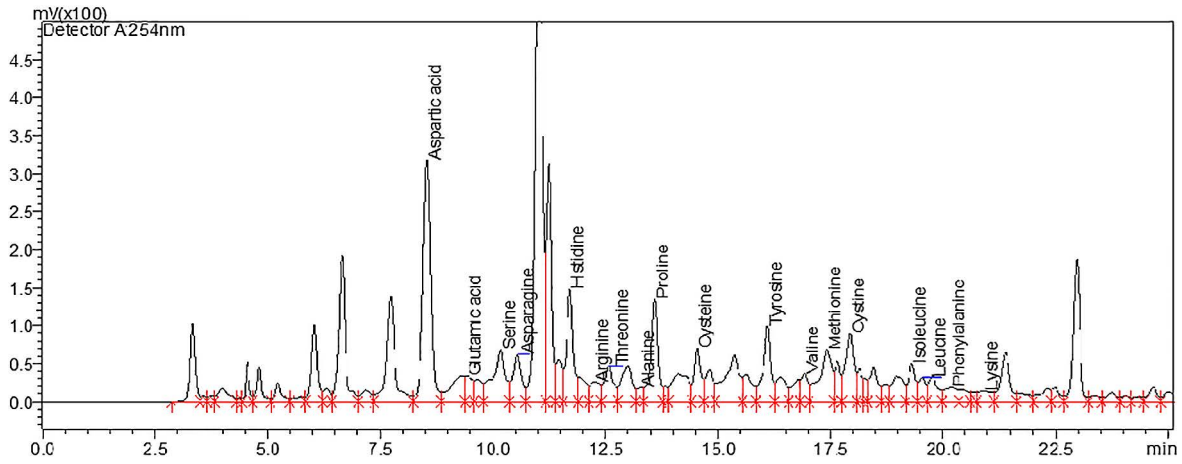

Figure 3. Amino acid composition of chickpeas of the 'Uzbekistan 32' variety

Source: authors' development

Data presented in Table 3 and Figure 3 indicate that 'Uzbekistan 32' possesses a lower overall amino acid profile than its counterparts, save for tyrosine. Notably, although aspartic acid reached its peak concentration at 2.74 g/100 g within this variety, this figure remains the lowest observed among the three varieties compared. This variety has the highest tyrosine content (0.65 g/100 g). The glutamic acid content (0.20 g/100 g) in this sample is significantly lower than in the other two varieties. The cystine content (1.53 g/100 g) is also the lowest among the three varieties. The lysine content (0.13 g/100 g) is average compared to 'Yulduz' (0.09) and 'Kyrgyz Local' (0.14). The 'Uzbekistan 32' variety showed good results in terms of leucine content in the grain. An analysis of the amino acid composition of chickpea grains of the 'Yulduz', 'Kyrgyz Local' and 'Uzbekistan 32' varieties using high-performance liquid chromatography revealed significant differences in the content of certain amino acids, which determine their potential nutritional value. All three varieties studied contain significant amounts of amino acids, confirming the status of chickpeas as an important source of plant protein. Eighteen amino acids were identified in the protein of the varieties studied, the content of which varies depending on the genotype.

Among the essential amino acids, methionine is of particular interest, as its content varied in the samples studied. The highest methionine content was found in the 'Kyrgyz Local' variety (0.85 g/100 g), followed by 'Yulduz' (0.80 g/100 g) and 'Uzbekistan 32' (0.72 g/100 g). These values are consistent with the data of other researchers: for example, S. Onder *et al.* (2023) report methionine content in Turkish chickpea varieties ranging from 0.65 to 0.68 g/100 g, which confirms the deficiency of sulphur-containing amino acids characteristic of legumes. N. Wang & J. Daun (2004) note that common legumes, including chickpeas, field peas, lentils and beans, contain about 1.0 g of methionine and cysteine per 16 g of nitrogen. According to FAO/WHO/UNU requirements, most chickpea varieties are deficient in methionine, which necessitates combining them with protein sources rich in sulphur-containing amino acids (Onder *et al.*, 2023).

The lysine content in the samples studied was relatively low, amounting to 0.09 g/100 g in the 'Yulduz' variety, 0.13 g/100 g in the 'Uzbekistan 32' variety, and 0.14 g/100 g in the 'Kyrgyz Local' variety. These data contrast with the results of studies in other regions. In Pakistani chickpea varieties, according to A. Iqbal *et al.* (2006), lysine was one of the dominant essential

amino acids (7.2% of protein), second only to leucine (8.7% of protein) and arginine (8.3% of protein). Turkish studies have shown that lysine is one of the three most common amino acids in chickpea protein isolates, along with glutamic and aspartic acids (Arik Kibar & Aslan, 2024). Studies by international authors confirm significant variability in the amino acid composition of chickpeas depending on the genotype. Turkish scientists have found significant differences in the content of hydrophobic amino acids between varieties: the 'Yasa' variety contained 32% hydrophobic amino acids, while in other isolates their share was about 28% (Onder *et al.*, 2023). The mass fraction of essential amino acids in chickpea protein isolates obtained by various extraction methods in the study by E. Arik Kibar & Ö. Aslan (2024) was 39.5-41.3 g/100 g. S. Grewal *et al.* (2023) demonstrated that the amino acid profile of chickpea genotypes with different protein contents shows a significantly higher average amino acid score for all essential amino acids compared to the WHO recommended values and is comparable to that of complete protein sources, allowing chickpeas to be considered a complete protein source.

It is important to note that the deficiency of sulphur-containing amino acids in chickpeas can be compensated for by combining them with cereal crops rich in methionine and cysteine. This practice is widespread in Asian countries, where legumes are traditionally consumed together with cereals, which allows the body's daily requirement for essential amino acids to be met (Zia-Ul-Haq *et al.*, 2007). A comparative analysis of various legumes showed that *Vigna unguiculata* (cowpea) is the richest in total essential amino acids, while *Cicer arietinum* (chickpea) has lower levels. Similarly, *Glycine max* (soybean) surpasses chickpea in terms of the total amount of replaceable and total amino acids (Köse *et al.*, 2024). The results obtained demonstrate that the protein of the studied chickpea varieties is characterised by a diverse amino acid composition, including 18 identified amino acids, the content of which varies significantly depending on the variety. The identified differences determine the specific nutritional characteristics of each variety and their potential for use in the development of functional foods.

Conclusions

A study of the amino acid composition of three varieties of chickpea (*Cicer arietinum* L.) – 'Kyrgyz Local', 'Uzbekistan 32' and 'Yulduz' – cultivated in the Kyrgyz Republic revealed significant varietal differences in their biochemical profiles. The differences in amino acid composition confirm that varietal characteristics and, possibly, growing conditions affect the chemical composition of chickpeas. Analysis performed by high-performance liquid chromatography with pre-column derivatisation with phenylisothiocyanate showed that the dominant amino acids in all samples are aspartic acid (content 2.74-3.69 g/100 g) and cystine (1.53-2.70 g/100 g), which confirms the high level of non-polar and sulphur-containing components in chickpea protein. The 'Yulduz' variety stands out for its maximum content of histidine (1.62 g/100 g) and methionine (0.80 g/100 g), as well as aspartic acid (3.69 g/100 g) and cystine (2.70 g/100 g), demonstrating excellent amino acid potential for enriching diets. The 'Kyrgyz Local' variety has the highest content of methionine (0.85 g/100 g), glutamic acid (0.78 g/100 g) and arginine (0.42 g/100 g), which makes it promising for improving soil nitrogen balance and nutrition. The 'Uzbekistan 32' variety is characterised by peak values of aspartic acid (2.74 g/100 g), cystine (1.53 g/100 g) and tyrosine (0.65 g/100 g), although it shows lower values for methionine (0.72 g/100 g).

Despite the overall high concentration of essential amino acids such as leucine (0.19-0.37 g/100 g), valine (0.20-0.26 g/100 g) and phenylalanine (0.21-0.31 g/100 g), the lysine content remains a limiting factor – from 0.09 g/100 g in 'Yulduz' to 0.14 g/100 g in 'Kyrgyz Local', which requires combining with cereals to achieve a complete profile. These results are consistent with global data on chickpeas as a valuable source of plant protein, but highlight the need for local biofortification to increase the level of sulphur-containing amino acids. The research results suggest that chickpeas have significant amino acid potential for strengthening food security and transitioning to sustainable nutrition in Kyrgyzstan. The high protein content with a favourable amino acid profile, combined with the agroecological sustainability of the crop, makes chickpeas a strategically important resource. Further research is needed on the amino acid composition of chickpea protein depending on other agronomic practices, including the influence of predecessors, fertilisers, sowing dates and rates.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Arik Kibar, E.A., & Aslan, Ö. (2024). Ultrasound-assisted extraction of chickpea proteins and their functional and technological properties. *Food Technology and Biotechnology*, 62(4), 488-500. doi: 10.17113/ftb.62.04.24.8502.

[2] Asanaliev, A.Zh., Sultanbaeva, V.A., Khegay, S.V., & Sodombekov, I.S. (2017). Chickpea productivity depending on sowing dates and patterns in the foothill zone of the Chui Valley. *Advances in Modern Natural Science*, 3, 46-50.

[3] Aschemann-Witzel, J., Gantriis, R.F., Fraga, P., & Perez-Cueto, F.J.A. (2021). Plant-based food and protein trend from a business perspective: Markets, consumers, and the challenges and opportunities in the future. *Critical Reviews in Food Science and Nutrition*, 61(18), 3119-3128. doi: 10.1080/10408398.2020.1793730.
[4] Chang, Y.W., Alli, I., Konishi, Y., & Ziomek, E. (2011). Characterization of protein fractions from chickpea (*Cicer arietinum* L.) and oat (*Avena sativa* L.) seeds using proteomic techniques. *Food Research International*, 44(9), 3094-3104. doi: 10.1016/j.foodres.2011.08.001.
[5] Convention on Biological Diversity. (1992, June). Retrieved from https://www.cbd.int/.
[6] Dhaliwal, S.K., Salaria P., & Kaushik, P. (2021). Pea seed proteins: A nutritional and nutraceutical update. In J.C. Jimenez-Lopez (Ed.), *Grain and seed proteins functionality* (Chapter 7). London: IntechOpen. doi: 10.5772/intechopen.95323.
[7] FAOSTAT. (n.d.). *Crops and livestock products*. Retrieved from https://www.fao.org/faostat/en/#data/QCL.
[8] Glusac, J., Isaschar-Ovdat, S., & Fishman, A. (2020). Transglutaminase modifies the physical stability and digestibility of chickpea protein-stabilized oil-in-water emulsions. *Food Chemistry*, 315, article number 126301. doi: 10.1016/j.foodchem.2020.126301.
[9] GOST 31640-2012. (2020). *Feed. Methods for determining dry matter content*. Retrieved from https://meganorm.ru/Data/523/52337.pdf.
[10] Grewal, S.K., *et al*. (2023) Characterization of chickpea cultivars and trait specific germplasm for grain protein content and amino acids composition and identification of potential donors for genetic improvement of its nutritional quality. *Plant Genetic Resources*, 20(6), 383-393. doi: 10.1017/S147926212300028X.
[11] International Seed Testing Association (ISTA). (n.d.). *International rules for seed testing*. Retrieved from https://www.seedtest.org/en/publications/international-rules-seed-testing.htmL.
[12] Iqbal, A., Ateeq, N., Khalil, I.A., Perveen, S., & Saleemullah, S. (2006). Physicochemical characteristics and amino acid profile of chickpea cultivars grown in Pakistan. *Journal of Foodservice*, 17, 94-101. doi: 10.1111/j.1745-4506.2006.00024.x.
[13] Köse, N., Karatas, F., & Saydam, S. (2024). Comparison of total protein and amino acid content of some legumes types. *MW Journal of Science*, 1(3), 8-17. doi: 10.5281/zenodo.14582470.
[14] Koul, B., Sharma, K., Sehgal, V., Yadav, D., Mishra, M., & Bharadwaj, C. (2022). Chickpea (*Cicer arietinum* L.) biology and biotechnology: From domestication to biofortification and biopharming. *Plants*, 11(21), article number 2926. doi: 10.3390/plants11212926.
[15] Liu, K., Bandara, M., Hamel, C., Knight, J.D., & Gan, Y. (2020). Intensifying crop rotations with pulse crops enhances system productivity and soil organic carbon in semi-arid environments. *Field Crops Research*, 248, article number 107657. doi: 10.1016/j.fcr.2019.107657.
[16] Ministry of Water Resources, Agriculture and Processing Industry of the Kyrgyz Republic (n.d.). Retrieved from https://agro.gov.kg/.
[17] National Statistical Committee of the Kyrgyz Republic (NSCKR). (n.d.). Retrieved from https://stat.gov.kg/en/.
[18] Olagunju, A.I., Omoba, O.S., Enujiugha, V.N., Alashi, A.M., & Aluko, R.E. (2018). Antioxidant properties, ACE/renin inhibitory activities of pigeon pea hydrolysates and effects on systolic blood pressure of spontaneously hypertensive rats. *Food Science & Nutrition*, 6(7), 1879-1889. doi: 10.1002/fsn3.740.
[19] Onder, S., Karaca, A.C., Ozcelik, B., Alamri, A.S., Ibrahim, S.A., & Galanakis, C.M. (2023). Exploring the amino-acid composition, secondary structure, and physicochemical and functional properties of chickpea protein isolates. *ACS Omega*, 8(1), 1486-1495. doi: 10.1021/acsomega.2c06912.
[20] Pankina, I.A., & Borisova, L.M. (2016). Grain legumes' swelling and solubility of their dry solids. *Scientific Journal of ITMO University. Processes and Food Production Equipment*, 2, 13-20. doi: 10.17586/2310-1164-2016-9-2-13-20.
[21] Patil, N.D., Bains, A., Sridhar, K., Bhaswant, M., Kaur, S., Tripathi, M., Lanterbecq, D., Chawla, P., & Sharma, M. (2024). Extraction, modification, biofunctionality, and food applications of chickpea (*Cicer arietinum*) protein: An up-to-date review. *Foods*, 13(9), article number 1398. doi: 10.3390/foods13091398.
[22] Roy, F., Boye, J.I., & Simpson, B.K. (2010). Bioactive proteins and peptides in pulse crops: Pea, chickpea and lentil. *Food Research International*, 43(2), 432-442. doi: 10.1016/j.foodres.2009.09.002.
[23] Salaria, S., Boatwright, J.L., Johnson, N., Madurapperumage, A., Joshi, P., Thavarajah, P., Vandemark, G., & Thavarajah, D. (2023). Fatty acid composition and genome-wide associations of a chickpea (*Cicer arietinum* L.) diversity panel for biofortification efforts. *Scientific Reports*, 13, article number 14002. doi: 10.1038/s41598-023-41274-3.
[24] Torutaeva, E., Asanaliev, A., Prieto-Linde, M.L., Zborowska, A., Ortiz, R., Bryngelsson, T., & Garkava-Gustavsson, L. (2014). Evaluation of microsatellite-based genetic diversity, protein and mineral content in chickpea accessions grown in Kyrgyzstan. *Hereditas*, 151, 81-90. doi: 10.1111/hrd2.00042.
[25] Wang, N., & Daun, J.K. (2004). The chemical composition and nutritive value of Canadian pulses. *Canadian Grain Commission Report*, 28, 19-29.

[26] Xu, W., McClements, D.J., Xu, Z., Meng, M., Zou, Y., Chen, G., Jin, Z., & Chen, L. (2024). Optimization of emulsion properties of chickpea protein and its application in food. *Journal of the American Oil Chemists' Society*, 101(10), 971-980. doi: 10.1002/aocs.12816.
[27] Yeasmen, N., & Orsat, V. (2025). Industrial processing of chickpeas (*Cicer arietinum*) for protein production. *Crop Science*, 65, article number e21361. doi: 10.1002/csc2.21361.
[28] Zia-Ul-Haq, M., Iqbal, S., Ahmad, S., Imran, M., Niaz, A., & Bhanger, M.I. (2007). Nutritional and compositional study of desi chickpea (*Cicer arietinum* L.) cultivars grown in Punjab, Pakistan. *Food Chemistry*, 105(4), 1357-1363. doi: 10.1016/j.foodchem.2007.05.004.
[29] Zotikov, V.I., Naumkina, T.S., Sidorenko, V.S., Gryadunova, N.V., & Naumkin, V.V. (2016). Leguminous crops – an important factor in sustainable, environmentally-oriented agriculture. *Legumes and Groat Crops*, 17(1), 6-13.

Кыргыз Республикасында өстүрүлгөн нокот сортторунун (*Cicer arietinum* L.) данынын аминокислоталык курамы

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Аннотация. Нокот (*Cicer arietinum* L.) өсүмдүк протеининин маанилүү булагы болуп саналат; бирок, Кыргыз Республикасында өстүрүлгөн сорттордун биохимиялык курамы боюнча маалыматтар чектелүү. Бул изилдөөнүн максаты өлкөдө өстүрүлгөн үч нокот сортунун ('Кыргыз жергиликтүү', 'Өзбекистан 32' жана 'Жылдыз') данынын аминокислота курамын аныктоо жана алардын азыктык баалуулугун аныктоо болгон. Орточо үлгүлөр 2024-жылдагы түшүмдөн ISTAнын ыкмасы боюнча чогултулган. Аминокислота анализи фенил изотиоцианат менен алдын ала колонка дериватизациясы менен кислота гидролизинен кийин жогорку натыйжалуу суюк хроматография (HPLC) аркылуу жүргүзүлдү. Изилдөө айрым аминокислоталардын курамы боюнча олуттуу сорттук айырмачылыктарды аныктады. Метиониндин эң жогорку курамы 'Кыргыз жергиликтүү' сортунда (0,85 г/100 г), андан кийин 'Жылдыз' (0,80 г/100 г) жана 'Өзбекистан 32' (0,72 г/100 г) сортунда катталган. Лизиндин курамы 0,09 г/100 г-дан ('Жылдыз') 0,14 г/100 г-га ('Кыргыз жергиликтүү') чейин өзгөрүп турган. Бардык үлгүлөрдөгү басымдуу аминокислоталар аспарагин кислотасы (2,74-3,69 г/100 г) жана цистин (1,53-2,70 г/100 г) болгон. 'Жылдыз' сорту гистидиндин максималдуу курамын (1,62 г/100 г) жана 'Өзбекистан 32' тирозинди (0,65 г/100 г) көрсөткөн. Алынган жыйынтыктар нокоттун жагымдуу аминокислота профилине ээ болгон өсүмдүк протеининин баалуу булагы макамын тастыктайт жана Кыргыз Республикасында тең салмактуу тамактанууну жана функционалдык азыктарды иштеп чыгууда колдонулушу мүмкүн

Негизги сөздөр: биохимиялык профиль; белок; жогорку натыйжалуу суюктук хроматографиясы; лизин; метионин; аргинин

Аминокислотный состав зерна сортов нута (*Cicer arietinum* L.), культивируемых в Кыргызской Республике

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Аннотация. Нут (*Cicer arietinum* L.) является важным источником растительного белка, однако данные о биохимическом составе сортов, культивируемых в Кыргызской Республике, ограничены. Целью исследования было определение аминокислотного состава зерна трех сортов нута (‘Кыргызский местный’, ‘Узбекистанский 32’ и ‘Юлдуз’), выращиваемых в республике, для оценки их пищевой ценности. Средние образцы отбирали согласно методике ISTA с урожая 2024 года. Аминокислотный анализ проводили методом высокоэффективной жидкостной хроматографии (ВЭЖХ) после кислотного гидролиза с предколоночной дериватизацией фенилизотиоцианатом. Исследование выявило существенные сортовые различия в содержании отдельных аминокислот. Наибольшее содержание метионина зафиксировано в сорте ‘Кыргызский местный’ (0,85 г/100 г), за которым следуют ‘Юлдуз’ (0,80 г/100 г) и ‘Узбекистанский 32’ (0,72 г/100 г). Содержание лизина варьировало от 0,09 г/100 г (‘Юлдуз’) до 0,14 г/100 г (‘Кыргызский местный’). Доминирующими аминокислотами во всех образцах были аспарагиновая кислота (2,74-3,69 г/100 г) и цистин (1,53-2,70 г/100 г). Сорт ‘Юлдуз’ продемонстрировал максимальное содержание гистидина (1,62 г/100 г), а ‘Узбекистанский 32’ – тирозина (0,65 г/100 г). Полученные результаты подтверждают статус нута как ценного источника растительного белка с благоприятным аминокислотным профилем и могут быть использованы при разработке сбалансированных рационов питания и функциональных пищевых продуктов в условиях Кыргызской Республики

Ключевые слова: биохимический профиль; белок; высокоэффективная жидкостная хроматография; лизин; метионин; аргинин

Received: 30.09.2025. Revised: 07.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 634.11: 632.35

DOI: 10.63621/bknau./1.2026.28

Assessment of the resistance of modern apple varieties to the bacterial blight pathogen *Erwinia amylovora*

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Abstract. Modern requirements for new apple varieties include not only high yield and improved fruit quality, but also resistance to the most dangerous diseases, including bacterial canker caused by *Erwinia amylovora*. The aim of this study was to evaluate the resistance of modern apple varieties common in Kyrgyzstan to the causative agent of fire blight under artificial infection conditions. For the experiment, a pure culture of the phytopathogenic bacterium *E. amylovora* (strain ZH-2) isolated from infected branches of the 'Talgarka' pear variety was used. Infection was carried out *in vitro* by applying a bacterial suspension with a concentration of 10^9 CFU/ml to the wound surfaces of shoots and leaves of two-year-old seedlings. The degree of damage was assessed visually 1, 6, 12 and 30 days after inoculation on a five-point scale, taking into account the percentage of damaged tissue. The results of the study showed significant differences in resistance between the eleven apple varieties studied. The most resistant varieties were 'Red Chief', 'Bishkek', and 'Golden', with damage levels ranging from 6.3 to 9.5%, indicating strong defensive responses and low levels of necrosis symptoms. The 'Fuji' variety showed an average level of susceptibility (about 16-18%), characterised by moderate damage to shoot tissues. The most susceptible to infection were the varieties 'Idared' (48%), 'Gala' (43%) and 'Ligolina' (37%), which showed rapid development of necrotic spots and wilting of shoots. The results obtained allow for identifying varieties that are promising for further propagation and breeding work, resistant to bacterial burn, and also give an idea of the range of susceptibility of modern apple varieties in the conditions of Kyrgyzstan

Keywords: artificial infection; degree of damage; phytopathogenic bacteria; tissue necrosis; *in vitro*

Introduction

The domestic apple tree (*Malus domestica* Borkh.) is one of the most important fruit crops. According to FAO (n.d.), annual global apple production exceeds 87.2 million tonnes; China is the largest producer

Suggested Citation: Konurbaeva, M., Doolotkeldieva, T., & Zholdoshbekova, S. (2026). Assessment of the resistance of modern apple varieties to the bacterial blight pathogen *Erwinia amylovora*. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 28-40. doi: 10.63621/bknau./1.2026.28.

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(41.39 million tonnes), followed by the United States and other countries. Kyrgyzstan ranks 45th in the world in apple production: approximately 147,593 tonnes. Therefore, controlling pests and diseases of apple trees is crucial to ensuring crop stability, improving product quality and expanding export potential. According to R. Yuvarani *et al.* (2025), the development of intensive horticulture, the introduction of disease-resistant varieties, the use of modern plant protection methods and the monitoring of the phytosanitary condition of plantations can significantly reduce losses from dangerous infections such as bacterial burn. At the same time, strengthening the Kyrgyz Republic's position in the global fruit and vegetable market and meeting the domestic market's demand for high-quality fruit products is closely linked to the effective protection of apple orchards. Bacterial fire blight of fruit crops is one of the most dangerous diseases of apple trees and other plants of the Rosaceae family, caused by the bacterium *Erwinia amylovora*. It is a quarantine disease and poses a serious threat to fruit plantations (Aćimović *et al.*, 2023; Moskalets *et al.*, 2023). The disease causes necrosis of all plant organs, leading to significant crop losses and tree death. The main strategy for combating the disease traditionally remains the destruction of infected trees, treatment with copper-containing preparations and other pesticides, and in some countries, the use of antibiotic solutions. However, the widespread use of such preparations causes the emergence of drug-resistant bacteria. For example, a study by A. Jimenez Madrid & M. Lewis Ivey (2023) revealed the strain resistance of *E. amylovora* to streptomycin and other antibiotics.

In the context of new developments in the field of protecting apple trees from bacterial blight, the following areas are particularly relevant. Firstly, genotypic and phenotypic assessment of the resistance of varieties and rootstocks. G. Kairova *et al.* (2023a), based on the results of a study of 59 apple varieties in Kazakhstan, found that in all genotypes studied, the markers of resistance to *E. amylovora* (e.g., AE10-375 and GE-8019) were identical in all genotypes studied, indicating limited existing genetic variability for resistance. Similarly, a study of 11 apple rootstocks in Kazakhstan revealed that the own-rooted rootstock lines G.41, G.16 and "62-396" show the best resistance to fire blight (Kairova *et al.*, 2023b). Secondly, a study of the wild apple tree *Malus sieversii*, the ancestral species of the domestic apple tree, revealed the presence of genotypes with high resistance to *E. amylovora* (Tegtmeier *et al.*, 2025). Thirdly, genomic and associative mapping of resistance to fire blight allow the identification of key regions and genes. R. Thapa *et al.* (2021) identified 23 and 38 quantitative trait loci (QTLs) significantly associated with resistance to shoot and flower blight, respectively. Finally, alternative environmentally friendly control approaches are emerging: for example, the isolation and characterisation of three bacteriophages infecting *E. amylovora* as a potential biological control agent (Hassan *et al.*, 2023). Thus, the relevance of the study lies in the need to assess the resistance of modern apple varieties and rootstocks to the bacterial blight pathogen *E. amylovora* in the conditions of the Kyrgyz Republic, with the aim of identifying the most promising ones for industrial and amateur horticulture and their rapid introduction into practice. In the context of climate change, increased international trade and stricter quarantine requirements, this approach is becoming particularly important.

The aim of this study was to assess the resistance of modern apple varieties to the bacterial blight pathogen (*Erwinia amylovora*) by conducting artificial infection of plants and analysing the severity of external symptoms of the disease in order to identify the most resistant varieties that are promising for cultivation in the Kyrgyz Republic.

Materials and Methods

Modern apple varieties (*Malus domestica* Borkh.), mainly imported from other countries and widely used by gardeners planting trees on their plots in Kyrgyzstan, were used as research objects. The selection of varieties was based on their popularity and official recommendations. The study was conducted at the experimental stationary site of the Kyrgyz-Turkish Manas University, Faculty of Agriculture (Bishkek, Kyrgyz Republic). For the experiment, two-year-old seedlings of 11 different apple varieties were planted in individual pots. A brief description of the varieties is given in Table 1.

Table 1. Characteristics of apple varieties grown in the Kyrgyz Republic

No.	Variety name	Origin	Brief description	Included in the state register
1	**'Starkrimson'**	American selection (Genus Star Delicious)	American apple tree variety. Ripening period: autumn-winter; apple taste: sweet and sour; average weight: medium (100-200 g); fruit colour: greenish-red, dark red; flesh colour: light yellow; transportability: good; frost resistance: weak; disease resistance: powdery mildew.	Introduced, regionalised in Kyrgyzstan and registered in 1980
2	**'Red Chief'**	American selection (Genus Red Delicious)	American apple tree. Ripening period: autumn-winter; apple taste: sweet; average weight: large (over 200 g); fruit colour: deep red; flesh: red-yellow, dense, medium juiciness; transportability: good; winter hardiness: high; drought resistance: average; disease resistance: good resistance to powdery mildew, bacterial burn.	Introduced and regionalised in Kyrgyzstan in 2015-2017, registered in 2019

Table 1. Continued

No.	Variety name	Origin	Brief description	Included in the state register
3	**'Bellefleur'**	American selection	American apple tree variety. Ripening period: autumn; apple taste: sweet and sour with a spicy note; average weight: medium-large (200 g); fruit colour: light yellow; flesh: white, juicy, fine-grained; transportability: excellent; resistance to low temperatures: weak; disease resistance: low, especially to scab.	Introduced and regionalised in Kyrgyzstan in 1938-1940
4	**'Golden'**	American selection ('Grimes Golden' x 'Golden Reinet')	American apple tree variety. Ripening period: winter; taste: dessert, with a rich aroma; average weight: large (140-160 g); fruit colour: light green at the beginning of ripening, then gradually acquires a golden-yellow colour, with a pink blush appearing on the sunny side; flesh: white with a slight greenish tint, dense; transportability: excellent, long-term preservation of marketable appearance; drought resistance: poor; disease resistance: low resistance to brown spot and powdery mildew.	Introduced and regionalised in Kyrgyzstan in 1980-1982
5	**'Bishkek'**	Kyrgyz selection	Apple tree of Kyrgyz selection. Ripening period: winter; taste: sweet and sour with a strong aroma; average weight: large, uniform (140-170 g); fruit colour: light green, creamy white with a bright crimson blush; flesh: juicy, greenish-white; transportability: excellent, can be stored for a long time in a cold room; disease resistance: increased resistance to scab, powdery mildew, apple fruit moth, highly resistant to bacterial burn.	Local variety, bred in Kyrgyzstan in 1990, registered in 2018
6	**'Niedzwetzky'**	Wild	A rare species of apple tree (red, Chinese), endemic, is a valuable material for breeding work to develop new varieties. I. Michurin used this species to obtain the varieties 'Red Bellefleur', 'Red Standard', etc. It grows in Kyrgyzstan (in the Chatkal Valley, in the Sary-Chelek Nature Reserve, in the Kara-Suu and Aflatun tracts, in the foothill forests of Kara-Alma and Ak-Terek-Kaba). It is found in the mountain ecosystems of Kazakhstan and Uzbekistan. It also grows in western China (Xinjiang Western District). Fruit: spherical, purple-red; average weight: small, below average; leaves: rounded-elongated, rich green-red colour.	Endemic
7	**'Idared'**	American selection ('Wagner' x 'Jonathan')	American apple tree variety. Ripening period: winter or late winter. On medium-sized rootstocks, trees begin bearing fruit in 5-6 years. Regular fruiting. The advantages of this variety are high ecological adaptability, yield, and high marketability of fruit. Susceptible to scab and powdery mildew.	In Kyrgyzstan, it was entered in the register in 2006
8	**'Ligolina'**	Polish selection	Polish apple tree variety. Late winter variety, high-yielding, resistant to scab and powdery mildew. Medium-sized trees. Fruits are above average in size, cylindrical. The main colour is yellow-green, with a blurred red blush covering almost the entire surface of the fruit. The quality of the fruit does not change during storage.	Not registered in the Kyrgyzstan registry
9	**'Early Geneva'**	American selection ('Quinty' x 'Julyred')	American apple tree variety. An early-ripening apple tree variety that differs from other varieties in its regular harvest, high yield and excellent taste. The variety is very early-bearing (1 year after planting). Resistant to scab and powdery mildew.	Registered in the Kyrgyzstan registry in 2019
10	**'Gala'**	New Zealand selection ('Golden Delicious' x 'Kidd's Orange Red')	A late autumn apple variety bred in 1962 in New Zealand by breeder J. Kidd as a result of crossing two varieties – 'Golden Delicious' x 'Kidd's Orange Red'. The new variety quickly gained worldwide popularity (2nd place in the world in terms of apple yield), and almost immediately after its development, orchards were planted in the USA, Canada, Brazil and Europe.	It was registered in the Kyrgyzstan registry in 2019
11	**'Fuji'**	Japanese selection ('Red Delicious' x 'Virginian Rale Janet')	The variety was obtained by crossing two American apple varieties – 'Red Delicious' and 'Virginian Rale Janet'. It was first obtained at the Japanese research station in Tohoku (Fujisaki village, Minamitsugaru district, Aomori prefecture) in the late 1930s and introduced to the market in 1962. Fuji apples are usually round and range in size from large to very large, with an average diameter of 75 mm. They contain 9 to 11% sugar by weight and have firm, crisp flesh that tastes sweeter than other varieties.	Registered in the Kyrgyzstan registry in 2025

Source: compiled by the authors

The full cycle of the experiment was conducted from early spring to the end of June 2025, which ensured an active phase of shoot and leaf growth for inoculation. During the adaptation phase, the plants were kept without the use of fertilisers; only standard soil substrate was used. Before infection, the plants were examined, and all specimens with signs of other diseases were excluded from the experiment. Ten seedlings were used from each variety. All experiments with plants were conducted in strict accordance with the principles of CBD (1992) and CITES (1973).

A pure culture of *Erwinia amylovora* bacteria was used for artificial infection. Artificial inoculation was carried out in late May – early June, after the appearance of stable shoot growth and full physiological development of the leaves. At the preliminary stage of the study, pure cultures of the phytopathogenic bacterium *Erwinia amylovora* were isolated from various infected branches and leaves of apple and pear trees. A total of 18 strains were obtained, which were subsequently tested for pathogenicity. The White test was used to assess pathogenicity: immature apple fruits were inoculated with a suspension of cells in physiological solution at a concentration of 10^9 cells/ml (OP_{620} = 1.0). Ten microlitres of the suspension were injected into the fruit tissue using a sterile syringe, after which the fruit was incubated in a humid chamber in Petri dishes at a temperature of 25°C for 5 days. The appearance of tissue necrosis and milky-white bacterial exudate in the inoculation area was considered a positive test result. Based on the test results, the *E. amylovora* culture with the laboratory designation ZH-2, isolated from infected branches of the 'Talgarka' pear variety collected in the Zheti-Oguz district of the Issyk-Kul region, was selected for further experiments. This strain was used for subsequent artificial infection of apple seedlings (Fig. 1).

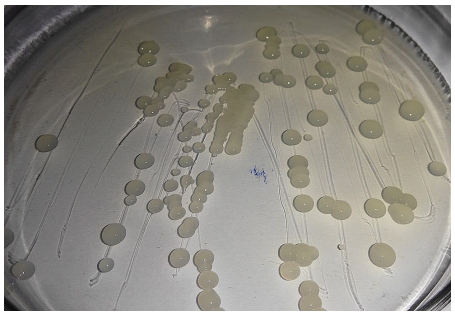

Figure 1. Laboratory strain ZH-2 – the causative agent of bacterial blight *Erwinia amylovora*
Source: authors' photo

To obtain biomass, the culture was grown at 27°C for 24-36 hours on a solid Levan nutrient medium with the following composition: yeast extract – 2 g, peptone – 5 g, NaCl – 5 g, sucrose – 50 g, agar – 20 g. To determine the number of live *Erwinia amylovora* cells, the colony-forming unit (CFU) counting method was used on a nutrient medium. From a 24-hour liquid culture, a series of tenfold serial dilutions (from 10^{-1} to 10^{-8}) in sterile phosphate-buffered saline (PBS). From each dilution, 0.1 ml of the suspension was seeded onto the surface of Levan nutrient medium, evenly distributed with a sterile glass spatula, and incubated at 27°C for 48 hours. After incubation, the number of colonies grown on plates containing 30-300 colonies was counted, and the number of CFU in 1 ml of the initial suspension was calculated using formula (1):

$$N = \frac{a \times 10^n}{V}, \quad (1)$$

where N is the number of CFU/ml; a is the average number of colonies per dish; 10^n is the dilution factor; V is the inoculum volume, ml.

The concentration of the suspension for inoculation was set at 10^9 CFU/ml. After artificial infection of apple seedlings and the appearance of characteristic symptoms of bacterial blight, leaf samples of equal weight were taken from the affected plants. The samples obtained were homogenised and sown on Levan medium for the purpose of re-isolating *E. amylovora* bacteria and determining the level of bacterial biomass on infected plants. The intensity of pathogen reproduction was assessed based on the number of colonies that grew, which made it possible to determine the degree of bacterial load on the seedlings after infection. To confirm the presence of the pathogen in infected tissues, rapid diagnostics were additionally performed using AgriStrip immunoassays (Bioreba, Switzerland), which allow the detection of specific *Erwinia amylovora* antigens. The positive reactions obtained served as preliminary confirmation of infection before bacteriological isolation on Levan's medium.

After inoculation, the plants were kept for 30 days under a protective canopy providing diffused natural light and protection from direct precipitation. The average air temperature during the observation period was 22-25°C, with relative humidity of 60-70%. To assess the resistance of varieties to *Erwinia amylovora*, a method of artificial infection of plants with a bacterial culture suspension at a concentration of 10^9 cells/ml was used. Artificial infection was carried out *in vitro* on young actively growing shoots. A sterile scalpel was used to create the wound. A small transverse incision 3-5 mm long was made on each shoot, located 5 mm below the shoot apex. Small punctures were made on the leaves near the central vein using a sterile injection needle (diameter 0.6 mm). Ten to twenty microlitres of *E. amylovora* bacterial suspension was applied to each wound surface using a micropipette. The suspension was evenly distributed over the wound area, ensuring that it completely wetted the damaged area. Infection was carried out on the shoots and leaves of the lower, middle and upper tiers of each plant. Control plants were

treated in a similar manner, but instead of the bacterial suspension, a sterile buffer solution was applied. The development of the infection was recorded visually 1, 6, 12 and 30 days after inoculation. The degree of damage was determined on a five-point scale: 0 – no symptoms, 1 – damage to up to 25% of the shoot, 2 – damage to 26-50%, 3 – damage to 51-75%, 4 – damage to more than 75% of the shoot or its death. The results obtained were statistically processed using analysis of variance (ANOVA) methods. The reliability of differences between varieties was assessed using Duncan/Tukey's test at a significance level of $p < 0.05$. All calculations were performed using IBM SPSS Statistics software, version 26.0.

Results and Discussion

Bacterial blight of fruit crops, caused by the bacterium *Erwinia amylovora*, is one of the most dangerous diseases affecting apple trees and other members of the Rosaceae family. The disease leads to significant economic losses, reduced yields, deterioration in fruit quality and, in particularly severe cases, the death of trees. The first signs of bacterial blight are darkening of inflorescences and young leaves, which turn brownish-black, as if burnt. According to A. Pedroncelli & G. Puopolo (2024), as the disease progresses, shoots wilt, gummosis occurs, and branches and trunks are affected, often resulting in the death of the tree. The disease spreads mainly through pollinating insects, raindrops, wind, and agricultural practices (EFSA PLH, 2014). Bacterial blight was first recorded in North America, but over time the disease spread to Europe, Asia, and Central Asian countries, including Kyrgyzstan (Wang *et al.*, 2025). In the Kyrgyz Republic, the development of the disease is facilitated by hot and humid weather during the apple blossoming period, as well as insufficient phytosanitary control. Agrotechnical, chemical and biological methods are used to combat bacterial blight. As noted by R. Mendes *et al.* (2024), among agrotechnical measures, sanitary pruning of affected branches, removal of plant debris, disinfection of tools and ensuring optimal water regime play an important role. Chemical protection involves the use of copper-based preparations, antibiotics (streptomycin), and bacteriophages, but their effectiveness varies depending on climatic conditions and the stage of infection development.

The most promising approach to combating fire blight is to cultivate disease-resistant varieties. Varieties with high resistance to *Erwinia amylovora* have been identified worldwide, including Enterprise, Florina, Liberty, and others. However, as noted by B. García-Fernández *et al.* (2023), the adaptation of these varieties to the conditions of Central Asia, including Kyrgyzstan, requires further research. Modern genotyping methods allow the identification of genes for resistance to fire blight, such as the FB_MR5 gene, which is associated with resistance to *Erwinia amylovora*. Genomic technologies and molecular selection contribute to the creation of new apple varieties with improved resistance characteristics. Studying the resistance of modern apple varieties to *Erwinia amylovora* bacterial blight is a pressing task, especially in the Kyrgyz Republic, where horticulture plays a significant role in the agricultural economy. Research in this area will enable the introduction of varieties adapted to local conditions, which will ensure stable production and improve fruit quality. In Kyrgyzstan, fire blight appeared around 2008-2009. According to T. Doolotkeldieva *et al.* (2021), the first signs were noticed in the Chüy region, then spread to the Issyk-Kul region and in subsequent years covered the entire republic, even reaching wild forest areas. Figure 2 shows a tree infected with bacterial blight.

Figure 2. Bacterial blight (*Erwinia amylovora*) infection of a 'Talgarka' pear tree

Note: sample collected during an expedition to the Issyk-Kul region of the Kyrgyz Republic

Source: authors' photo

In 2011, bacterial blight was registered as a quarantine disease by the Ministry of Water Resources, Agriculture and Processing Industry of the Kyrgyz Republic. Employees of the Department of Plant Protection and Quarantine surveyed more than 5,000 hectares of fruit plantations, and it is now known that 37 genera and 129 species of the Rosaceae family are affected: these include pears, quince, apples, peaches, apricots, raspberries, roses, persimmons, walnuts, etc. (Ministry of Water Resources..., n.d.). Figure 3 shows the results of a laboratory experiment to assess the damage to apple fruit caused by bacterial canker, the causative agent of which is the bacterium *Erwinia amylovora*. The bacterium, penetrating through mechanical damage or natural stomata, causes tissue necrosis and exudate secretion, which is typical of bacterial canker. The presence of exudate indicates the active phase of the disease and a high level of infection. Fruits with less pronounced symptoms are strains with low pathogenicity for infecting plants with bacterial canker.

As shown in Figure 3, not all strains are capable of causing disease. Petri dishes show that some of the fruits contain pronounced signs of bacterial damage: darkening of tissues, necrotic spots, exudate secretion (whitish or yellowish drops of bacterial fluid), which is

characteristic of *Erwinia amylovora* infection. In the dishes, however, some fruits show only superficial necrotic spots without bacterial exudate, which may indicate a weaker reaction of the strain. Thus, this experiment allows for visual differentiation of the pathogenic strain, which was subsequently selected for further experiments to determine the experimental variants for the resistance and susceptibility of seedlings of various apple varieties to the causative agent of bacterial blight. To visually represent the differences in the response of varieties to artificial inoculation, photographic monitoring of the manifestation of infection symptoms was carried out throughout the experiment. Figure 4 shows two-year-old seedlings of all studied apple varieties after treatment with *Erwinia amylovora* suspension, demonstrating characteristic manifestations of bacterial blight.

Figure 3. Manifestation of *Erwinia amylovora* pathogenicity on unripe apple fruits
Source: authors' photo

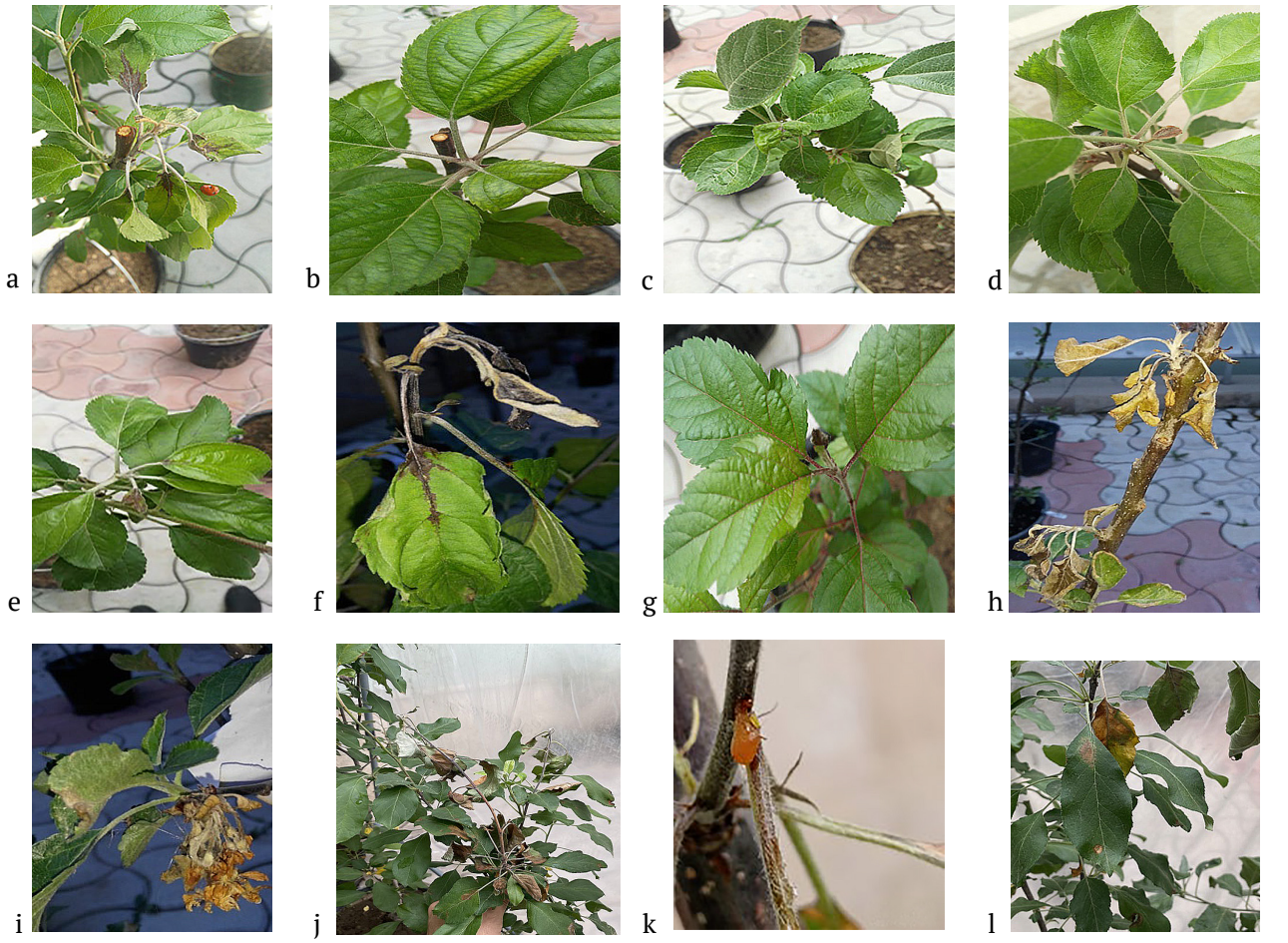

Figure 4. Artificial infection of two-year-old apple seedlings with *Erwinia amylovora*, the causative agent of fire blight
Note: a – 'Starkrimson' variety, b – 'Red Chief', c – 'Bellefleur', d – 'Bishkek', e – 'Golden', f – 'Idared', g – 'Niedzwetzky', h – 'Ligolina', i – 'Early Geneva', j – 'Gala', l – 'Fuji'
Source: authors' photos

Figure 4 shows the external manifestations of infection in different varieties 30 days after inoculation. It can be seen that susceptible varieties ('Idared', 'Gala', 'Ligolina') show pronounced blackening of young shoots, drying of the tops and the appearance of necrotic areas on the leaves. Moderately resistant varieties ('Starkrimson', 'Fuji', 'Early Geneva') show localised necrosis on leaf blades and partial wilting of shoots. The most resistant varieties ('Red Chief', 'Bishkek', 'Golden'), as well as the species 'Niedzwetzky', retain their green leaf colour and minimal damage, limited to isolated necrotic spots at the inoculation sites. Figure 4 reflects the visual differences in the degree of damage to the studied genotypes and confirms the results of the quantitative assessment. Figure 5 shows the average degree of damage to apple seedlings.

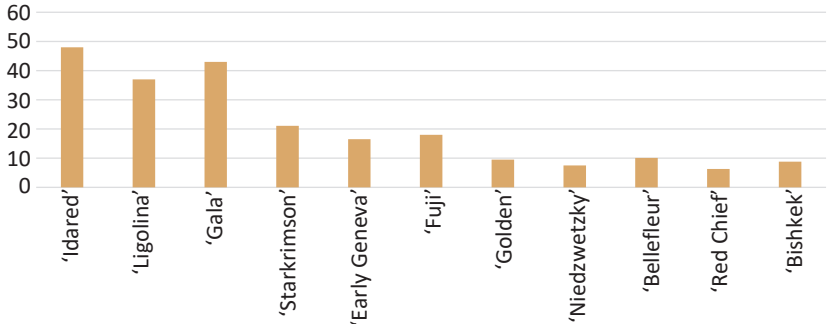

Figure 5. Average degree of damage to apple seedlings by bacterial blight (%)
Source: compiled by the authors

As shown in Figure 5, the following results were obtained after artificial infection over a period of one month. The 'Idared' variety showed 48% damage to seedlings from bacterial blight – a variety with a high degree of damage. The variety itself is winter-hardy but susceptible to disease. The 'Gala' variety had an average infection rate of 43% – it is a popular variety with good taste qualities, but has moderate resistance to various diseases. The 'Ligolina' variety (37% infection rate) is relatively vulnerable to infection compared to other varieties. The 'Starkrimson' variety showed 21.1% damage from bacterial blight over the course of a month – a beautiful red variety that is moderately susceptible to disease. The 'Fuji' variety (16.5%) is moderately resistant. The 'Early Geneva' variety (18%) is an early variety that is resistant to certain diseases. The 'Bellefleur' variety (10.1%) is an old variety with good shelf life and low susceptibility to disease. The 'Golden' variety (9.5%) is a famous yellow variety with high shelf life and resistance. The 'Bishkek' variety (8.8%) is a local variety with good adaptability and low susceptibility to disease. The species 'Niedzwetzky' (7.5%) is a decorative apple tree variety that is resistant to disease. The 'Red Chief' variety (6.3%) is one of the most moderately resistant varieties and has high marketability. In addition, it has been noted that the climatic conditions of Kyrgyzstan contribute to the active spread of the disease. High temperatures and humidity during the growing season create optimal conditions for infection, which requires a more detailed study of the influence of climatic factors on the development of the disease. The identified resistant varieties, such as 'Red Chief', 'Bishkek' and 'Golden', are of particular interest for further introduction into production. Their use can significantly reduce crop losses and reduce the need for chemical protection. Diagnostic and bacteriological studies were conducted to confirm the presence of the bacterial blight pathogen in infected tissues and to quantitatively assess the bacterial load. Figures 6 and 7 show the results of rapid diagnosis using an immunostrip test and the isolation of *Erwinia amylovora* colony-forming units on a selective nutrient medium.

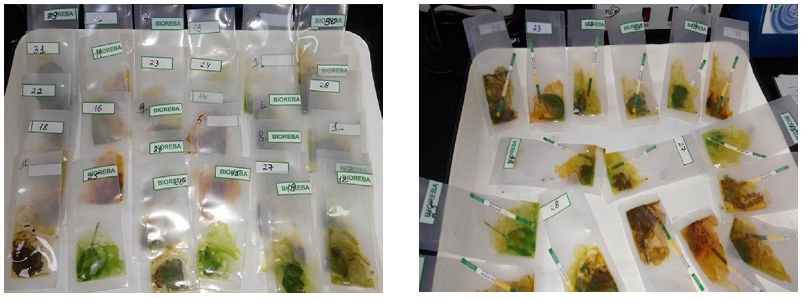

Figure 6. Immunoassay strips for the detection of *Erwinia amylovora* bacteria
Source: authors' photo

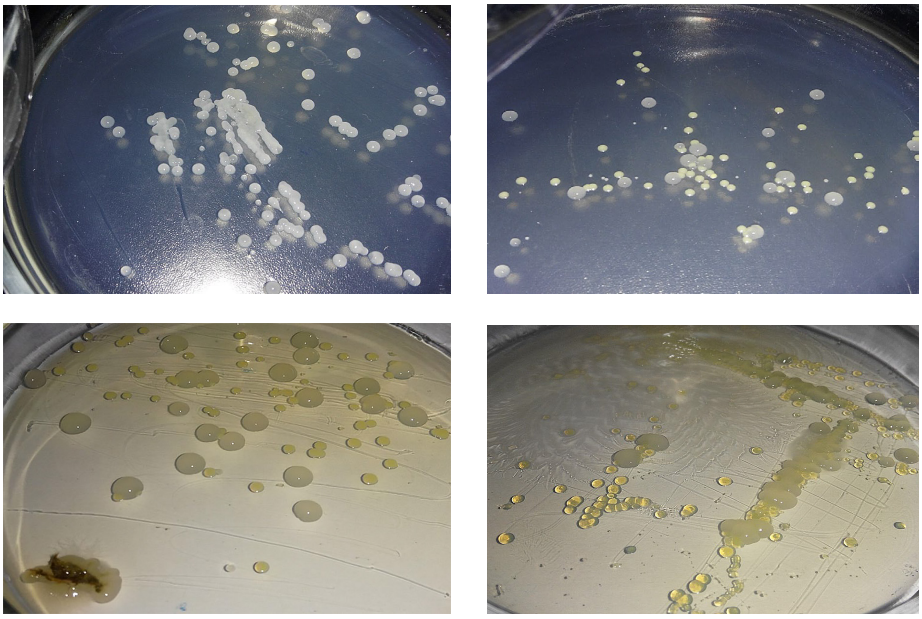

Figure 7. Colony-forming unit of *Erwinia amylovora* bacteria on Levan's nutrient medium
Source: authors' photo

Figures 6 and 7 demonstrate laboratory confirmation of apple tree seedlings infected with *Erwinia amylovora*, the causative agent of fire blight. Figure 6 shows a positive result of an immunoassay strip test, which allows rapid detection of specific pathogen antigens in the tissue samples under investigation. Figure 7 shows *E. amylovora* colonies grown on Levan's nutrient medium; the growth intensity and number of colonies formed reflect differences in bacterial load between samples of different varieties. The combination of visual diagnosis and bacteriological isolation confirms both the fact of infection and the varying degrees of pathogen reproduction in the tissues of the varieties, which is consistent with the data obtained on the level of damage.

The results of bacteriological analysis showed the presence of *Erwinia amylovora* bacteria in all analysed samples. However, the number of CFU varied significantly depending on the degree of tissue damage. The highest number of CFU was observed in severely affected samples, while in tissues with visually less pronounced symptoms, the number of bacteria was significantly lower (Table 2). The data obtained indicate different susceptibility of seedlings to infection, which may be due to their individual physiological characteristics or resistance to the pathogen.

Table 2. Colony-forming unit of *Erwinia amylovora* bacteria

No.	Name of varieties	*Erwinia amylovora*	CFU/ml
1	'Idared'	+	$35.8 * 10^6$
2	'Early Geneva'	+	$19.3 * 10^6$
3	'Ligolina'	+	$23.4 * 10^6$
4	'Starkrimson'	+	$25.7 * 10^6$
5	'Red Chief'	+	$21.3 * 10^6$
6	'Bellefleur'	+	$9.3 * 10^6$
7	'Golden'	+	$8.7 * 10^6$
8	'Bishkek'	+	$12.2 * 10^6$
9	'Niedzwetzky'	+	$26.1 * 10^6$
10	'Gala'	+	$30.4 * 10^6$
11	'Fuji'	+	$24.7 * 10^6$

Source: compiled by the authors

Table 2 presents data on the number of colony-forming units of *Erwinia amylovora* isolated from infected tissues of various apple varieties after artificial inoculation. It can be seen that the highest CFU values are observed in highly susceptible varieties ('Idared', 'Gala', 'Ligolina'), which corresponds to their high degree of infection, while in resistant varieties ('Golden', 'Bishkek', 'Red Chief') and in the 'Bellefleur' variety, the number of pathogen cells isolated is significantly lower. The data presented confirm the differences in

bacterial load between varieties and are consistent with visual assessments of resistance. Figure 8 presents summarised data from the quantitative analysis of bacterial load, showing the comparative distribution of *Erwinia amylovora* colony-forming units among the apple varieties studied.

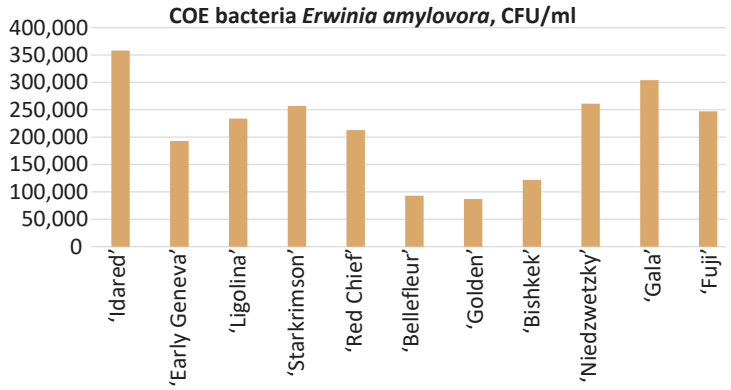

Figure 8. CFU of *Erwinia amylovora* bacteria

Source: compiled by the authors

The highest number of *Erwinia amylovora* bacteria cells was isolated from the affected tissue of the 'Idared' variety – a total of 358,000 cells/ml. The lowest number of cells was isolated from the affected tissues of the 'Golden' variety – 870,000 cells/ml. An interesting feature is the high level of CFU in the species 'Niedzwetzky', despite the low visual degree of damage, which may indicate the role of the variety as a possible carrier or reservoir of bacteria in the absence of pronounced symptoms. Table 3 shows the results of multiple comparisons of the degree of damage to apple fruit.

Table 3. Results of multiple comparisons of the degree of damage to apple fruit by bacterial blight (Duncan/Tukey test, $p < 0.05$)

Variety	Average degree of damage (%)	Duncan group
'Idared'	48	a
'Ligolina'	37	ab
'Gala'	43	ab
'Starkrimson'	21.1	bc
'Early Geneva'	16.5	bc
'Fuji'	18	bc
'Golden'	9.5	c
'Niedzwetzky'	7.5	c
'Bellefleur'	10.1	c
'Red Chief'	6.3	c
'Bishkek'	8.8	c

Note: mean values marked with the same letters are not statistically different from each other according to Duncan/Tukey test ($p > 0.05$)

Source: compiled by the authors

The results of the study demonstrate significant differences in the resistance of modern apple varieties to bacterial blight caused by *Erwinia amylovora*. The 'Idared' variety proved to be the most susceptible to the disease, as confirmed by the high degree of infection (48%). This may be due to its genetic predisposition to infections, as well as insufficient resistance to pathogens, which is consistent with data on its susceptibility to other diseases, such as scab and powdery mildew. The 'Ligolina' and 'Gala' varieties also showed a relatively high degree of damage, indicating the need for further research to identify the factors contributing to their vulnerability. In contrast, the 'Red Chief', 'Golden', 'Bishkek' varieties and the species 'Niedzwetzky' showed a low degree of infection, making them promising for cultivation in the Kyrgyz Republic. This is confirmed by the data from multiple comparisons presented in Table 2. The results of this study confirm significant differences in the resistance of modern apple varieties to bacterial canker caused by *Erwinia amylovora*. Similar data were obtained in the work of H. Aldwinckle & M. Malnoy (2009), which reports on the high resistance of some apple varieties to fire blight due to the presence of specific genetic markers. In particular, the

species 'Niedzwetzky' and the varieties 'Bishkek' and 'Golden' showed a low degree of damage, which is consistent with studies conducted in Central Asia and Europe. The high susceptibility of the 'Idared' and 'Gala' varieties confirms the findings of previous studies, which noted that these varieties have insufficient resistance to bacterial blight and require additional protective measures (Emeriewen *et al.*, 2021). This fact points to the need for breeding programmes aimed at improving the resistance of these varieties or finding alternative options adapted to local conditions. To optimise breeding programmes, it is critical to understand the molecular genetic mechanisms underlying resistance. At the molecular level, a study by S. Schröpfer *et al.* (2021) revealed the activation of genes involved in the formation of flavonoids and terpenoids, as well as a heat shock response in the susceptible response, indicating specific defence mechanisms in apple trees.

The use of artificial infection in this study made it possible to determine the degree of resistance of varieties under controlled experimental conditions. Studies have shown that commercial apple varieties have different levels of susceptibility to bacterial canker, and assessing the resistance of varieties and rootstocks is one of the key areas of research, which is also consistent with the conclusions of S. Kostick *et al.* (2019). In addition, this study confirmed that genotypes of the wild apple tree *Malus sieversii* can be a source of resistance, as previously reported by J. Harshman *et al.* (2017). Wild *Malus* species are of particular interest in breeding programmes, as they are sources of complex resistance not only to bacterial canker. A comprehensive analysis of *Malus* species for resistance to scab (*V. inaequalis*) and ornamental value showed that wild and hybrid species, in particular the berry apple, outperform the domestic apple, confirming their value as sources of resistance for breeding programmes (Moskalets *et al.*, 2024). The results obtained in the current study emphasise the importance of breeding resistant varieties as the main direction in the fight against bacterial blight, since chemical control methods, including the use of copper- and antibiotic-containing preparations, have limited effectiveness and can lead to the formation of resistant strains of bacteria. Thus, this study confirms the importance of introducing resistant apple varieties into horticultural practice in Kyrgyzstan and other regions with similar phytopathological problems.

Conclusions

The study conducted a comprehensive assessment of the resistance of modern apple varieties (*Malus domestica*) to the bacterial blight pathogen (*Erwinia amylovora*) in the Kyrgyz Republic. Through artificial infection with the phytopathogenic culture ZH-2, significant differentiation of varieties in terms of their susceptibility was established. The differences identified are critical for optimising plant protection strategies in the region, especially given the status of fire blight as a quarantine disease. The most resistant varieties were 'Red Chief', 'Bishkek' and 'Golden', with a degree of damage not exceeding 9.5% (while the susceptible variety 'Idared' suffered damage of up to 48%). These varieties, as well as the wild species 'Niedzwetzky', which showed a low percentage of damage, are the most promising for introduction into commercial and amateur horticulture in Kyrgyzstan. They can serve as a basis for creating sustainable orchards and reducing dependence on chemical control methods, including antibiotics, to which the pathogen is developing resistance. In contrast, the varieties 'Idared', 'Gala' and 'Ligolina' showed high or moderate susceptibility, requiring additional protective measures, including the use of more resistant rootstocks, when growing them.

Further research should focus on a more in-depth study of the molecular and physiological mechanisms of resistance in highly resistant varieties (e.g., 'Bishkek' and 'Red Chief'). This includes molecular genetic analysis to identify QTL loci and genes responsible for resistance to *E. amylovora*, which will accelerate the breeding process. It is also relevant to screen a larger sample of local wild *Malus* (in particular, *Malus sieversii*) as potential sources of new resistance genes for cross-breeding. Finally, it is advisable to conduct field trials of selected resistant varieties in different soil and climatic zones of Kyrgyzstan to confirm their ecological adaptability and commercial value in the long term.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Aćimović, S.G., Santander, R.D., Meredith, C.L., & Pavlović, Ž.M. (2023). Fire blight rootstock infections causing apple tree death: A case study in high-density apple orchards with *Erwinia amylovora* strain characterization. *Frontiers in Horticulture*, 2, article number 1082204. doi: 10.3389/fhort.2023.1082204.

[2] Aldwinckle, H., & Malnoy, M. (2009). Plant regeneration and transformation in the Rosaceae. *Transgenic Plant Journal*, 3(1), 1-39.

[3] Convention on Biological Diversity (CBD). (1992, May). Retrieved from https://www.cbd.int/convention.

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). (1973, March). Retrieved from https://cites.org/eng.

[5] Doolotkeldieva, T., Bobushova, S., Carnal, S., & Rezzonico, F. (2021). Genetic characterization of *Erwinia amylovora* isolates detected in the wild walnut-fruit forest of South Kyrgyzstan. *Journal of Plant Pathology*, 103, 109-120. doi: 10.1007/s42161-021-00752-1.
[6] EFSA Panel on Plant Health (PLH). (2014). Scientific opinion on the pest categorisation of *Erwinia amylovora* (Burr.) Winsl. *et al*. *EFSA Journal*, 12(12), article number 3922. doi: 10.2903/j.efsa.2014.3922.
[7] Emeriewen, O.F., Richter, K., Flachowsky, H., Malnoy, M., & Peil, A. (2021). Genetic analysis and fine mapping of the fire blight resistance locus of *Malus* ×*arnoldiana* on linkage group 12 reveal first candidate genes. *Frontiers in Plant Science*, 12, article number 667133. doi: 10.3389/fpls.2021.667133.
[8] FAO. (n.d.). *Crops and livestock products*. Retrieved from https://www.fao.org/faostat/en/#data/QCL.
[9] García-Fernández, B., Dolcet-Sanjuan, R., Micheletti, D., Antón-Díaz, M.J., Solsona, C., Fernández, M., Abad, X., & Dapena, E. (2023). Susceptibility evaluation to fire blight and genome-wide associations within a collection of Asturian apple accessions. *Plants*, 12(23), article number 4068. doi: 10.3390/plants12234068.
[10] Harshman, J.M., Evans, K.M., Allen, H., Potts, R., Flamenco, J., Aldwinckle, H.S., Wisniewski, M.E., & Norelli, J.L. (2017). Fire blight resistance in wild accessions of *Malus sieversii*. *Plant Disease*, 101(10), 1738-1745. doi: 10.1094/PDIS-01-17-0077-RE.
[11] Hassan, W., Ahmed, O., Hassan, R.E., Youssef, S.A., & Shalaby, A.A. (2023). Isolation and characterization of three bacteriophages infecting *Erwinia amylovora* and their potential as biological control agent. *Egyptian Journal of Biological Pest Control*, 33, article number 60. doi: 10.1186/s41938-023-00689-w.
[12] Jimenez Madrid, A.M., & Lewis Ivey, M.L. (2023). An overview of streptomycin resistance in *Erwinia amylovora* from Ohio apple orchards. *Plant Health Progress*, 24(1), 56-61. doi: 10.1094/PHP-08-22-0074-RS.
[13] Kairova, G., Daulet, N., Solomadin, M., Sandybayev, N., Orkara, S., Beloussov, V., Kerimbek, N., Gritsenko, D., & Sapakhova, Z. (2023a). Identification of apple varieties resistant to fire blight (*Erwinia amylovora*) using molecular markers. *Horticulturae*, 9(9), article number 1000. doi: 10.3390/horticulturae9091000.
[14] Kairova, G., Pozharskiy, A., Daulet, N., Solomadin, M., Sandybayev, N., Khusnitdinova, M., Nizamdinova, G., Sapakhova, Z., & Gritsenko, D. (2023b). Evaluation of fire blight resistance of eleven apple rootstocks grown in Kazakhstani fields. *Applied Sciences*, 13(20), article number 11530. doi: 10.3390/app132011530.
[15] Kostick, S.A., Norelli, J.L., & Evans, K.M. (2019). Novel metrics to classify fire blight resistance of 94 apple cultivars. *Plant Pathology*, 68(5), 985-996. doi: 10.1111/ppa.13012.
[16] Mendes, R.J., Regalado, L., Rezzonico, F., Tavares, F., & Santos, C. (2024). Deciphering fire blight: From *Erwinia amylovora* ecology to genomics and sustainable control. *Horticulturae*, 10(11), article number 1178. doi: 10.3390/horticulturae10111178.
[17] Ministry of Water Resources, Agriculture and Processing Industry of the Kyrgyz Republic. (n.d.). Retrieved from https://agro.gov.kg/.
[18] Moskalets, T., Kratiuk, O., Ivankiv, M., Shevchenko, S., & Shevchuk, N. (2024). Bio-ecological characteristics of *Malus genus* species in the context of prospective directions in horticulture and landscape forestry. *Scientific Horizons*, 27(12), 9-26. doi: 10.48077/scihor12.2024.09.
[19] Moskalets, T., Pelekhata, N., Svitelskyi, M., Verheles, P., & Yakovenko, R. (2023). Bacterial blight of viburnum (*Pseudomonas syringae* pv. *viburnum*): Biological features, causes, and consequences of manifestation, methods of control in the system of decorative and fruit gardening. *Scientific Horizons*, 26(5), 46-55. doi: 10.48077/scihor5.2023.46.
[20] Pedroncelli, A., & Puopolo, G. (2024). This tree is on fire: A review on the ecology of *Erwinia amylovora*, the causal agent of fire blight disease. *Journal of Plant Pathology*, 106, 823-837. doi: 10.1007/s42161-023-01397-y.
[21] Schröpfer, S., Vogt, I., Broggini, G.A.L., Dahl, A., Richter, K., Hanke, M.V., Flachowsky, H., & Peil, A. (2021). Transcriptional profile of AvrRpt2EA-mediated resistance and susceptibility response to *Erwinia amylovora* in apple. *Scientific Reports*, 11, article number 8685. doi: 10.1038/s41598-021-88032-x.
[22] Tegtmeier, R., Švara, A., Gritsenko, D., & Khan, A. (2025). *Malus sieversii*: A historical, genetic, and conservational perspective of the primary progenitor species of domesticated apples. *Horticulture Research*, 12(1), article number uhae244. doi: 10.1093/hr/uhae244.
[23] Thapa, R., Singh, J., Gutierrez, B., Arro, J., & Khan, A. (2021). Genome-wide association mapping identifies novel loci underlying fire blight resistance in apple. *Plant Genome*, 14, article number e20087. doi: 10.1002/tpg2.20087.
[24] Wang, J., Zhao, Y., Wu, S., Gu, X., Liu, X., Tian, Y., Hu, B., & Zhao, Y. (2025). Genome analysis reveals *Erwinia amylovora* in China is closely related to those of Kyrgyzstan and Kazakhstan. *Phytopathology Research*, 7(1), article number 31. doi: 10.1186/s42483-025-00316-6.
[25] Yuvarani, R., Shankar, U., Gowdar, S.B., Kumar, S., & Hiremath, S.S. (Eds). (2025). *Plant health and disease management: A modern approach*. Ghosiyana: Textify Publishers. doi: 10.69973/TP/2025/52.

Заманбап алма сортторунун *Erwinia amylovora* бактериялдык күйүк козгогучуна туруктуулугун баалоо

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Аннотация. Алманын жаңы сортторуна коюлган заманбап талаптарга жогорку түшүмдүүлүк менен мөмөнүн сапатын жакшыртуу гана эмес, ошондой эле эң коркунучтуу ооруларга, анын ичинде *Erwinia amylovora* бактериясы козгогон бактериалдык күйүккө туруктуулук да кирет. Бул изилдөөнүн максаты Кыргызстанда кеңири таралган заманбап алма сортторунун бактериалдык күйүктүн козгогучуна туруктуулугун жасалма жугузуу шартында баалоо болду. Эксперимент үчүн 'Талгарка' алмурут сортуна таандык жабыркаган бутактардан бөлүнүп алынган фитопатогендик *E. amylovora* бактериясынын таза (ZH-2) штаммы колдонулду. Жугузуу *in vitro* ыкмасы менен жүргүзүлүп, эки жаштагы көчөттөрдүн бүчүр жана жалбырак беттерине 10^9 КОЕ/мл концентрациядагы бактерия суспензиясы жаракатталган жерлерге сүртүлдү. Жугузгандан кийин 1, 6, 12 жана 30-күндөрү жабыркоонун деңгээли кыймылсыз (визуалдык) түрдө беш баллдык шкала боюнча, жабыркаган ткандардын пайызын эске алуу менен аныкталды. Изилдөөнүн жыйынтыктары каралган он бир алма сорту арасында туруктуулуктун олуттуу айырмачылыктарын көрсөттү. Эң туруктуу сорттор катары 'Ред Чиф', 'Бишкек' жана 'Голден' белгиленип, алардын жабыркоо деңгээли 6,3-9,5 %ди түзүп, өсүмдүктөрдүн коргонуу реакцияларынын күчтүү экенин жана некроз белгилеринин начар өнүккөнүн аныкталды. Орточо туруктуулук 'Фуджи' сортунда (16-18 %) байкалып, бүчүр ткандарынын бир аз жабыркашы менен мүнөздөлдү. Эң начар туруктуулукка ээ болгон сорттор 'Айдаред' (48 %), 'Гала' (43 %) жана 'Лаголина' (37 %) болуп, бул сорттордо некроздук тактардын тез өнүгүшү жана бүчүрлөрдүн солушу катталды. Алынган жыйынтыктар бактериалдык күйүккө туруктуу сорторду көбөйтүүдө жана селекциялык иштерде колдонууга мүмкүнчүлүк берип, ошондой эле Кыргызстан шартында заманбап алма сортторунун ооруларга болгон туруктуулук диапазону жөнүндө маалымат берет

Негизги сөздөр: жасалма жугузуу; жабыркоо даражасы; фитопатогендик бактериялар; ткандардын некрозу; *in vitro*

Оценка устойчивости современных сортов яблони к возбудителю бактериального ожога Erwinia amylovora

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Аннотация. Современные требования к новым сортам яблони включают не только высокую урожайность и улучшенное качество плодов, но и устойчивость к наиболее опасным заболеваниям, в том числе к бактериальному ожогу, вызываемому *Erwinia amylovora*. Целью данного исследования была оценка устойчивости современных сортов яблони, распространенных в Кыргызстане, к возбудителю бактериального ожога при искусственном заражении. Для эксперимента использовали чистую культуру фитопатогенной бактерии *E. amylovora* (штамм ZH-2), выделенную из пораженных ветвей груши сорта 'Talgarka'. Заражение проводили методом *in vitro*, нанося суспензию бактерий с концентрацией 109 КОЕ/мл на раневые поверхности побегов и листьев двухлетних саженцев. Оценку степени поражения проводили визуально через 1, 6, 12 и 30 дней после инокуляции по пятибалльной шкале, учитывающей процент пораженной ткани. Результаты исследования показали значительные различия в устойчивости между изучаемыми одиннадцатью сортами яблони. Наиболее устойчивыми оказались сорта 'Red Chief', 'Bishkek' и 'Golden', у которых уровень поражения составил от 6,3 до 9,5 %, что свидетельствует о выраженных защитных реакциях растений и низкой степени развития симптомов некроза. Средний уровень восприимчивости проявил сорт 'Fuji' (около 16-18 %), характеризующийся умеренным поражением тканей побегов. Наиболее чувствительными к инфекции оказались сорта 'Idared' (48 %), 'Gala' (43 %) и 'Ligolina' (37 %), у которых наблюдалось быстрое развитие некротических пятен и увядание побегов. Полученные результаты позволяют выделить перспективные для дальнейшего размножения и селекционной работы сорта, устойчивые к бактериальному ожогу, а также дают представление о диапазоне восприимчивости современных сортов яблони в условиях Кыргызстана

Ключевые слова: искусственное заражение; степень поражения; фитопатогенные бактерии; некроз тканей; *in vitro*

Received: 06.10.2025. Revised: 11.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 636 32 /38.082

DOI: 10.63621/bknau./1.2026.41

Biological and productive features of fine-fleeced sheep in purebred breeding and crossbreeding in south-eastern Kazakhstan

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Abstract. In Kazakhstan, sheep farming remains an important sector, providing both food and raw materials for industry. In the context of declining wool value, the development of meat production has become particularly relevant, making the selection of suitable breeds essential for improving productivity. The aim of the study was to assess imported fine-wool rams from Australia and the Kyrgyz Republic when used for crossbreeding with Kazakh Fine-Wool ewes under the foothill conditions of the Akbulak farm in Almaty region. Three groups of ewes, each consisting of 150 head, were formed, using 3 Australian Meat Merino (AMM) rams, 3 Kyrgyz Mountain Merino (KMM) rams and 3 Kazakh Fine-Wool (KF) rams. Both purebreeding and industrial crossbreeding methods were applied, enabling accelerated modification of hereditary and physiological characteristics. The results showed that the experimental rams exhibited a strong constitution, high live weight and excellent wool yield. Clinical indicators in all groups remained within physiological norms, with no significant intergroup differences. Haematological parameters were maintained at an optimal level and varied seasonally, reflecting the intensity of oxidative-reduction processes. The highest fertility was recorded in Group I (KF × KF) at 121.0%, which exceeded Groups II (AMM × KF) and III (KMM × KF) by 1.65% and 3.30%, respectively. Lamb survival to weaning in Group I reached 97.3%, surpassing that of contemporaries by 1.4% and 1.7%. The practical value of the research lies in demonstrating that the use of AMM and KMM rams in Kazakh Fine-Wool flocks can improve wool fineness, enhance the histomorphological structure of the skin-fleece system, increase ewe fertility and lamb survival, and contribute to higher mutton production in the foothill regions of south-eastern Kazakhstan

Keywords: Kazakh Fine-Fleeced breed; Australian Meat Merino; Kyrgyz Mountain Merino; fertility; live weight; body measurements; physiological and haematological parameters

Suggested Citation: Prmanshaev, M., Basitov, K., & Ataibekov, B. (2026). Biological and productive features of fine-fleeced sheep in purebred breeding and crossbreeding in south-eastern Kazakhstan. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 41-53. doi: 10.63621/bknau./1.2026.41.

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Introduction

Sheep farming remains one of the most important areas of animal husbandry in the Republic of Kazakhstan, providing meat, wool and milk and making a significant contribution to the socio-economic development of pastoral regions. However, the modern development of the industry requires the introduction of technological solutions aimed at increasing the efficiency of pasture management and improving the productive qualities of breeds used in Kazakhstan. It is becoming increasingly important to develop fast-growing animals that are resistant to climatic factors and capable of producing high yields of mutton and wool. Productivity can be increased both by improving existing breeds and by combining genetic lines that are highly adaptable and productive. One of the effective tools for increasing the efficiency of sheep breeding is the use of crossbreeding, which allows for the acceleration of the consolidation of desirable traits. Practice shows that correctly selected combinations of producers contribute to the improvement of the constitution, meat productivity and quality characteristics of wool in offspring (Iskakov *et al.*, 2017). In this regard, it is important from a scientific and practical point of view to study the breeding efficiency and productivity of Kazakh Fine-Wool sheep in various combinations with producers of other highly productive fine-wool breeds that differ in wool and meat characteristics.

The development of sheep breeding in modern conditions is determined by a complex of factors, among which the improvement of selection work and the increase in the adaptive and productive potential of animals play a key role. The global market is seeing steady growth in demand for high-quality fine wool and young lamb, which increases the need to improve fine-wool sheep in two areas simultaneously: improving wool fibre characteristics and increasing meat productivity. Data from E. Islamov *et al.* (2021) confirm that the productivity of fine-wool breeds can increase significantly with the optimal organisation of breeding and genetic programmes. The market situation in Kazakhstan is also shaping a trend towards increased lamb production, which requires adaptation of breeding approaches. A significant portion of lamb is produced on farms where industrial crossbreeding is considered an effective method for rapidly improving the meat quality of the livestock. It is important to note that low sheep productivity is often due to improper breeding practices, including the prolonged use of the same producers, which leads to inbreeding and a decrease in reproductive performance (Vijayakumar *et al.*, 2025). At the same time, preserving the genetic integrity of breeds and stable exterior traits is only possible through consistent purebred breeding, which is especially relevant for regional genotypes of fine-wool sheep (Lakota, 2025). One of the indicators of the breeding value of fine-wool sheep is wool fineness. As noted by A. Rahim *et al.* (2025), this trait determines the quality of yarn, the strength of textile products and the marketability of wool products. Moreover, fibre fineness largely correlates with the physiological condition of animals and their potential for high productive performance. Modern approaches to breeding also involve the use of technological innovations to improve the accuracy of selection and assessment of animal behavioural characteristics, which allows the most valuable individuals to be identified without additional stress on the herd (Emsen *et al.*, 2025).

A summary of the scientific data presented shows that improving the efficiency of fine-wool sheep breeding requires a comprehensive approach, including the improvement of genetic resources, the scientifically based organisation of the selection process, and the adaptation of crossbreeding schemes to the natural and climatic conditions of the regions. However, the question of the optimal selection of combinations of producers for specific areas of Kazakhstan remains open, which makes further research in this direction scientifically and practically significant. The aim of the study was to evaluate the biological and productive characteristics of Kazakh Fine-Wool sheep in purebred breeding and crossbreeding in south-eastern Kazakhstan. To achieve this goal, the following tasks were set: to identify the reproductive qualities of the breeding stock; to analyse the productive and adaptive characteristics of animals of different genotypes; to evaluate clinical and haematological indicators in relation to the conditions of keeping.

Materials and Methods

The research was conducted in 2018-2024 at the Akbulak farm in the Zhambyl district of the Almaty region (Kazakhstan), located in the foothills at an altitude of 650-820 m above sea level. The experiment included 450 ewes of the Kazakh Fine-Wool breed aged 3-4 years, class I according to the bonitation, with a live weight of 65-68 kg, normal reproductive history and confirmed veterinary status. Nine rams of three genotypes were used for crossbreeding: Kazakh Fine-Wool, Kyrgyz Mountain Merino and Australian Meat Merino. The 3-3.5-year-old producers were brought in from certified breeding farms in the respective countries and had documents confirming vaccination, infection diagnosis and the absence of parasitic diseases. The ewes were divided into three groups by randomisation, taking into account age, body weight and physiological condition, with 150 animals in each group. The animals were kept on autumn, winter and summer pastures. All animals were kept under the same grazing conditions: during the warm season, they were grazed on natural wormwood-grass and mixed-grass pastures, and in winter, they were fed alfalfa hay (2.5-3 kg per head) and barley bran (0.3-0.5 kg). The nutritional value of the feed was determined using laboratory

methods in accordance with GOST 31675-2012 (2013) and GOST 13496.4-2019 (2020). Climatic factors (temperature, humidity, wind, precipitation) and the epizootic situation were monitored daily. The experiment used a flock of Class I ewes of the KF 450 breed, with a live weight of 66.2 kg, original wool yield of 5.9 kg, washed wool yield of 3.12 kg, wool length of 9.15 cm, and wool fineness of 22.96 μm.

The ewes were inseminated between 20 October and 10 November each year with freshly collected sperm using an artificial vagina (IMV Technologies, France). The quality of ejaculates (volume, concentration, motility, morphology) was assessed using a SpermVision photometer (Minitube, Germany) and an MBS-10 microscope (MICROmed, Ukraine). For insemination, 0.1 ml of semen containing at least 80 million actively motile spermatozoa was used. Pregnancy in ewes was determined using a Dramiński ANIMAL profi ultrasound machine (Dramiński, Poland) on the 45th day after insemination. The physiological parameters of the animals (body temperature, respiratory rate and pulse rate) were measured seasonally three times a day – at 08:00, 13:00 and 18:00 – using a Vet-100 veterinary thermometer and counting physiological cycles for 1 minute. Blood for analysis was taken on an empty stomach from the jugular vein into VACUETTE tubes with EDTA (Greiner Bio-One, Austria), after which laboratory tests were performed on a Mindray BC-2800Vet haematology analyser (Mindray, China) in accordance with ISO/IEC 17025:2019 (2021). Haemoglobin, erythrocyte, serum protein and mean erythrocyte diameter were determined. All procedures were performed in accordance with ethical standards according to the Code of Practice… (2014).

To assess the external characteristics of the sheep, linear measurements were taken, including height at the withers and sacrum, oblique body length, chest depth and width, chest circumference behind the shoulder blades, and pastern circumference. The measurements were taken with a metal tape measure and a measuring stick with an accuracy of 0.5 cm by two specialists independently of each other, after which the average value for each animal was calculated. Based on the measurements obtained, body conformation indices were calculated using standard zootechnical analysis methods regulated by GOST R 57784-2017 (2019) and methodological recommendations for the evaluation of meat-wool sheep. The body elongation index was determined as the ratio of the oblique length of the body to the height at the withers, multiplied by 100%. The massiveness index was calculated as the ratio of chest circumference to height at the withers, also expressed as a percentage. The bone index was determined as the ratio of the metacarpal circumference to the live weight of the animal, multiplied by 1,000 to facilitate comparison of indicators. The compactness index was calculated using the formula: chest circumference × 100/ oblique body length. The pelvic-chest shape index was determined based on the ratio of chest width to width at the hocks. All indices were calculated in accordance with generally accepted zootechnical methods that allow assessing the proportionality, muscle development, and body type of animals. To ensure accuracy, each indicator was calculated twice, after which the average value was analysed (Zhumadillayev *et al.*, 2021). The coefficient of variation (Cv) for assessing the degree of variability in lamb weight at different ages was calculated using the classic biometric formula (1):

$$Cv = \frac{s}{\bar{X}} \times 100\%, \quad (1)$$

where S is the standard deviation of the trait, and is its arithmetic mean. The mean values and standard deviations were calculated automatically using R 4.1.2, SPSS 26.0, and MS Excel 2019 software. The obtained coefficients of variation (in the range of 8.1-11.9%) reflected the low level of variability of the trait within each group. The calculations were performed in three repetitions, which ensured the statistical reliability of the results.

The reproductive qualities of ewes were assessed based on the percentage of inseminated and lambing animals, the number of lambs born, and their survival rate up to 4.5 months. The weight of the animals was determined before morning feeding with an accuracy of 0.1 kg using Kern FKB 65K0.1 electronic scales (Kern & Sohn, Germany). External measurements – height at the withers and sacrum, body length, chest depth and width, chest circumference and pastern – were taken using a Stanley PowerLock metal tape measure (Stanley Black & Decker, USA) and a Zootech Measuring Stick MS-250 (Kaixin, China). Based on linear measurements, body conformation indices (stretch, massiveness, bone structure, etc.) were calculated using formulas regulated by GOST R 57784-2017 (2019). Each measurement was performed by two independent specialists with double repetition per animal. Wool productivity was determined by measuring the fleece and analysing the fibre fineness using the OFDA 2000 device (BSC Electronics, Australia). Statistical data processing was performed using methods of variational statistics, Student's criterion, one-factor ANOVA and Tukey's post-hoc test at a significance level of $p < 0.05$. The calculations were performed using R 4.1.2 (R Foundation for Statistical Computing, Austria), IBM SPSS Statistics 26.0 (IBM, USA) and Microsoft Excel 2019 (Microsoft, USA) software.

Throughout the study period, the experimental groups of sheep were kept in accordance with seasonal pasture rotation, which is a mandatory element of the traditional system of pastoral animal husbandry in foothill areas. In spring and autumn, the animals were kept on lowland pastures with poorer vegetation cover, while in the summer months they were transferred to highly productive foothill pastures with more diverse and nutritious grass cover. The herds were moved along established routes twice a year – at the end of May

and the beginning of September – with an adaptation period of 5-7 days. Pasture conditions, grass composition and land productivity were documented annually based on an assessment of botanical composition, grass height and estimated green mass yield.

The physical condition of the animals was assessed seasonally using a set of indicators: body condition (1-5-point scale), skin turgor, coat condition, respiratory and heart rates, body temperature, as well as a visual assessment of activity and behaviour. Overall body condition was determined by palpating the lumbar and spinous processes of the spine, which made it possible to record changes in the animals' energy status against the background of seasonal fluctuations in feed availability. In addition, physiological parameters were recorded before blood sampling, which served as additional indicators of the functional state of the organism. The analysis of seasonal shifts in blood parameters (haemoglobin, erythrocytes, serum protein) was compared with data on pasture type, diet composition and climatic conditions, which made it possible to take into account the influence of barometric pressure, air temperature and oxygen content in the summer and autumn periods. All results were interpreted taking into account the movement of animals between pastures at different altitudes and changes in their feeding status throughout the year.

Results and Discussion

In Kazakhstan, the Kazakh Fine-Wool breed was developed in 1946 by crossbreeding Kazakh fat-tailed ewes with Prekos rams. An analysis of the long-term results of breeding and selection work to improve the Kazakh Fine-Wool breed of sheep has established that their average wool fineness is 22.5-23.4 microns (Zhumadillayev *et al.*, 2021). Consequently, the most important task for the future is to improve the technological qualities of the wool of the Kazakh Fine-Wool breed. At the same time, it is necessary to preserve the meat qualities and good adaptability to natural climatic and feed conditions, which will significantly increase the profitability and cost-effectiveness of Kazakh Fine-Wool sheep.

In solving this problem, considerable importance is attached to enriching the gene pool of Kazakh Fine-Wool sheep by using the best breeds from other countries. According to D. Rasali *et al.* (2006), Australian Merino wool best meets the current requirements of the global market, as the light industry obtains 30% more yarn from it. Modern merino sheep in Australia and the Kyrgyz Republic are well developed, with high (3-4 kg) yields of washed wool of high quality and a clean fibre yield of 60-70%. The most interesting breeds in this regard are the Australian Meat Merino and Kyrgyz Mountain Merino. Australian Meat Merinos optimally combine high wool quality with good meat productivity and reproductive capacity. In the best flocks, they yield 8-9 kg of wool. According to A. Ombayev *et al.* (2020), Kyrgyz Mountain Merinos, which are bred for wool and meat, are characterised by good reproductive capacity, early maturity, high wool fineness and meat quality. On average, 5-6 kg of wool with a fineness of 18-22 microns is sheared from each sheep. They easily adapt to changing environmental conditions. The improvement of selection and breeding work in sheep farming is carried out on the basis of selecting rams according to economically useful traits and identifying improvers for their widespread use, since the genetic improvement of sheep is mainly achieved through producers. Studies have confirmed that the effectiveness of breeding work increases with a comprehensive assessment of rams, taking into account their biological and productive characteristics (Table 1).

Table 1. Productivity of experimental sheep

Sex and age group	Breed	n	Live weight, kg	Wool yield, kg		Wool length, cm	Quality of fine wool, µm
				greasy	clean		
Rams	KF	3	109.5 ± 4.00	11.20 ± 0.58	6.37	10.57 ± 0.22	23.5 ± 0.37
	AMM	3	112.6 ± 4.28	10.23 ± 0.39	6.45	10.21 ± 0.30	21.00 ± 0.71
	KMM	3	106.3 ± 5.31	11.16 ± 0.43	7.09	11.10 ± 0.49	20.60 ± 0.24
Ewes	KF	450	66.2 ± 0.51	5.9 ± 0.20	3.12	9.15 ± 0.09	22.96 ± 0.05

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; n – number of animals in the group; X ± m – arithmetic mean value of the trait and its error

Source: compiled by the authors based on research results

As shown in Table 1, the live weight of rams was quite high (106.3-112.6 kg). Kazakh Fine-Wool rams slightly exceeded KMM rams in this respect by 3.2 kg, or 2.9%. In terms of unwashed wool yield, AMM rams were inferior to KF rams by 0.89 kg, or 7.9%, and to KMM rams by 0.78 kg, or 7.0%. No significant differences were found in the yield of washed wool, which ranged from 6.37 to 7.09 kg. KMM rams had longer wool – 11.10 cm, which is their distinctive feature. Their superiority over Kazakh Fine-Wool rams was 0.43 cm, or 4.8%, and over AMM rams – 0.89 cm, or 8.0%. During visual assessment during bonitation, the wool of the rams was fine merino, with a fineness of 23.5 microns for the Kazakh Fine-Wool breed, 21.0 microns for the AMM breed, and 20.60 microns for the Kyrgyz Mountain Merino breed. The imported AMM and KMM breeds had finer wool than the KF breed, by 2.5 µm, or 10.6%, and 2.9 µm, or 12.3%, respectively. In order to obtain a more complete description

of the rams and ewes used in the experiment, their external characteristics were studied. For this purpose, body measurements were taken from all rams and 30 ewes, which are presented in Table 2.

Table 2. Measurements of breeding rams and ewes

Indicator	Breeding rams			Ewes
Breed	KF	AMM	KMM	KF
n	3	3	3	30
Height at withers, cm	80.5	80.0	81.5	68.5 ± 0.14
Height at the croup, cm	81.5	82	83.5	68.9 ± 0.12
Oblique torso length, cm	82	81	81.5	68.5 ± 0.14
Chest depth, cm	42.5	42.0	41	35.6 ± 0.12
Chest width, cm	38	35	36	32.7 ± 0.13
Chest circumference, cm	123.5	122.0	120	106.5 ± 0.14
Wrist circumference, cm	10	10	10.5	9.0 ± 0.12

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; n – number of animals in the group; ewe indicators are presented as the mean value ± standard error of the mean (X ± m)
Source: compiled by the authors based on research results

For selection purposes, tall animals with well-developed meat conformation and a strong constitution are of greatest interest. As can be seen from Table 2, no significant differences in basic measurements were found. The rams in the experimental groups are tall and fairly large, as evidenced by their height measurements. They have well-defined meat conformation, a long torso, and a deep and broad chest, characteristic of meat animals. Characteristically, they have well-filled thighs, combined with a developed hindquarter, which determines their good meatiness. The animals are of strong constitution, with pastern circumference measurements ranging from 10.0 to 10.5 cm across breeds. A similar pattern was found in ewes. When assessing the exterior of farm animals, it is important to know the development of body conformation indices. This is necessary to evaluate the proportions and harmony of the animal's body and its suitability for a particular economic use. The body conformation indices, as well as body measurements, characterise the experimental rams and ewes as long-legged animals with a long torso, deep and broad chest, strong constitution, and pronounced meat conformation. Thus, in the growth and overall development of the studied sheep breeds, general biological patterns characteristic of fine-wool sheep of meat productivity and some features depending on their origin have been identified. At the same time, a slight decrease in productivity in imported rams of the AMM and KMM breeds is probably explained by their lesser adaptability to the foothill conditions of south-eastern Kazakhstan and year-round grazing (Khamzina *et al.*, 2025).

In addition to comparing the exterior of the experimental breeding rams, the experiment aimed to study the individual characteristics of each ram depending on their origin as a potential sire of future offspring. As pointed out by N. Ruziboev & B. Ashurov (2025), a ram selected for its phenotype and origin is of breeding value only if it has sufficient sexual activity, is capable of long-term exploitation with year-round grazing on natural pastures, and produces good quality semen. Thus, the studies conducted show that the experimental rams of various breeds have the best sperm production indicators, which characterises their high reproductive capacity.

The study of the acclimatisation of imported experimental sheep in the foothill zone of the south-eastern region of Kazakhstan includes the body's responses to new, unfamiliar climatic factors – high temperatures and dry air in the summer months, as well as increased atmospheric pressure and thin air in the foothill pastures (Dossybayev, *et al.*, 2019). Fine-wool sheep tolerate high ambient temperatures and direct sunlight easily. Table 3 shows the results of two years of experiments measuring the temperature, respiratory rate and pulse rate of sheep. In the morning, the body temperature, respiration, and pulse rate of the animals in the compared groups were at their lowest, and increased during the day. This is probably due not only to the increase in ambient temperature, but also to the large number of stimuli that cause a certain reaction in animals, as indicated in the work of V. Dvalishvili & V. Milchevsky (2021). As the ambient air temperature increased, the body temperature, respiratory rate and pulse rate of the rams in groups I and II were significantly lower than those of the other groups. The relative increase in body temperature, respiratory rate and pulse rate in the rams in groups I and II was significantly lower than that in the rams in groups III and IV. The results obtained for physiological indicators confirm the conclusions of A. Abdulmuslimov *et al.* (2024) and Y. Islamov *et al.* (2025) on the need to take regional characteristics into account when selecting breeds for crossbreeding. Rams of Australian and Kyrgyz origin showed stable clinical parameters (Table 3), however, during the summer period at an air temperature of +27°C, KMM rams showed an increase in respiratory rate to 49 breaths/min and an

increase in body temperature to 39.6°C, which indicates a lower adaptability to the hot climate of the foothills compared to the local Kazakh Fine-Wool breed. This is consistent with the data of Y. Islamov *et al.* (2025) on the importance of animals' adaptive capabilities when moving to new climatic zones.

Table 3. Average body temperature, number of breaths and heartbeats per minute (average over 2 years)

Time and place of observation	Time of day, hours	Air temperature, °C	I (KF) n=3			II (AMM) n=3			III (KMM) n=3			IV ewes (KF) n=3		
			body temperature, °C	breathing	pulse	body temperature, °C	breathing	pulse	body temperature, °C	breathing	pulse	body temperature, °C	breathing	pulse
Winter	8	4	38.9	14	71	38.6	22	73	38.9	22	68	38.5	21	66
	13	6	39.5	22	72	39.2	23	70	39.0	23	69	39.2	21	67
Early spring	8	6	39.2	23	78	39.4	24	75	39.2	21	74	39.4	22	74
	13	11	39.4	21	77	39.6	22	75	39.7	21	84	39.5	22	85
	19	12	39.6	25	24	39.2	25	24	38.8	20	80	39.2	21	81
Spring	8	16	39.6	89	85	39.3	86	81	38.9	37	98	39.1	34	96
	13	19	40.0	196	103	39.6	190	96	39.3	39	102	39.3	36	104
Summer	8	20	39.2	34	86	39.2	36	85	39.2	26	84	38.6	24	83
	13	26	39.5	71	95	39.4	69	95	39.3	46	90	39.6	49	88
	19	22	39.6	74	94	39.6	71	92	39.4	74	92	39.4	74	91
Autumn	8	9	39.3	62	82	39.3	62	81	38.9	24	69	38.4	23	68
	13	14	39.5	82	83	39.2	79	85	39.0	26	83	38.3	24	85

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; n – number of animals in the group; breathing – number of respiratory movements per minute; pulse – number of heartbeats per minute; I – group of Kazakh Fine-Wool rams; II – group of Australian Meat Merino rams; III – group of Kyrgyz Mountain Merino rams; IV – group of Kazakh Fine-Wool ewes

Source: developed by the authors based on research results

In winter and spring pastures, when the ambient temperature was no higher than 14-17°C, the experimental rams of groups I and II felt satisfactory and grazed well. Although their physiological indicators remained normal, they still differed slightly from the same indicators in rams of group III and ewes of group IV. When the ambient air temperature in the pasture rose to 27°C and above in summer, the body temperature of some animals in groups III and IV rose to 39.6°C, their breathing rate to 49 and their pulse rate to 88 beats per minute. During the heat, they were depressed, did not respond to external stimuli, did not graze, some had diarrhoea, and their body condition score decreased. Normal rapid breathing and increased body temperature for rams in groups I and II is an ecological feature. Their physical thermoregulation mechanism is highly developed for hot climates and is probably different in nature from that of rams in groups III and ewes in group IV. The data obtained show that imported test animals from different geographical areas differ in clinical indicators, probably due to their constitutional structure. They possess the necessary plasticity to adapt to the foothill pastures of south-eastern Kazakhstan with increased partial oxygen pressure and tolerate high temperatures normally, which causes normal shifts in their vital functions. According to N. Zhumadillayev *et al.* (2022), an important indicator is the change in the morphological composition of blood in farm animals in connection with changes in living conditions. Studies have shown that experimental sheep from different natural and climatic zones in different seasons of the year differ in their red blood cell patterns (Table 4).

Table 4. Red blood cell patterns of breeding rams and ewes from different geographical zones by season

Groups	Seasons	n	Haemoglobin content, g/l	Erythrocyte content, million/µl	% protein in serum	Average red blood cell diameter, µm
I (KF)	Autumn	10	57.3±0.41	11.3±0.50	7.4±0.09	3.96
	Spring	10	50.6±0.44	10.4±0.47	–	3.94
	Summer	10	61.0±0.33	14.4±0.68	8.4±0.26	3.97
II (AMM)	Autumn	10	56.4±0.30	9.3±0.29	7.2±0.24	3.96
	Spring	10	49.7±0.31	8.6±0.31	–	3.94
	Summer	10	60.0±0.40	12.5±0.64	8.1±0.29	3.98

Table 4. Continued

Groups	Seasons	n	Haemoglobin content, g/l	Erythrocyte content, million/µl	% protein in serum	Average red blood cell diameter, µm
III (KMM)	Autumn	10	56.7 ± 0.26	10.4 ± 0.41	6.4 ± 0.20	3.84
	Spring	10	48.5 ± 0.40	9.8 ± 0.31	–	3.86
	Summer	10	59.7 ± 0.52	13.4 ± 0.40	7.1 ± 0.24	4.04
IV (ewe lambs KF)	autumn	10	58.4 ± 0.51	10.4 ± 0.29	7.4 ± 0.22	3.99
	Spring	10	49.7 ± 0.31	9.8 ± 0.32	–	3.96
	Summer	10	60.7 ± 0.38	14.4 ± 0.46	8.1 ± 0.16	4.06

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; n – number of animals in the group; I – group of Kazakh Fine-Wool rams; II – group of Australian Meat Merino rams; III – group of Kyrgyz Mountain Merino rams; IV – group of Kazakh Fine-Wool ewes; indicators are presented as the mean value ± standard error of the mean (X ± m)
Source: compiled by the authors based on research results

The data obtained are consistent with the results of S. Ceccobelli *et al.* (2023), who found that fine-wool sheep show significant variability in physiological parameters depending on the season and housing conditions. In the experiments conducted on Kazakh Fine-Wool rams, seasonal variation was also noted: erythrocytes increased from 10.4 million/µl in autumn to 14.4 million/µl in summer, reflecting the body's adaptive response to changes in pasture altitude and oxygen levels. The highest blood haemoglobin and erythrocyte content, as well as serum protein content in the experimental sheep, was observed in the summer when the sheep were on summer pastures located at an altitude of 600-800 m above sea level. The increase in haemoglobin and red blood cell content in all groups of sheep during the summer period is associated with their transfer to high-altitude pastures (600-800 m above sea level) with lower barometric pressure. Haemoglobin in KF rams increased from 50.6 units in spring to 61.0 units in summer (+20.5%), indicating a compensatory response of the haematopoietic system to high-altitude hypoxia. O. Karatieieva *et al.* (2022) emphasise that such physiological adaptations are closely related to the constitutional characteristics of animals and are an important criterion in selection. A comparison of the results of blood composition studies in experimental sheep from different natural and climatic zones showed that in all seasons of the year, rams in groups I and III had lower levels of haemoglobin in the blood and protein in the serum, they had fewer erythrocytes per unit of diameter, and they were smaller than the rams and ewes in groups I and IV. There are probably grounds for saying that the rams in groups II and III have a reduced ability to adapt to the conditions of the foothills of south-eastern Kazakhstan.

Sheep production and its profitability depend to a large extent on the number and quality of young animals raised. In modern sheep farming, in a market economy, one of the important factors contributing to an increase in the industry's production is the proper organisation of herd reproduction (Deniskova *et al.*, 2019). To achieve this, it is necessary to ensure maximum hereditary determination, fertility of ewes and lamb survival. This leads to the most important problem of intensive use of the reproductive composition of the flock to obtain the largest number of lambs in a short biologically acceptable period of time, which is one of the most difficult problems in sheep breeding. A certain level of fertility is a breed characteristic and an important component of their adaptive qualities to environmental conditions and the system of keeping and feeding. The adaptive ability of animals allows them to adapt to frequently changing environmental conditions in which they can reproduce, grow, develop and produce stable yields. In this study, the reproductive qualities of Kazakh Fine-Wool ewes in purebred breeding and two-breed crossbreeding with Australian Meat Merino and Kyrgyz Mountain Merino rams were studied, and the following indicators were examined in the resulting purebred and crossbred young stock: the ability of ewes to conceive, their fertility, and survival during the suckling period (Table 5). A total of 450 ewes were inseminated, with a fertility rate of 97.3-98.0%. The highest fertility rate (98.0%) was observed in ewes of group I inseminated with rams of the Kazakh Fine-Wool breed. A total of 176-182 live lambs were obtained in the experimental groups. A higher percentage of barren ewes was observed in ewes of groups II and III inseminated with semen from rams of the AMM and KMM breeds – 2.7%. Fertility in all groups of ewes was good – 117.0-121.0%. At the same time, the fertility of ewes in group I, inseminated with semen from KF rams, was 2.0-4.0% higher than that of ewes inseminated with semen from imported rams. During the suckling period, the highest survival rate was observed in lambs obtained from KF rams – 97.3% and from AMM rams – 95.9%, rather than from imported KMM rams – 95.6%. The fertility rates obtained correspond to the data of A. Azhibekov *et al.* (2023) and K. Yessengaliev & G. Kassimova (2023) for fine-wool sheep in the south-eastern region. The higher fertility of KF × KF ewes (121.0%) compared to industrial crossbreeding variants (119.0% and 117.0%) is explained by the better adaptation of the local genotype to pasture conditions. K. Yessengaliev & G. Kassimova (2023)

indicate that when using meat genotype producers, there is a 2-4% decrease in fertility, which is compensated by an increase in the live weight of offspring. In this experiment, lambs from AMM exceeded their peers in weight by 2.7-5.7%, which confirms the feasibility of industrial crossbreeding to increase meat productivity.

Table 5. Reproductive qualities of ewes

Indicator	Group			Total
	I	II	III	
	KF × KF	AMM × KF	KMM × KF	
Number of inseminated ewes, heads	150	150	150	450
Ewes that have given birth, head	147	146	146	439
Fertility, %	98	97.3	97.3	97.5
Lambs obtained, head	182	179	176	537
Fertility, %	121.0	119	117.0	119.0
Survival rate during the suckling period, %	97.3	95.9	95.6	96

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; I – crossbreeding group Kazakh Fine-Wool × Kazakh Fine-Wool (KF × KF); II – crossbreeding group Australian Meat Merino × Kazakh Fine-Wool (AMM × KF); III – crossbreeding group Kyrgyz Mountain Merino × Kazakh Fine-Wool (KMM × KF); fertility (%) – ratio of ewes that lambed to the number of ewes inseminated; prolificacy (%) – number of lambs born per 100 ewes; survival rate (%) – survival of lambs during the suckling period

Source: developed by the authors based on research results

In meat sheep farming, live weight is a comprehensive indicator that characterises the growth, development and meat productivity of animals. Ultimately, it determines the amount of product obtained (Lakota, 2025). According to J. Young *et al.* (2011), changes in average live weight, its increase or decrease over the years, serve as a clear illustration of the state of breeding work with the breed. An increase in live weight is a consequence of improved animal development and a more sophisticated selection and matching system. Against the backdrop of higher live weight, the effectiveness of sheep selection and the formation of animals of the desired type increases. A special criterion determining the growth and development of animals should be considered to be the dynamics of live weight variability with age. Based on the indicators of this trait and its variability, it is impossible to plan breeding and selection work or to select and match parent pairs (Table 6).

Table 6. Age-related variability in the live weight of lambs of different genotypes

Group	Sex	n	At birth		4.5 months		12 months	
			X ± mX	Cv	X ± mX	Cv	X ± mx	Cv
I KF × KF	rams	10	3.7 ± 0.13	11	37.3 ± 0.85	7.5	56.6 ± 0.51	4.8
	ewes	16	3.5 ± 0.10	11.7	36.7 ± 0.56	6.4	47.0 ± 1.50	5.9
II AMM × KF	rams	38	3.8 ± 0.66	9.6	38.6 ± 0.30	6	57.9 ± 0.54	4.2
	ewes	20	3.6 ± 0.10	11.4	37.0 ± 0.43	6.8	48.3 ± 0.59	5.5
III KMM × KF	rams	14	3.9 ± 0.13	11.9	37.8 ± 0.71	8.4	56.9 ± 0.48	3.9
	ewes	10	3.6 ± 0.10	8.1	37.0 ± 0.67	6.8	47.0 ± 1.52	5.7

Note: KF – Kazakh Fine-Wool breed; AMM – Australian Meat Merino; KMM – Kyrgyz Mountain Merino; n – number of animals in the group; X ± m – mean value of the trait and standard error of the mean; Cv – coefficient of variation, %; I – crossbreeding group Kazakh Fine-Wool × Kazakh Fine-Wool (KF × KF); II – crossbreeding group Australian Meat Merino × Kazakh Fine-Wool (AMM × KF); III – crossbreeding group Kyrgyz Mountain Merino × Kazakh Fine-Wool (KMM × KF)

Source: developed by the authors based on research results

The experimental lambs from all crossbreeding options had average indicators at birth: the average live weight of rams in groups II and III was 3.8 and 3.9 kg, respectively, and that of ewe lambs was 3.6 kg. Newborn rams in group I were significantly inferior to their peers in live weight by 2.7 and 5.7%, respectively. The difference in live weight between ewe lambs of all groups is insignificant and mathematically unreliable. At the same time, it should be noted that at birth, the variability of live weight is still insignificant and amounts to 11.9% for rams and 11.7% for ewe lambs. The differences in live weight observed in lambs at birth were significantly smoothed out by the age of 4.5 months, as evidenced by the coefficients of variation. In terms of live weight, both rams and ewes had the highest growth energy when weaned from their mothers. In absolute terms, the live weight gain in rams was in the range of 33.3-34.9 kg, and in ewes – 33.4 kg.

The high early maturity of lambs in all groups mainly depends on the genotype of the parents, in this case on the maternal side. As can be seen, they pass on these abilities well through inheritance. In addition,

this can be attributed to the high milk yield of Kazakh Fine-Wool ewes, which ensures enhanced growth and development of lambs. The early maturity of young animals and their weight in the first year of life are of exceptional importance in the formation of meat qualities in sheep. In young animals of all groups at one year of age, it was quite high in all crossbreeding options. The average live weight of ewe lambs, depending on the crossbreeding options, ranged from 47.0 to 48.3 kg and reached 70-75% of the live weight of their mothers. According to the data obtained, the most intensive live weight gain of lambs in all crossbreeding options from birth to 4.5 months of age was within the range of 98.4-103.1%; from 4.5 months to one year – 65.9-66.6%, and ewes, respectively, 97.2-99.1% and 76.6-78.0%. Analysis of the data obtained showed that lambs in all crossbreeding variants differed in terms of better growth and development during the suckling period, after which the growth rate decreased significantly until one year of age.

According to J. Oberpenning *et al*. (2025), the study of the external characteristics of animals is not only scientifically significant but also a production necessity. Under the conditions of the existing technology in the industry, constitutional strength and optimal size are of vital importance for increasing meat productivity with round-the-clock grazing in the foothills of south-eastern Kazakhstan. In the studies conducted, the method of measuring basic external measurements was used to obtain a more complete and objective assessment of the growth and development of animals. To fully characterise the physique of the test animals, the most important physique indices were calculated for the animals under study. In doing so, both the patterns common to all groups and the characteristics specific to each animal selection variant were identified. Lambs in groups I and II differed in their more intensive growth during the suckling period. Thus, in rams and ewes of group II, the height measurements at the withers during this period increased by 46.6 and 41.9%, respectively, in group I – by 48.6 and 48.2%, and in group III – by 43.6 and 44.7%. By the age of one year, the growth rate had decreased significantly and varied between 16.3-20.5% for rams and 13.6-23.2% for ewes, depending on their origin. Similar data were obtained for the growth of cross-sectional height measurements for the specified periods and amounted to 37.3-21.2% and 31.8-25.0% for groups I and II, respectively, and 40.0-18.8 and 41.0-12.5% for group III. Measurements characterising the meat qualities of group II: lambs – 68.0-35.4%, 51.8-21.6%, 71.3-30.9% and ewe lambs 62.4-26.0%; 61.2-8.4%; 63.9-31.6%, in group I – 54.7-18.3%; 69.8-30.0%; 60.0-18.3% and 42.7-29.1%; 39.3-31.8%; 70.8-33.3%; and in group III – 60.7-20.5%; 49.3-20.0%; 65.7-33.5% and 44.6-27.3%; 37.1-30.3%; 63.8-31.9%.

As can be seen, the lambs of group II slightly surpassed the lambs of groups I and III in terms of growth and development intensity according to the main exterior measurements. Moreover, the greatest oblique body length at one year of age was observed in the rams and ewe lambs of group II, followed by the rams of group I. The difference in chest width between the experimental animals is quite significant. Both rams and ewes of group II differ particularly in these measurements, surpassing their peers by 7.7-9.0% and 11.0-14.8%, respectively. The chest of the experimental animals is characterised by an increase not only in width but also in depth. Thus, depending on their origin, the depth of the chest in rams ranges from 35.1 to 35.9 cm, and in ewes from 33.0 to 34.7 cm. The chest circumference behind the shoulder blades in the experimental animals varies significantly depending on their origin. The largest chest circumference at one year of age is also found in rams and ewes of group II (106.0-104.7 cm). Differences in limb development between the test animals of all groups are not particularly evident, with the exception of ewes of group III, which slightly exceed their peers in terms of metacarpal circumference.

The differences noted in the measurements of individual body parts of the experimental animals only partially reflect their overall exterior type. As a result, body type indices are of great importance, as they fully characterise and, to the greatest extent, allow for judging the development of the organism, its body proportions and overall constitutional type. The animals studied are characterised by varying degrees of development of the elongation (or format) index with age. At the same time, a higher format index is characteristic of meat-type animals. According to the data obtained, the highest value was recorded at birth in rams and ewe lambs of group III (64.4-64.2%). At the age of 4.5 months, lambs of groups I and III, and at the age of one year, ewe lambs of groups I and III exceeded rams in size by 2.3-4.6%. At birth, the lowest compactness index was observed in lambs of group III (90.7-93.2%), and the highest in lambs of group II (102.7-103.1%). Rams and ewe lambs of group I differed insignificantly from each other. However, at 4.5 months of age, some differences appeared depending on origin. Thus, the indicators of this index were slightly higher for ewe lambs in group II (172.4%) and ram lambs in group III (169.0%). At 12 months of age, the lowest value of this index was recorded in rams of group I (152.4 cm) and ewes of group III (153.6 cm). It should be noted that the values of this index in the studied animals changed unpredictably with age. The highest values of the mass index in all age periods were observed in lambs of group II, and at the same time, at 4.5 months of age, they were slightly inferior to animals of group III. No significant differences were found in the bone index of the animals in the compared groups. Thus, based on the studies conducted, it can be concluded that in the selection process, in order to increase the productivity of Kazakh Fine-Wool sheep at the Akbulak farm, along with purebred breeding

(KF × KF), it is advisable to use Australian Meat Merino and Kyrgyz Mountain Merino rams with Kazakh Fine-Wool ewes in industrial crossbreeding.

Conclusions

The studies conducted showed that the genetic resources of fine-wool sheep brought to the foothills of south-eastern Kazakhstan are highly diverse and form pronounced differences in a number of productive and biological traits. It was established that Australian Meat Merino rams demonstrated a statistically significant advantage in live weight compared to producers of the Kazakh Fine-Wool breed and Kyrgyz Mountain Merino; the magnitude of superiority was 2.83% and 5.92%, respectively, with a coefficient of variation Cv = 12.7%, which indicates a fairly high stability of the trait within breed groups. The results confirm the presence of a pronounced growth potential in AMM rams, which is of important breeding and production significance for the foothill zone conditions. Analysis of clinical, physiological and haematological blood parameters showed that all the groups of rams studied, despite their different origins and the specific natural and climatic conditions of their habitats, demonstrated a sufficient level of adaptation to the new environmental conditions. Haemoglobin, erythrocyte and serum protein levels were within the physiological norm and changed predictably depending on the season, which indicates the high adaptive potential of the genotypes studied. Such stability of homeostatic mechanisms allows for the effective use of compact meat-wool genotypes in the region's pasture-based livestock farming conditions.

Of particular importance are the results related to the evaluation of offspring from different crossbreeding options. Lambs obtained from the combination of AMM × KF demonstrated more intensive live weight gain at all age stages and significantly outperformed their peers from the KF × KF and KMM × KF combinations by 2.7-5.7%. This confirms the effectiveness of including Australian Meat Merino rams in breeding programmes to improve the meat productivity of fine-wool sheep in south-eastern Kazakhstan. The data obtained form a scientific and practical basis for further improvement of crossbreeding schemes aimed at increasing the productivity and adaptability of sheep. Prospects for further research include studying the multigenerational dynamics of productive traits, assessing the stability of the genotypes obtained in various climatic conditions, and determining the long-term impact of crossbreeding on the meat, wool, and reproductive qualities of animals.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Abdulmuslimov, A., Yuldashbaev, Y., Kubatbekov, T., Chylbak-ool, S., Savchuk, S., & Kulmakova, N. (2024). Sheep farming development: Utilizing the biological capabilities of Dagestan breed sheep and crossbreeds. *IOP Conference Series: Earth and Environmental Science*, 1405(1), article number 012033. doi: 10.1088/1755-1315/1405/1/012033.

[2] Azhibekov, A.S., Derkenbaev, S.M., Osmonaliev, S.K., Samykbaev, A.K., Shergaziev, U.A., & Bekturov, A.B. (2023). Questions of admixture crossing in semi-fine-wool sheep breeding in Kyrgyzstan. *BIO Web of Conferences*, 66, article number 10003. doi: 10.1051/bioconf/20236610003.

[3] Ceccobelli, S., *et al.* (2023). A comprehensive analysis of the genetic diversity and environmental adaptability in worldwide Merino and Merino-derived sheep breeds. *Genetics Selection Evolution*, 55, article number 24. doi: 10.1186/s12711-023-00797-z.

[4] Code of Practice for the Housing and Care of Animals Bred, Supplied or Used for Scientific Purposes. (2014, December). Retrieved from https://surl.lu/qmqbya.

[5] Deniskova, T., *et al.* (2019). Population structure and genetic diversity of sheep breeds in Kyrgyzstan. *Frontiers in Genetics*, 10, article number 1311. doi: 10.3389/fgene.2019.01311.

[6] Dossybayev, K., Orazymbetova, Z., Mussayeva, A., Saitou, N., Zhapbasov, R., Makhatov, B., & Bekmanov, B. (2019). Genetic diversity of different breeds of Kazakh sheep using microsatellite analysis. *Archives Animal Breeding*, 62, 305-312. doi: 10.5194/aab-62-305-2019.

[7] Dvalishvili, V.G., & Milchevsky, V.D. (2021). Selection of quantitative traits when crossing fine-coarse wool sheep with Tsigai rams. *IOP Conference Series: Earth and Environmental Science*, 848(1), article number 012069. doi: 10.1088/1755-1315/848/1/012069.

[8] Emsen, E., Kutluca Korkmaz, M., & Odevci, B.B. (2025). Artificial intelligence-assisted selection strategies in sheep: Linking reproductive traits with behavioral indicators. *Animals*, 15(14), article number 2110. doi: 10.3390/ani15142110.

[9] GOST 13496.4-2019. (2020). *Feed, compound feed, compound feed raw materials. Methods for determining nitrogen and crude protein content*. Retrieved from https://vsegost.com/Catalog/71/71526.shtml.

[10] GOST 31675-2012. (2013). *Feed. Methods for determining crude fibre content using intermediate filtration*. Retrieved from https://vsegost.com/Catalog/52/52702.shtml.
[11] GOST R 57784-2017. (2019). *Breeding farm animals. Methods for determining productivity parameters of beef cattle*. Retrieved from https://vsegost.com/Catalog/65/65600.shtml.
[12] Iskakov, K.A., Kulataev, B.T., Zhumagaliyeva, G.M., & Pares Casanova, P.M. (2017). Productive and biological features of Kazakh Fine-Wool sheep in the conditions of the Almaty region. *Online Journal of Biological Science*, 17(3), 219-255. doi: 10.3844/ajassp.2017.219.225.
[13] Islamov, E.I., Kulmanova, G.A., Kulataev, B.T., Bekbaeva, D.N., & Zhumanova, A.S. (2021). Enhancement of the reliability of animal genotyping for improving wool productivity in South-Kazakh Merino sheep. *Archives of Razi Institute*, 76(6), 1703-1714. doi: 10.22092/ari.2021.356235.1809.
[14] Islamov, Y.I., Beishova, I.S., Kulmanova, G.A., Ibrayev, D.K., & Mukhametzharova, I.E. (2025). Zootechnical and genealogical characteristics of lines of Kazakh meat-wool semi-fine-wool sheep and South Kazakh Merino bred in the Moyynkum sands of the Zhambyl region. *Science and Education*, 6(3), 96-105. doi: 10.52578/2305-9397-2025-3-96-105.
[15] ISO/IEC 17025:2019. (2021). *General requirements for the competence of testing and calibration laboratories*. Retrieved from https://meganorm.ru/Data/712/71232.pdf.
[16] Karatieieva, O., Polishchuk, T., & Posukhin, V. (2022). Evaluation of productive qualities of sheep of Askani fine-wool breed. *Ukrainian Black Sea Region Agrarian Science*, 26(2), 59-66.
[17] Khamzina, A., Smagulov, D., Dossybayev, K., Kantanen, J., & Khamzin, K. (2025). Assessing runs of homozygosity reveals production traits of Kazakh sheep breeds. *Brazilian Journal of Biology*, 85, article number e292980. doi: 10.1590/1519-6984.292980.
[18] Lakota, E. (2025). Productivity of Kuibyshev sheep of different intra-breed types. *Journal of Osh State University. Agriculture: Agronomy, Veterinary and Zootechnics*, 4(2), 28-36. doi: 10.52754/16948645_2025_4(2)_28.
[19] Oberpenning, J., Brügemann, K., & Koenig, S.A. (2025). Characterization of German sheep production systems and derivation of respective economic values for breeding traits. *Veterinary and Animal Science*, 27, article number 100432. doi: 10.1016/j.vas.2025.100432.
[20] Ombayev, A., Ukbaev, H., Shamekenova, R., & Abdurasulova, A. (2020). Astrakhan breeds sheep of Kazakhstan. *News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Agricultural Sciences*, 1(55), 17-23. doi: 10.32014/2020.2224-526X.3.
[21] Rahim, A., Rajaravindra, K.S., Chaudhary, R., Pourouchottamane, R., Chauhan, P., Gowane, G.R., & Kumar, A. (2025). Comparison of different models for the estimation of genetic parameters of wool traits in intercross sheep. *Small Ruminant Research*, 245, article number 107462. doi: 10.1016/j.smallrumres.2025.107462.
[22] Rasali, D.R., Shrestha, J.N.B., & Crow, G.H. (2006). Development of composite sheep breeds in the world: A review. *Canadian Journal of Animal Science*, 86(1), 1-24. doi: 10.4141/A05-073.
[23] Ruziboev, N., & Ashurov, B. (2025). The state, achievements, and prospects for the development of sheep breeding in Uzbekistan. *Journal of Osh State University. Agriculture: Agronomy, Veterinary and Zootechnics*, 4(2), 37-47. doi: 10.52754/16948645_2025_4(2)_37.
[24] Vijayakumar, C., Chitrambigai, K., & Enbavelan, P.A. (2025). Optimizing sheep reproductive performance through technological interventions. *International Journal of Veterinary Sciences and Animal Husbandry*, 10(4), 27-31. doi: 10.22271/veterinary.2025.v10.i4a.2175.
[25] Yessengaliev, K., & Kassimova, G.V. (2023). The use of sheep producers of the Akzhaik meat and wool breed to improve the meat productivity of fine-fleeced sheep. *Science and Education*, 4(73), 21-27. doi: 10.52578/2305-9397-2023-4-21-27.
[26] Young, J.M., Thompson, A.N., Curnow, M., & Oldham, C.M. (2011). Whole-farm profit and the optimum maternal liveweight profile of Merino ewe flocks lambing in winter and spring are influenced by the effects of ewe nutrition on the progeny's survival and lifetime wool production. *Animal Production Science*, 51, 821-833. doi: 10.1071/AN10078.
[27] Zhumadillayev, N., Dossybayev, K., Khamzina, A., Kapasuly, T., Khamzina, Z., & Tlevlesov, N. (2022). SNP genotyping characterizes the genome composition of the New Baisary fat-tailed sheep breed. *Animals*, 12(11), article number 1468. doi: 10.3390/ani12111468.
[28] Zhumadillayev, N., Yuldashbaev, Y., Karynbaev, A., Khudaiberdiev, A., & Efendiev, B. (2021). Exterior features and productivity of Kazakh Fine-Wool sheep and crossbreeds with meat breeds. *E3S Web of Conferences*, 262, article number 02019. doi: 10.1051/e3sconf/202126202019.

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Аннотация. Казакстанда кой чарбачылыгы азык-түлүк менен камсыздоодо жана өнөр жай үчүн чийки зат берүүдө маанилүү тармак бойдон калууда. Жүндүн наркынын төмөндөшүнө байланыштуу эт багытын өнүктүрүү өзгөчө актуалдуу болуп, продуктивдүүлүктү жогорулатууга багытталган породаларды тандоо зарыл. Изилдөөнүн максаты – Австралиядан жана Кыргыз Республикасынан алынып келген тункорундуу асыл тукум кочкорлорун Казакстандын тункорундуу кой породасынын качкындары менен, Алматы облусунун тоо этектериндеги “Акбулак” фермердик чарбасында жүргүзүлгөн аргындаштыруу учурунда баалоо болгон. Ар биринде 150 баштан турган үч топ түзүлүп, алар үчүн Австралиялык эт мериносу (АВММ) породасынан 3 кочкор, Кыргыз тоо мериносу (КГМ) породасынан 3 кочкор жана Казак тункорундуу (КТ) породасынан 3 кочкор колдонулган. Иште таза тукум багуу жана муун өзгөрүүсүн тездеткен өнөр жайлык аргындаштыруу ыкмалары колдонулган. Натыйжалар көрсөткөндөй, катышкан кочкорлор бекем конституциясы, чоң тирүү салмагы жана жүндүн жакшы настригине ээ болушкан. Клиникалык көрсөткүчтөр бардык топтордо физиологиялык норманын чегинде болуп, олуттуу айырмачылыктар аныкталган эмес. Кан аралашмасынын гематологиялык көрсөткүчтөрү оптималдуу деңгээлде сакталган жана мезгилдерге жараша өзгөрүп турган, бул кычкылдануу-калбасуу процесстеринин интенсивдүүлүгүн чагылдырган. I топтогу (КТ × КТ) качкындардын туут боюнча көрсөткүчү эң жогору – 121,0 % түзүп, II (АВММ × КТ) жана III (КГМ × КТ) топтордон тиешелүүлүгүнө жараша 1,65 % жана 3,30 % жогору болгон. Козулардын эмчектен чыгарганга чейинки сакталуусу I топто 97,3 % түзүп, бул көрсөткүч теңтуштарына караганда 1,4 % жана 1,7 % жогору болгон. Иштин практикалык мааниси – АВММ жана КГМ породасындагы кочкорлорду Казакстандык тункорундуу кой породасынын үйүрлөрүндө колдонуу жүндүн жукадыгын жакшыртууга, тери-тал чачынын гистоморфологиялык түзүлүшүн өркүндөтүүгө, туурттуулук менен козулардын сакталуусун жогорулатууга жана эт багытындагы өндүрүштү көбөйтүүгө өбөлгө түзөрүн көрсөтөт

Негизги сөздөр: казак уяң жүндүү койлору; австралиялык эт мериносу; кыргыз тоо мериносу; төлдөө; тирүү салмагы; дененин өлчөөлөрү; физиологиялык жана гематологиялык параметрлер

Биологические и продуктивные особенности тонкорунных овец при чистопородном разведении и скрещивании на Юго-востоке Казахстана

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Аннотация. В Казахстане овцеводство сохраняет важное значение как источник продовольствия и сырьевой базы промышленности, а в условиях обесценивания шерсти особую актуальность приобретает развитие мясного направления. Цель исследования заключалась в оценке завезенных тонкорунных баранов-производителей из Австралии и Кыргызской Республики при их использовании в скрещивании с матками казахской тонкорунной породы в предгорной зоне фермерского хозяйства «Акбулак» Алматинской области. Были сформированы три группы маток по 150 голов, для которых использовали три барана австралийского мясного мериноса (АВММ), три барана кыргызского горного мериноса (КГМ) и три барана казахской тонкорунной породы (КТ). Применялись чистопородное разведение и промышленное скрещивание, обеспечивавшие ускоренное изменение наследственных и физиологических характеристик животных. Результаты показали, что подопытные бараны обладали крепкой конституцией, крупной живой массой и отличным настригом шерсти. Клинические показатели у всех баранов находились в пределах физиологической нормы, существенных различий между группами не выявлено. Гематологический состав крови сохранялся на оптимальном уровне и изменялся по сезонам, отражая интенсивность окислительно-восстановительных процессов. Плодовитость маток I группы (КТ × КТ) была самой высокой – 121,0 %, что на 1,65 % и 3,30 % выше по сравнению со II (АВММ × КТ) и III (КГМ × КТ) группами. Сохранность молодняка до отъема у маток I группы составила 97,3 %, что превышало показатели сверстниц на 1,4 % и 1,7 %. Практическая ценность работы состоит в том, что использование баранов АВММ и КГМ в стадах казахской тонкорунной породы способствует улучшению тонины шерсти, формированию гистоморфологических структур кожно-волосяного покрова, повышению плодовитости и сохранности ягнят, а также увеличению производства баранины в предгорных зонах юго-востока Казахстана

Ключевые слова: казахская тонкорунная порода; австралийский мясной меринос; кыргызский горный меринос; плодовитость; живая масса; промеры тела; физиологические и гематологические показатели

Received: 23.09.2025. Revised: 08.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 631.874

DOI: 10.63621/bknau./1.2026.54

The role of organic matter and green manure in increasing the fertility of typical grey soils and cotton yields

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Abstract. In conditions of soil degradation and reduction of organic matter during intensive cotton cultivation, the search for environmentally sustainable ways to restore soil fertility and increase crop yields is becoming particularly relevant. The aim of this study was to assess the effect of various organic fertilisers and green manure crops on the fertility indicators of typical grey soils in the southern regions of the Kyrgyz Republic and on cotton yields. Field studies were conducted with two cotton varieties, 'Fergana-3' and 'K 43', including the application of manure, winter rye as green manure, and crushed cotton stalks (guzapai). The results showed a significant improvement in the agrochemical indicators of the soil, expressed in an increase in the content of humus, total nitrogen, gross phosphorus and potassium. The most effective method of increasing yield was the application of manure at a dose of 30 t/ha, which ensured a yield increase of up to 107.2% for the 'Fergana-3' variety and 98.3% for the 'K 43' variety. The use of green manure also contributed to a significant increase in yield (up to 73.8%) and the accumulation of organic matter and nutrients in the soil. The use of crushed cotton stalks had a positive but less pronounced effect, increasing the yield by 50-59%. It was found that both varieties respond positively to the application of organic fertilisers, with the 'K 43' variety characterised by higher absolute productivity. The results confirm the advisability of the systematic use of organic fertilisers and soil-conserving technologies in cotton production in southern Kyrgyzstan and are of practical importance for the development of effective agronomic recommendations aimed at improving the environmental sustainability and economic efficiency of cotton production

Keywords: organic fertilisers; manure; winter rye; soil fertility; sustainable agriculture

Introduction

Cotton remains one of the key technical crops in countries with irrigated agriculture due to the high demand for cotton fibre and sustained demand from the textile industry. In the southern part of the Kyrgyz Republic, cotton cultivation has traditionally developed on typical serozems, which, with favourable thermal resources and irrigation, provide the potential for high yields. At the same time, long-term cultivation of cotton in a monoculture is accompanied by increased anthropogenic pressure on the soil cover, which leads to a gradual decline in its fertility.

Modern research shows that in intensive agriculture, the content and quality of soil organic matter becomes a key limiting factor for the sustainability of

Suggested Citation: Mamasukurov, A., & Karabaev, N. (2026). The role of organic matter and green manure in increasing the fertility of typical grey soils and cotton yields. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 54-62. doi: 10.63621/bknau./1.2026.54.

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agrocenoses. Accelerated humus mineralisation due to regular soil cultivation, the use of mineral fertilisers and irrigation leads to a deterioration in agrophysical properties, a decrease in biological activity and an imbalance of nutrients (Wei *et al.*, 2025). This problem is particularly acute for serozems in arid and semi-arid regions, as natural humus accumulation processes are extremely slow. A number of studies in recent years have emphasised that the restoration and maintenance of soil fertility in cotton-growing regions is impossible without the systematic return of organic matter. Thus, A. Makhkamova & B. Kamilov (2023) found that the prolonged absence of organic fertilisers in the cotton production system leads to a 25-40% decrease in humus content and deterioration of soil structure. Similar results were obtained by H. Oruj *et al*. (2021), who showed that irrigated cotton monoculture increases soil compaction and reduces microbiological activity, especially in the upper arable horizon.

In this regard, particular attention is paid to the use of organic fertilisers and green manure crops as tools for the biologisation of agriculture. M. Cheng *et al*. (2021) noted that the systematic removal of plant residues in cotton cultivation contributes to a decrease in organic carbon content and a deterioration in the agrophysical properties of the soil. Studies conducted in China and Central Asian countries have shown that the use of cereal green manure in cotton crop rotations contributes to humus accumulation, nitrogen loss reduction, and improvement of the agrophysical properties of serozems (Saleem *et al.*, 2010). At the same time, the effectiveness of green manure is largely determined by the timing of phytomass incorporation and its biochemical composition. A separate area of modern research is related to the use of cotton plant residues as a source of organic matter (Ma *et al.*, 2021). At the same time, S. Isaev *et al*. (2021) pointed to the limited rate of mineralisation of coarse cotton plant residues and a possible temporary deficiency of available nitrogen, which requires scientific justification of doses and methods of application.

Despite the availability of a significant number of international studies, the impact of long-term systematic application of various forms of organic matter and green manure crops in irrigated cotton cultivation in the southern Kyrgyz Republic remains insufficiently studied. The lack of long-term field experiments adapted to the conditions of typical serozems limits the possibility of developing practical recommendations aimed at a sustainable increase in soil fertility and stable crop yields. The aim of this study was to determine the comparative effectiveness of various sources of organic matter in irrigated cotton cultivation and to establish their impact on the agrochemical indicators of typical serozems and cotton productivity in the southern Kyrgyz Republic.

Materials and Methods

Field studies were conducted in 2021-2023 at an experimental site in the Aravan district of the Osh region of the Kyrgyz Republic. The study area is located in an irrigated agriculture zone and is characterised by typical serozems formed in arid climatic conditions. The soils of the experimental site had a medium loamy granulometric composition, a slightly alkaline soil solution reaction and a low organic matter content, characteristic of serozems in cotton-growing areas. The objects of the study were two cotton varieties – 'Fergana-3' and 'K 43'. The experiment was designed as a single-factor field trial with randomised block design. Each variant had three replicates. The area of one plot was 50 m^2, and the total area of the experiment was 1,050 m^2. Cotton was sown in the first ten days of April and harvested in September-October at the stage of full technical ripeness.

A variant without organic and mineral fertilisers was used as a control. The study focused on organic sources of nutrients, and therefore mineral variants were excluded from the analysis of results. The following variants were studied in the experiment: control (without fertilisers); manure at a dose of 30 t/ha; green manure; crushed cotton stalks. Manure was applied in autumn during primary soil cultivation at a dose of 30 t/ha in terms of wet weight. Well-rotted cattle manure with an average organic matter content of 20-22%, total nitrogen – 0.45-0.55%, phosphorus (P_2O_5) – 0.20-0.25% and potassium (K_2O) – 0.50-0.60% was used. Winter rye was used as a green manure crop (Zhi *et al.*, 2016). Rye was sown in the second decade of October after cotton harvesting at a sowing rate of 180 kg/ha. By the beginning of April of the following year, the green manure mass had reached the tillering stage – the beginning of stem elongation. The average above-ground biomass was 22-25 t/ha in wet weight. Green manure was incorporated by ploughing to a depth of 20-22 cm 10-12 days before cotton sowing. In the variant using cotton plant residues, about 250 cwt/ha of chopped stems (guzapai) were applied annually. The stems were mechanically chopped to a fraction of 5-7 cm and evenly distributed over the soil surface. The incorporation was carried out during the main soil cultivation to a depth of 18-20 cm. The dry mass of plant residues was used. Irrigation was carried out according to the scheme accepted for the cotton-growing zone, ensuring the maintenance of optimal soil moisture during the growing season. Plant density was 90-100 thousand plants/ha. All agrotechnical methods, with the exception of the factors under study, were the same for all experimental variants.

Soil samples were taken from the arable layer (0-30 cm) at the beginning and end of the growing season. Laboratory analyses were carried out in the agrochemical laboratory of the Kyrgyz National Agrarian

University named after K.I. Skryabin. The humus content was determined using the Tyurin method in the modification GOST 26213-91 (1993), total nitrogen – using the method of J. Ping *et al.* (2004), GOST 26107-84 (1985), gross phosphorus and potassium according to GOST 26205-91 (1993). Sample selection and preparation were carried out in accordance with GOST 17.4.4.02-84 (1986). Cotton yield was recorded separately for each plot and then converted to hectares. Statistical processing of the results was performed using Microsoft Excel and Statistica 10.0 software. The reliability of the differences between the variants was assessed using analysis of variance (ANOVA) with a significance level of $p < 0.05$. The results are presented as mean values with standard deviation (SD). The study was conducted in accordance with generally accepted ethical standards for scientific research (CBD, 1992), without the use of objects requiring special bioethical permission.

Results and Discussion

The results of field studies on the effect of organic fertilisers such as manure, intermediate winter green manure crops (winter rye) and the use of crushed cotton stalks (guzapai) on raw cotton yield are shown in Table 1.

Table 1. Raw cotton yield by variant

Variants	Variety 'Fergana-3'					Variety 'K 43'				
	Repetitions					Repetitions				
	1	2	3	Average	Yield increase, %	1	2	3	Average	Yield increase, %
Control (without fertilisers)	16.6	16.7	15.9	16.4		18.6	16.7	18.8	18	
Manure at a dose of 30 t/ha	33.4	34.8	33.7	34	107.2	35.6	35.7	35.9	35.7	98.3
Green manure crop	28.1	27.7	29.1	28.5	73.6	30.1	31.6	32.3	31.3	73.8
Cotton stalks, shredded	25.4	25.3	26.4	25.7	56.7	27.4	28.8	29.9	28.7	59.1

Source: compiled by the authors

The data in Table 1 show that the highest yields were achieved when manure was applied at a rate of 30 t/ha. The manure application option is undoubtedly the most effective organic fertiliser for both cotton varieties, providing the maximum yield increase in both absolute and relative terms. For the 'Fergana-3' variety, the increase was 107.2%, and for the 'K 43' variety, it was 98.3%. This indicates that manure is a multifunctional fertiliser, improving not only the supply of nutrients (nitrogen, phosphorus, potassium) to the plant, but also the soil structure, increasing the humus content, promoting the activation of soil microbiota and moisture retention.

Green manure crops proved to be the second most effective option, providing a yield increase of up to 73.8%. Interestingly, the Chinese variety 'K 43' yielded 2.8 cwt/ha more than 'Fergana-3', which may indicate better adaptation to the use of green manure and the ability to use nitrogen formed as a result of green mass mineralisation more efficiently. The option with chopped cotton stalks (guzapai) provided a yield increase of more than 50%. The use of guzapai as a fertiliser provides a closed cycle: plant residues are returned to the soil, reducing its depletion. However, unlike manure or green manure, guzapai decomposes slowly and is poorer in mobile forms of nitrogen, which limits its effect. The higher result of the Chinese variety (by 3 cwt/ha) again demonstrates its better adaptation to different types of organic matter. The results of the effect of various forms of organic matter on the yield of raw cotton for the studied variants and varieties are presented in Figure 1.

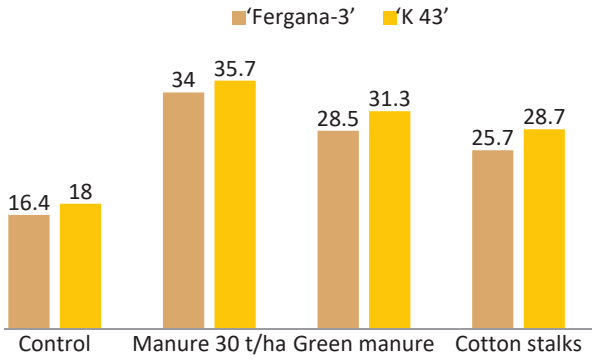

Figure 1. Raw cotton yield by variant

Source: compiled by the authors

Figure 1 illustrates the clear positive response of both cotton varieties to the application of organic fertilisers compared to the control variant. The highest yield was recorded when manure was applied at a dose of 30 t/ha. The use of green manure also provided a significant increase in yield compared to the control, but the effect was less pronounced than with manure. The variant with the incorporation of chopped cotton stalks was characterised by intermediate yield values. In all variants of the experiments, the 'K 43' variety demonstrated a higher absolute yield compared to the 'Fergana-3' variety, which indicates its greater productivity in irrigated agriculture. At the same time, the response of both varieties to the studied agrotechnical methods was similar, which indicates the universality of organic fertilisers for increasing cotton yields regardless of varietal characteristics. The results of

the assessment of the effectiveness of various forms of organic matter and green manure in improving the fertility of serozems in southern Kyrgyzstan are presented in Table 2.

Table 2. Effect of winter green manure (winter rye) on soil fertility indicators

Variety 'Fergana-3'				Variety 'K 43'			
Variants				Variants			
Control	Manure, 30 t/ha	Green manure	Cotton stalks	Control	Manure, 30 t/ha	Green manure	Cotton stalks
Humus, %							
0.88	1.11	1.32	1.28	0.98	1.16	1.21	1.05
Total nitrogen, %							
0.098	0.126	0.14	0.126	0.098	0.154	0.154	0.112
Gross phosphorus, %							
0.184	0.264	0.216	0.248	0.176	0.26	0.248	0.248
Gross potassium, %							
2.25	2.18	2.25	2.187	2.25	1.875	2.375	2.187

Source: compiled by the authors

The data presented in Table 2 characterise the influence of various forms of organic matter on the agrochemical indicators of fertility of typical serozems when cultivating cotton. The results obtained indicate a positive effect of all the organic methods studied on the content of humus and nutrients compared to the control variant. The most pronounced increase in humus content was observed in the variant with green manure, where the maximum accumulation of organic matter in the arable layer was recorded (1.32% for the 'Fergana-3' variety and 1.21% for the 'K 43' variety). This indicates the high efficiency of winter rye as a source of easily degradable biomass, which contributes to the activation of humus-forming processes. The application of manure also provided a significant increase in humus content (1.11% and 1.16%, respectively), which is associated with its complex effect on the physical and biochemical properties of the soil. The use of crushed cotton stalks led to an increase in humus content compared to the control (1.28% and 1.05%), but the effect was less pronounced, which is probably due to the slower mineralisation of coarse plant residues.

The total nitrogen content in the soil increased in all variants with the use of organic fertilisers. The highest values were observed in variants with manure and green manure, which reflects the active involvement of nitrogen in the biological cycle and improved nitrogen nutrition of plants. The application of cotton plant residues also contributed to nitrogen accumulation, but to a lesser extent, which may be due to the temporary immobilisation of nitrogen by microorganisms during the decomposition of organic matter. Analysis of gross phosphorus showed that its highest accumulation was characteristic of the variant with manure application (0.264% for 'Fergana-3' and 0.26% for 'K 43'), which is due to the supply of phosphorus in available and organically bound forms. The variants with green manure and cotton stalks also provided an increase in phosphorus content compared to the control, which indicates the role of organic matter in the mobilisation of soil phosphorus compounds. Changes in gross potassium content were less pronounced, but the use of green manure crops contributed to an increase in its content, especially in the 'K 43' variety (2.375%). This may be due to the biological mobilisation of potassium from poorly soluble compounds under the influence of root exudates from green manure crops and the activation of soil microflora.

The results obtained convincingly demonstrate the need for the systematic return of organic matter to the soil when cultivating cotton. One of the key problems of modern cotton growing in the region is the practice of completely removing above-ground phytomass after harvesting. After cotton harvesting, stems, leaves and bolls are traditionally removed from the field and used for economic purposes, which significantly limits the amount of plant residues entering the soil. Along with the above-ground part, a significant part of the root system is removed from the arable layer, as a result of which only a small amount of cotton roots remain in the soil. This practice leads to a sharp reduction in the return of organic matter and the formation of conditions for accelerated humus mineralisation. As noted by C. Bednarz *et al.* (2000), the use of manure in cotton cultivation contributes to an increase in organic carbon content and improvement of the water-resistant structure of the soil, which has a positive effect on plant productivity. M. Elms *et al.* (2001) note that organic fertilisers have a complex effect, combining direct plant nutrition with the activation of soil microflora and increased availability of phosphorus and potassium.

The data obtained in this study confirm that with the existing cotton cultivation technology, the supply of fresh organic matter to the soil remains minimal, which negatively affects fertility indicators. S. Liu *et al.* (2013) showed that with cotton monoculture and the absence of organic fertilisers, the intensity of organic matter mineralisation exceeds its supply, leading to degradation of the arable horizon. D. Saini *et al.* (2023) point out that the lack of plant residues in the farming system is

accompanied by a decrease in microbiological activity and deterioration of soil structure, especially under irrigation conditions. In addition, in the cotton-growing regions of southern Kyrgyzstan, the fertilisation system in a number of farms is characterised by a predominance of mineral fertilisers with the dominant use of nitrogen forms and limited or complete absence of organic plant nutrient sources. This one-sided approach to mineral nutrition leads to an imbalance of nutrients in the soil and accelerates the degradation of irrigated arable land. As noted by Y. Yang *et al.* (2014), the prolonged use of predominantly nitrogen fertilisers without compensation for organic matter contributes to a decrease in humus content, deterioration of soil structure and an increase in soil density. According to G. Yang *et al.* (2012), excess mineral nitrogen under irrigation conditions enhances the mineralisation of organic matter and reduces soil biological activity, which negatively affects the sustainability of agroecosystems. Similar conclusions are presented in the work of J. Zhang & F. Zhang (2024), which shows that the unbalanced use of mineral fertilisers in cotton cultivation is accompanied by a deterioration in the physicochemical and microbiological properties of serozems. As a result, conditions are created for an increase in the environmental load on irrigated agricultural landscapes and a decrease in the long-term productivity of cotton crops.

The increase in humus content observed in this study when manure and green manure are applied confirms the key role of organic carbon sources in stabilising the humus status of serozems, as previously reported by W. Lu *et al.* (2025). In particular, the authors noted that the systematic application of organic fertilisers in irrigated agriculture compensates for the loss of organic matter resulting from intensive mineralisation. The high efficiency of green manure crops in humus accumulation is consistent with the results of studies by I. Rochester (2011), which showed that cereal green manure crops incorporated during the active growth phase form a significant influx of easily degradable organic matter and stimulate the microbiological processes of humus formation. M. Saleem *et al.* (2010) emphasise that green manure crops are particularly effective on soils with an initially low organic matter content, which includes the typical serozems of southern Kyrgyzstan.

The increase in total nitrogen content in the manure and green manure variants is consistent with the findings of B. Huang *et al.* (2023), according to which organic fertilisers contribute not only to the direct supply of nitrogen but also to the activation of soil microflora, which ensures its more uniform incorporation into the biological cycle. The authors showed that the use of microbial organic fertilisers significantly enhances the metabolism of rhizosphere microorganisms, promotes the absorption of nutrients by roots and the colonisation of beneficial microbial communities, which ultimately improves the microbiological health of the soil. The higher responsiveness of the 'K 43' variety to nitrogen observed in this study is also consistent with the observations of S. Neemisha & N. Rani (2022), which indicate varietal differences in the use of organically bound nitrogen. The data obtained on gross phosphorus confirm the conclusions of J. Ping *et al.* (2004), according to which manure is one of the most effective sources of phosphorus in cotton cultivation, providing it in available and organically bound forms. The changes in potassium content recorded in the green manure variants are consistent with the data of A. Sparta *et al.* (2025), indicating the ability of green manure crops to activate the release of potassium from poorly soluble soil minerals. This is especially important for serozems, where potassium is often present in poorly available forms.

Increasing and maintaining soil fertility is considered one of the key factors for sustainable growth in cotton yields in irrigated agriculture. According to a number of researchers, the efficiency of cotton production is largely determined by the balance of organic matter in the soil, which is formed under the influence of fertilisation systems and agricultural techniques (Hulugalle, 2005). Insufficient supply of organic residues leads to accelerated humus mineralisation and a decrease in soil productivity. Serozems in arid regions are characterised by an initially low organic matter content and high sensitivity to degradation processes under intensive use. Research by K. Macnunlu *et al.* (2025) shows that in arid climates and under irrigation, a reduction in the proportion of organic fertilisers in the farming system is accompanied by a deterioration in the agrophysical properties of the soil, an increase in its density and a decrease in its water-holding capacity.

Thus, the results of this study confirm and complement existing scientific ideas about the positive effect of organic fertilisers and green manure crops on the agrochemical fertility of soils. The data obtained indicate the advisability of the comprehensive use of manure, green manure and cotton plant residues as the basis for a sustainable farming system in cotton-growing areas in the south of the Kyrgyz Republic.

Conclusions

The studies conducted have shown that the systematic use of organic fertilisers has a pronounced positive effect on the agrochemical condition of typical serozems and cotton productivity in irrigated agriculture in the south of the Kyrgyz Republic. It has been established that the application of organic nutrients contributes to an increase in the content of humus, total nitrogen, phosphorus and potassium in the soil, thereby creating more favourable conditions for the growth and development of cotton plants. The highest efficiency was recorded when manure was applied at a dose of 30 t/ha, which ensured the maximum improvement in soil fertility indicators and the greatest increase in raw cotton yield. The yield increase reached 107.2% for the 'Fergana-3'

variety and 98.3% for the 'K 43' variety, which indicates the high agronomic value of this technique. Manure proved to be a multifunctional organic fertiliser, providing not only nutrients, but also improving the physical condition of the soil and activating biological processes.

The use of green manure crops (winter rye) also showed high efficiency, ensuring a sustainable increase in cotton yields (up to 73.8%) and a significant accumulation of humus and total nitrogen in the soil. This confirms the advisability of using green manure as an environmentally friendly and resource-saving method of increasing the fertility of serozems, especially in conditions of a shortage of organic fertilisers of animal origin. The use of chopped cotton stalks (guzapai) provided a smaller but stable positive effect, increasing yields by 50-59%. Returning plant residues to the soil contributes to the partial replenishment of organic matter and the formation of a closed cycle of substances in the agricultural system, which is especially important when farm resources are limited. Both cotton varieties studied responded positively to the application of organic fertilisers. At the same time, the 'K 43' variety was characterised by a higher absolute yield, while the 'Fergana-3' variety showed a more pronounced response to organic methods in relative terms. The results confirm that restoring and maintaining soil fertility is impossible without the systematic return of organic matter, especially in conditions of prolonged cotton monoculture and increasing soil degradation processes. Prospects for further research are related to the study of the long-term impact of organic fertilisers and green manure crops on soil biological activity, carbon and nutrient balance, as well as the assessment of the economic efficiency of various organic farming systems in cotton production, taking into account climate change.

Acknowledgements

The authors express their sincere gratitude to the management of the Kyrgyz National Agrarian University named after K.I. Skryabin for their organisational support and creation of favourable conditions for conducting research.

Funding

This work was made possible thanks to funding and technical support from the Kyrgyz National Agrarian University named after K.I. Skryabin.

Conflict of Interest

The authors declare that there is no conflict of interest that could influence the interpretation of the research results or the presentation of data in this article.

References

[1] Bednarz, C.W., Bridges, D.C., & Brown, S.M. (2000). Analysis of cotton yield stability across population densities. *Agronomy Journal*, 92(1), 128-135. doi: 10.2134/agronj2000.921128x.

[2] Cheng, M., Wang, H., Fan, J., Zhang, S., Wang, Y., Li, Y., Sun, X., Yang, L., & Zhang, F. (2021). Water productivity and seed cotton yield in response to deficit irrigation: A global meta-analysis. *Agricultural Water Management*, 255, article number 107027. doi: 10.1016/j.agwat.2021.107027.

[3] Convention on Biological Diversity (CBD). (1992, May). Retrieved from https://www.cbd.int/.

[4] Elms, M.K., Green, C.J., & Johnson, P.N. (2001). Variability of cotton yield and quality. *Communications in Soil Science and Plant Analysis*, 32(3-4), 351-368. doi: 10.1081/CSS-100103012.

[5] GOST 17.4.4.02-84. (1986). *Environmental protection. Soils. Methods of sampling and preparing samples for chemical, bacteriological, and helminthological analysis*. Retrieved from https://surl.li/qxtlku.

[6] GOST 26107-84. (1985). *Soils. Methods for determining total nitrogen*. Retrieved from https://surl.li/vdrzwa.

[7] GOST 26205-91. (1993). *Soils. Determination of mobile phosphorus and potassium compounds using the Machigin method as modified by the Central Institute of Agrochemistry (CINAO)*. Retrieved from https://surl.li/anucfj.

[8] GOST 26213-91. (1993). *Soils. Methods for determining organic matter*. Retrieved from https://meganorm.ru/Index2/1/4294828/4294828267.htm.

[9] Huang, B., Chen, Y., Pei, Z., Jiang, L., Zhang, Y., Wang, J., & Wang, J. (2023). Application of microbial organic fertilisers promotes the utilisation of nutrients and restoration of microbial community structure and function in rhizosphere soils after dazomet fumigation. *Frontiers in Microbiology*, 13, article number 1122611. doi: 10.3389/fmicb.2022.1122611.

[10] Hulugalle, N.R. (2005). Recovering leached N by sowing wheat after irrigated cotton in a Vertisol. *Journal of Sustainable Agriculture*, 27(2), 39-51. doi: 10.1300/J064v27n02_04.

[11] Isaev, S., Khasanov, S., Ashirov, Y., Karabaeva, T., & Gofirov, A. (2021). Effect of water and resource saving technologies of cotton growing on cotton yield. *E3S Web of Conferences*, 244, article number 02012. doi: 10.1051/e3sconf/202124402012.

[12] Liu, S.M., Constable, G.A., Reid, P.E., Stiller, W.N., & Cullis, B.R. (2013). The interaction between breeding and crop management in improved cotton yield. *Field Crops Research*, 148, 49-60. doi: 10.1016/j.fcr.2013.04.006.

[13] Lu, W., Zhou, Y., Ma, X., Gao, J., Guo, J., Fan, X., Xing, W., Gao, W., Lin, M., & Wang, R. (2025). Impacts of organic fertiliser substitution on soil ecosystem functions: Synergistic effects of nutrients, enzyme activities, and microbial communities. *Agronomy*, 15(12), article number 2798. doi: 10.3390/agronomy15122798.

[14] Ma, F., Wang, Y., Yan, P., Wei, F., Duan, Z., Yang, Z., & Liu, J. (2021). Effect of cotton residues incorporation on soil properties, organic nitrogen fractions, and nitrogen-mineralising enzyme activity under long-term continuous cotton cropping. *PeerJ*, 9, article number e11053. doi: 10.7717/peerj.11053.
[15] Macnunlu, K., Hasanova Baba-zade, R., & Hasanova, T. (2025). Ecological sustainability of agroecosystem and productivity assessment in the Barda area using NDVI and SAVI. *Advances in Biology & Earth Sciences*, 10(1), 148-157. doi: 10.62476/abes.101148.
[16] Makhkamova, A., & Kamilov, B. (2023). Importance of humine preparation and organic fertilisers in improving the fertility of eroded typical grey soils. *E3S Web of Conferences*, 376, article number 02015. doi: 10.1051/e3sconf/202337602015.
[17] Neemisha, S., & Rani, N. (2022). Rejuvenating soil health using organic manures for sustainable agriculture. In H.B. Singh & A. Vaishnav (Eds.), *New and future developments in microbial biotechnology and bioengineering* (pp. 181-198). Amsterdam: Elsevier. doi: 10.1016/B978-0-323-85579-2.00014-9.
[18] Oruj, H.A., Vidadi, H.N., Firuddin, G.R., Nabil, O.R., & Mamadbagir, H.A. (2021). Composition and amount of nutrients entering the soil with cotton biomass and green manure. *Turkish Journal of Computer and Mathematics Education*, 12(2), 3127-3129.
[19] Ping, J.L., Green, C.J., Bronson, K.F., Zartman, R.E., & Dobermann, A. (2004). Identification of relationships between cotton yield, quality, and soil properties. *Agronomy Journal*, 96(6), 1588-1597. doi: 10.2134/agronj2004.1588.
[20] Rochester, I.J. (2011). Assessing internal crop nitrogen use efficiency in high-yielding irrigated cotton. *Nutrient Cycling in Agroecosystems*, 90, 147-156. doi: 10.1007/s10705-010-9418-9.
[21] Saini, D.K., Impa, S.M., McCallister, D., Patil, G.B., Abidi, N., Ritchie, G., Jaconis, S.Y., & Jagadish, K.S.V. (2023). High day and night temperatures impact on cotton yield and quality – current status and future research direction. *Journal of Cotton Research*, 6, article number 16. doi: 10.1186/s42397-023-00154-x.
[22] Saleem, M.F., Bilal, M.F., Awais, M., Shahid, M.Q., & Anjum, S.A. (2010). Effect of nitrogen on seed cotton yield and fibre qualities of cotton (*Gossypium hirsutum* L.) cultivars. *Journal of Animal & Plant Sciences*, 20(1), 23-27.
[23] Sparta, A., Hamdani, J.S., Yuwariah, Y., & Wulandari, E. (2025). Effects of *Tithonia diversifolia* biomass soil amendments on three annual crops (peanut, maize and soybean) grown in succession in an intercropping system with bananas in Ultisol. *Biological Agriculture & Horticulture*, 41(1), 65-78. doi: 10.1080/01448765.2024.2438378.
[24] Wei, X., Qin, D., Yin, Z., Wang, G., Li, L., Feng, L., & Xu, Q. (2025). Evaluating the impact of green manure incorporation on cotton yield, soil fertility, and net eco-economic benefits. *Agronomy*, 15(3), article number 559. doi: 10.3390/agronomy15030559.
[25] Yang, G., Tang, H., Tong, J., Nie, Y., & Zhang, X. (2012). Effect of fertilisation frequency on cotton yield and biomass accumulation. *Field Crops Research*, 125, 161-166. doi: 10.1016/j.fcr.2011.08.008.
[26] Yang, Y., Yang, Y., Han, S., Macadam, I., & Liu, D.L. (2014). Prediction of cotton yield and water demand under climate change and future adaptation measures. *Agricultural Water Management*, 144, 42-53. doi: 10.1016/j.agwat.2014.06.001.
[27] Zhang, J., & Zhang, F. (2024). Cotton grown in rotation with soybean alters soil organic matter over time. *Eurasian Soil Science*, 57(10), 1688-1697. doi: 10.1134/S1064229324600611.
[28] Zhi, X.Y., Han, Y.C., Li, Y.B., Wang, G.P., Du, W.L., Li, X.X., Mao, S.C., & Feng, L. (2016). Effects of plant density on cotton yield components and quality. *Journal of Integrative Agriculture*, 15(7), 1469-1479. doi: 10.1016/S2095-3119(15)61174-1.

Типтүү боз топурактардын күрдүүлүгүн жана пахтанын түшүмүн жогорулатууда органикалык заттар менен сидераттардын ролу

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Аннотация. Топурактын деградациясы жана пахтаны интенсивдүү өстүрүүдөн улам органикалык заттардын азайышы шартында топурактын асылдуулугун калыбына келтирүүнүн жана түшүмдүүлүгүн жогорулатуунун экологиялык жактан туруктуу жолдорун издөө өзгөчө актуалдуу. Бул изилдөөнүн максаты ар кандай органикалык жер семирткичтердин жана жашыл кык өсүмдүктөрүнүн Кыргыз Республикасынын түштүк аймактарындагы типтүү сиерозем топурактарынын асылдуулугуна жана пахтанын түшүмдүүлүгүнө тийгизген таасирин баалоо болгон. Талаа изилдөөлөрү эки пахта сорту, ‘Фергана-3’ жана ‘К 43’ менен жүргүзүлдү, анын ичинде кык, кышкы кара буудайды жашыл кык катары колдонуу жана майдаланган пахта сабактарын (гуза-пай) колдонуу. Жыйынтыктар топурактын агрохимиялык параметрлеринин бир кыйла жакшырганын көрсөттү, бул гумустун, жалпы азоттун, жалпы фосфордун жана калийдин курамынын жогорулашынан көрүндү. Түшүмдүүлүктү жогорулатуунун эң натыйжалуу ыкмасы кыкты гектарына 30 т өлчөмүндө чачуу болду, натыйжада ‘Фергана-3’ сорту үчүн түшүмдүүлүк 107,2 %га чейин жана ‘К 43’ сорту үчүн 98,3 %га чейин жогорулады. Жашыл кыкты колдонуу да түшүмдүүлүктүн бир кыйла жогорулашына (73,8 %га чейин) жана топуракта органикалык заттардын жана азык заттардын топтолушуна салым кошту. Майдаланган пахта сабактарын колдонуу оң, бирок анча байкалбаган таасир тийгизип, түшүмдүүлүктү 50-59 %га жогорулатты. Эки сорт тең органикалык жер семирткичтерди колдонууга жакшы жооп берери, ал эми ‘К 43’ сорту жогорку абсолюттук түшүмдүүлүктү көрсөтөрү аныкталды. Жыйынтыктар Түштүк Кыргызстандын пахта өндүрүүсүндө органикалык жер семирткичтерди жана топуракты үнөмдөөчү технологияларды системалуу түрдө колдонуунун мүмкүнчүлүгүн тастыктайт жана пахта өндүрүүнүн экологиялык туруктуулугун жана экономикалык натыйжалуулугун жогорулатууга багытталган натыйжалуу айыл чарба сунуштарын иштеп чыгуу үчүн практикалык мааниге ээ

Негизги сөздөр: органикалык жер семирткичтер; кык; кышкы кара буудай; топурактын асылдуулугу; туруктуу айыл чарбасы

Роль органического вещества и сидератов в повышении плодородия типичных сероземов и урожайности хлопчатника

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Аннотация. В условиях деградации почв и снижения их органического вещества при интенсивном возделывании хлопчатника особую актуальность приобретает поиск экологически устойчивых способов восстановления плодородия почв и повышения урожайности сельскохозяйственных культур. Целью настоящего исследования являлась оценка влияния различных органических удобрений и сидератов на показатели плодородия типичных сероземов южных регионов Кыргызской Республики и урожайность хлопчатника. Проведены полевые исследования с двумя сортами хлопчатника – ‘Фергана-3’ и ‘К 43’, включающие применение навоза, озимой ржи в качестве сидерата и измельченных стеблей хлопчатника (гуза-паи). Результаты показали значительное улучшение агрохимических показателей почвы, выражающееся в увеличении содержания гумуса, общего азота, валового фосфора и калия. Наиболее эффективным приемом повышения урожайности оказалось внесение навоза в дозе 30 т/га, обеспечившее прибавку урожая до 107,2 % у сорта ‘Фергана-3’ и 98,3 % у сорта ‘К 43’. Применение сидератов также способствовало существенному росту урожайности (до 73,8 %) и накоплению органического вещества и элементов питания в почве. Использование измельченных стеблей хлопчатника оказало положительное, но менее выраженное воздействие, обеспечив увеличение урожая на 50-59 %. Установлено, что оба сорта положительно реагируют на внесение органических удобрений, при этом сорт ‘К 43’ характеризуется более высокой абсолютной продуктивностью. Полученные результаты подтверждают целесообразность систематического применения органических удобрений и почвосберегающих технологий в хлопководстве юга Кыргызстана и имеют практическую значимость для разработки эффективных агротехнических рекомендаций, направленных на повышение экологической устойчивости и экономической эффективности производства хлопка

Ключевые слова: органические удобрения; навоз; озимая рожь; плодородие почвы; устойчивое земледелие

Received: 03.10.2025. Revised: 12.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 634.21:664.844(292.53)

DOI: 10.63621/bknau./1.2026.63

Potential for apricot farming and processing in Central Asia

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Abstract. Apricot (*Prunus armeniaca* L.) remains one of the key fruits of temperate zones, with Central Asia serving as a major centre of its origin and genetic diversity. The study aimed to evaluate the economic potential of fresh and dried apricot production and trade worldwide, with a special focus on Central Asian countries, and to assess the efficiency of various drying technologies. Data from FAOSTAT, WITS, Tridge and WTO for 2020-2025, along with a systematic review of scientific literature on drying technologies (Scopus, Web of Science, etc.), were used; return on investment (ROI) and gross profit were calculated for traditional sun drying, convective, infrared and freeze-drying methods assuming an annual output of 50 tonnes of dried apricots. It was established that global apricot production reached approximately 4.5 million tonnes in 2024; Turkey, Uzbekistan and Iran remain the leading producers, but in 2025 catastrophic spring frosts in Turkey (particularly in Malatya province) reduced output, causing a sharp rise in global prices for fresh and dried apricots. In Central Asia, Uzbekistan (~526-540 thousand tonnes in 2024), Tajikistan (~313-348 thousand tonnes in 2024-2025) and Kyrgyzstan (~57 thousand tonnes in 2023-2024) demonstrate substantial export potential; Turkey exported dried apricots worth USD 404.5 million in 2024, yet regional suppliers (especially Uzbekistan and Tajikistan) gain competitive advantages in 2025. ROI calculations showed: sun drying – 7.3%, convective – 23.4%, infrared – 28.5%, freeze-drying – 33.9%; infrared and freeze-drying provide the highest product quality. The findings can be applied by farmers, processors and investors in Central Asia (primarily Kyrgyzstan) to select appropriate drying technologies, reduce post-harvest losses and access premium export markets (EU, USA, Russia)

Keywords: harvested area; yield; drying technology; equipment; return on investment; operating costs

Introduction

Central Asia represents a pivotal centre of origin and genetic diversity for apricots (*Prunus armeniaca* L.), providing an abundance of germplasm resources vital to global breeding and conservation initiatives. The region's agro-ecological zones support extensive apricot cultivation, making this fruit a cornerstone of rural

Suggested Citation: Tynarbekova, M., Smanalieva, J., & Henle, T. (2026). Potential for apricot farming and processing in Central Asia. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 63-76. doi: 10.63621/bknau./1.2026.63.

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livelihoods and agricultural income across Kyrgyzstan, Uzbekistan, and Tajikistan. However, the sector faces mounting challenges stemming from environmental degradation, climate variability, and institutional fragmentation following the collapse of collective farming systems in the early 1990s. F. Su *et al.* (2024) demonstrated that Central Asian countries, characterised by fragile ecosystems and less advanced agricultural infrastructure, are particularly vulnerable to climate change impacts on food security. A. Mirzabaev *et al.* (2023) identified land degradation as a critical barrier to poverty reduction across the region, threatening the sustainability of fruit production systems. These environmental pressures are compounded by socioeconomic constraints; A. Azarov *et al.* (2019) documented how smallholder farmers continue to struggle with market access, technological gaps, and resource limitations inherited from post-Soviet transitions. Despite these challenges, Y. Zhang *et al.* (2025) argued that Central Asia's abundant per-capita land resources present significant opportunities for achieving food self-sufficiency and contributing to global food security through strategic agroforestry development.

Apricots hold particular economic and nutritional importance in this context. The fruit is cultivated predominantly in regions characterised by warm, dry summers and cold winters, with mature trees yielding 22.5-90 kg annually depending on climatic conditions and management practices. Apricots provide essential dietary components including fibre, minerals (potassium, calcium, iron, magnesium), vitamins A and C, and B-complex vitamins (U.S. Department of Agriculture, 2022). A. Ahmed *et al.* (2020) highlighted the fruit's rich phytochemical profile, including antioxidants, carotenoids, and xanthophylls, whilst M. Al-Soufi *et al.* (2022) emphasised regular apricot consumption's role in chronic disease prevention. Beyond fresh consumption, apricot processing generates significant value-added opportunities. N. Karataş & M. Şengül (2020) described diverse utilisation pathways including drying, canning, and juice production. Apricot kernels and shells represent promising by-products; M. Kiralan *et al.* (2019) documented their applications in oil extraction, cosmetics, and benzaldehyde production, whilst recent research has explored their potential in activated carbon manufacturing.

The short shelf life of fresh apricots necessitates effective preservation technologies. Drying remains the most widely adopted method for extending storage duration and enabling year-round market access. Traditional sun drying dominates in Central Asia due to favourable climatic conditions and minimal capital requirements; however, this approach suffers from quality inconsistencies, hygiene concerns, and weather dependency. S. Kayran & İ. Doymaz (2021) noted that sulphur dioxide (SO_2) pre-treatment is commonly employed to preserve colour and inhibit microbial growth, yet M. Tynarbekova *et al.* (2025) emphasised growing consumer demand for organic, sulphur-free products, particularly in premium export markets.

This study aimed to analyse current global and Central Asian apricot production trends, evaluate the economic potential of fresh and dried apricot trade with particular attention to the 2025 Turkish frost crisis, and compare the techno-economic viability of traditional and modern drying technologies. The findings were intended to inform investment decisions and technology selection for processors and farmers in Central Asia, particularly Kyrgyzstan, to reduce post-harvest losses and access higher-value export markets.

Materials and Methods

This study employed a secondary data analysis approach combined with a comparative techno-economic evaluation of apricot drying technologies. All analyses focused on global and Central Asian apricot production and trade trends up to the most recent available years (primarily 2020-2025), with particular emphasis on the disruptive impact of the 2025 spring frost in Turkey. Production, yield, and harvested area data for fresh apricots worldwide and in selected Central Asian countries (Kyrgyzstan, Uzbekistan, Tajikistan) were retrieved from the FAOSTAT (n.d.) database. Export and import statistics for fresh and dried apricots in 2023-2024 were obtained from Tridge (n.d.), WTO (n.d.), and WITS (2024) reports. Data on the 2025 Turkish frost impact and resulting production collapse were compiled from industry reports and market analyses.

To review drying technologies and post-harvest loss reduction strategies, a systematic literature search was conducted in the following databases: Scopus, Web of Science, ScienceDirect, PubMed, Google Scholar, and Semantic Scholar. Keywords included "apricot drying", "dried apricot production", "infrared drying apricot", "freeze-drying fruit", "post-harvest losses apricot", "Central Asia", "Kyrgyzstan", "Uzbekistan", "Tajikistan", and "Turkey". Inclusion criteria limited publications to the period 2000-2025.

The economic comparison of drying methods was performed using a standardised scenario assuming an annual production target of 50 metric tonnes of dried apricots (equivalent to ~333 tonnes of fresh apricots at an average drying yield of 15%). Key assumptions included:

- purchase price of fresh apricots: USD 0.20 per kg (conservative regional average for smallholder supply in Central Asia);
- full capacity utilisation and 200 operating days per year;
- technology-specific selling prices for dried product reflecting quality differences (higher for infrared and freeze-dried apricots due to premium positioning);
- operating expenditures (OPEX) encompassing raw materials, energy/utilities, labour, packaging, logistics, and maintenance;

- capital expenditures (CAPEX) limited to drying equipment and basic processing infrastructure (sourced from 2025 equipment quotations and literature estimates).

Return on investment (ROI) was calculated using the formula (1):

$$ROI\ (\%) = (Annual\ net\ profit / CAPEX) \times 100, \quad (1)$$

where annual net profit = annual revenue – annual OPEX.

Gross profitability was defined as (Revenue – OPEX including depreciation)/Revenue.

All financial metrics exclude financing costs, taxes, land acquisition, detailed depreciation schedules, and inflation effects to ensure cross-technology comparability. Results represent indicative benchmarks and are sensitive to input price volatility, energy tariffs, and market access; project-specific feasibility studies are recommended prior to investment. Data processing and visualisation were carried out using Microsoft Excel. All monetary values are reported in United States dollars (USD) at the respective years' average exchange rates.

Results and Discussion

Key economic indicators for apricot production worldwide

Figure 1 shows an increasing tendency of apricot production worldwide from 2000 to 2024 according to the Food and Agriculture Organization (FAOSTAT, n.d.). Worldwide apricot production amounted to approximately 4.5 million t in 2024.

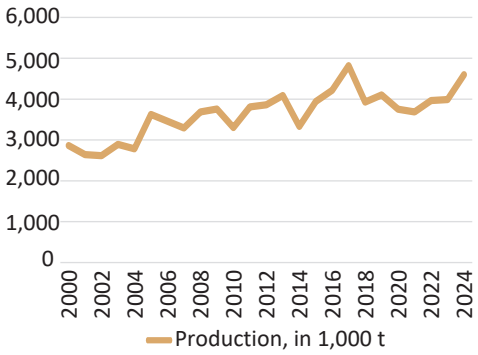

Figure 1. Production of apricots in world from 2000 to 2024

Source: compiled by the authors based on FAOSTAT (n.d.)

In 2022, apricot production remained relatively stable, with Turkey (639.67 thousand tonnes), Uzbekistan (347.47 thousand tonnes), and Iran (319.33 thousand tonnes) maintaining their positions as the world's leading producers (Fig. 2). Collectively, these countries dominated global output. By 2024, however, the production landscape had evolved, with Tajikistan and Greece gaining prominence among major apricot-producing nations.

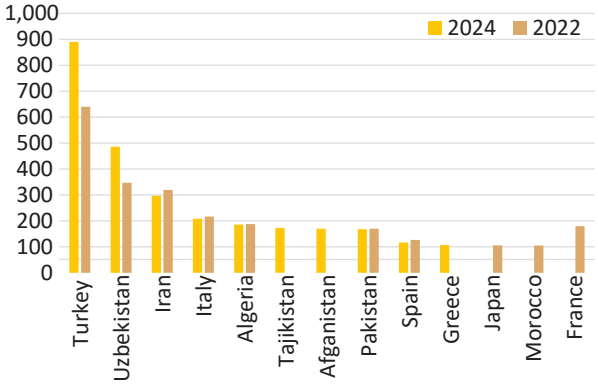

Figure 2. Top 10 countries in the world in terms of apricot production in the years 2022 and 2024

Source: compiled by the authors based on FAOSTAT (n.d.)

Turkey is the world's largest apricot producer, accounting for over half of global dried apricot output, with traditional production concentrated in Malatya and surrounding provinces. (Poyraz & Gül, 2022). According to A. Polat & O. Caliskan (2013), apricot cultivation is practised in almost all regions of Turkey, except the particularly humid areas surrounding the Black Sea and the high plateaus of the East Anatolian Region: Elazig, Kayseri, Kahramanmaras, Sivas, and Erzincan. In Turkey, the practice of farming regional cultivars, in conjunction with the introduction of foreign cultivars from Greece, France, Italy, Spain, and the USA, can extend the cropping season to May and June. However, apricot production in Turkey in 2025 has been highly unusual due to extreme weather conditions. Severe frosts in 2025 damaged Turkey's apricot harvest, leading to a sharp rise in prices for fresh, dried, and frozen apricots worldwide. Malatya Province, which accounts for 85% of Turkey's apricot production, was particularly hard hit. Nearly all 13 million trees were damaged during the flowering period. Projected apricot production fell from 750,000 tonnes in 2024 to just 10,000 tonnes in 2025 (Expana, 2025).

Global demand for dried apricots has increased notably in recent years, driven by consumer perception of their beneficial health properties. Key importing markets include the USA, Germany, France, Russia, and the United Kingdom, positioning dried apricots as a significant commodity in international trade (WTO, n.d.). In 2022, Turkey dominated global exports (Fig. 3). Export values demonstrated continued growth in 2023, reflecting sustained demand across major consumer markets and the premium positioning of dried apricots in the health food sector. According to WTO (n.d.), in 2022, Turkey was the leading exporter, with export values exceeding USD 400 million. On the demand side, the main importing countries were the United States (USD 64.2 million), Germany (USD 38.6 million), France (USD 36.2 million), Russia (USD 30.5 million), and the United Kingdom (USD 25.3 million),

indicating that demand was concentrated in large consumer and high-income markets. Kyrgyzstan was also ranked 12th in dried apricot exports, with USD 2.67 million in export value. Table 1 shows the global export performance of dried apricots in 2024 according to WITS (2024). The consistency between the major importing countries identified in 2022 and the export expansion observed in 2024 suggests stable international demand. By 2024, Turkey further reinforced its dominant position, exporting USD 404.5 million worth of dried apricots with a volume of approximately 76,439 tonnes. This increase in export value and substantial shipment volume underscore Turkey's continued comparative advantage and scale efficiency. Other exporters remained comparatively minor participants (WITS, 2024).

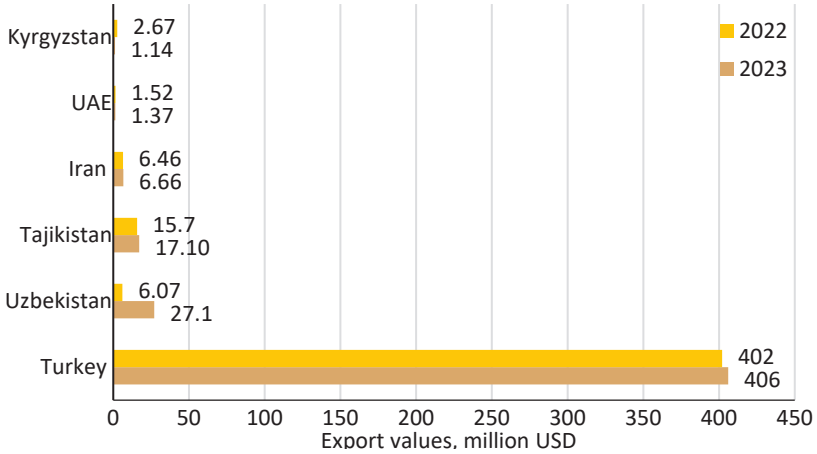

Figure 3. Dried apricot exports worldwide in 2022 and 2023, by leading countries
Source: compiled by the authors based on WTO (n.d.)

Table 1. Global trade in dried apricots: Leading exporters

Country/region	Export value (USD thousand)	Export volume (kg)	Unit price (USD/kg)
Turkey	404,491.37	76,439,100	5.30
Uzbekistan	17,514.57	11,264,500	1.55
France	15,678.09	2,137,120	7.33
Germany	12,357.97	1,826,590	6.77
European Union	12,218.93	1,538,160	7.94

Source: compiled by the authors based on WITS (2024)

Overall, the data show a market characterised by extreme supply-side concentration, with Turkey accounting for the vast majority of global exports in both value and volume terms with an average unit price of USD 5.30/kg. Uzbekistan follows as the second top exporter in 2024 with the lowest unit price. France, Germany, and the European Union stand out, with significantly smaller volumes but higher unit prices in some cases (France: USD 7.33/kg, EU: USD 7.94/kg). The data indicate that while Turkey leads in scale, European exporters capture higher per-unit value, reflecting product differentiation and access to premium markets.

Key economic indicators for apricot production in Central Asia

Figure 4 shows the production volume (a) and harvested area (b) of apricots in Central Asian countries compared to those in Turkey, according to the FAO in 2024 (FAOSTAT, n.d.).

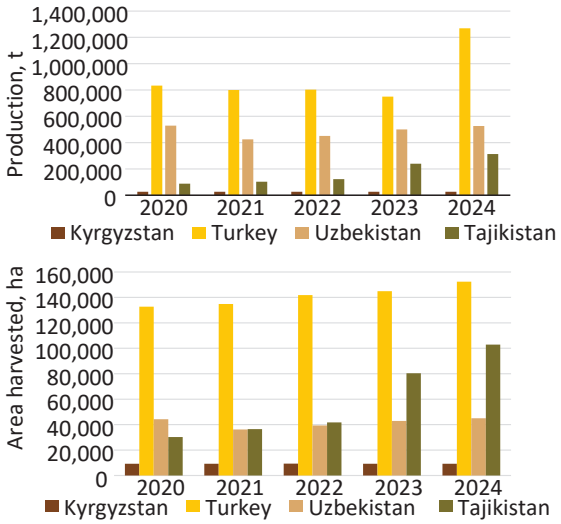

Figure 4. Production quantity (a), harvested area (b) of apricots in Central Asian countries
Source: compiled by the authors based on FAOSTAT (n.d.)

The apricot yield in Uzbekistan is substantially higher than in Kyrgyzstan, Tajikistan, and Turkey. This is probably due to regional cultivars and traditional experience as well as modern agricultural technology, such as effective water management, which is used in Uzbekistan. Climate factors disrupt flower bud dormancy, leading to floral anomalies (Polat & Caliskan, 2013). Thus, environmental conditions and cultivation practices remain critical factors in determining the stability of apricot yields across the region.

Uzbekistan. Uzbekistan is one of the most significant apricot-producing countries in Central Asia, with extensive apricot orchards in the Fergana and Zaraf-shan valleys. Apricot orchards constitute approximately 70-80% of orchard land in key producing regions. The combination of a longer summer, high temperatures, and low relative humidity creates optimal conditions for apricot drying (Mirzaeva & Makhmudova, 2020). The country's apricot production plays a pivotal role in its agricultural sector, providing both domestic consumption and export opportunities. Uzbekistan cultivates a diverse range of apricot cultivars for both fresh consumption and processing. According to FAOSTAT (n.d.), apricot production in Uzbekistan amounted to 529,109 t in 2020 and 526,693 t in 2024. The decline in production was attributed to adverse weather conditions in 2022. Thus, Uzbekistan ranked second globally in apricot exports, behind only Spain, which supplied 96,000 t of fresh apricots to foreign markets in 2020. In 2020, for the first time, Uzbekistan surpassed even Turkey in the export volume of fresh apricots (EastFruit, 2022a). In 2024 Uzbekistan ranked second among the largest exporters (Table 1). In Uzbekistan, farmers have recently begun implementing innovative technologies, such as drip irrigation and the cultivation of dwarf apricot varieties, which are now bearing fruit (Figs. 5, 6).

Figure 5. Farmers' practices in cultivating apricots in Uzbekistan

Note: water consumption unit for drip irrigation, underground water is extracted through a well from a depth of 180 meters, Pap district of Namangan region, Uzbekistan, April 2024

Source: photo by the authors

The yield of dwarf apricot orchards is 10 t of ripe apricots per ha. Harvesting begins on May 1 or 2, and fresh apricots are sold for USD 3 per kilogram. According to EastFruit (2022b), the main importers of fruit and vegetables from Uzbekistan are Russia (42.5%), Kazakhstan (18.9%), China (9.1%), and Pakistan (8.8%).

Figure 6. Orchard featuring dwarf varieties of apricot trees

Note: Pap district of Namangan region, Uzbekistan, April 2024. The illustration shows new varieties of dwarf apricots and their cultivation practices; these apricot varieties were ready for harvest as early as May 1st, 2024

Source: photo by the authors

Kyrgyzstan. The fruit processing industry is a priority, export-oriented sector in Kyrgyzstan's agro-industrial economy. According to Programme for the Development… (2017), the industry's production capacity is based on 27 industrial enterprises and more than 300 mini-workshops. In 2022, up to 425,517 t and in 2025 of fruit and berries were produced in the country. Apricots are the second most important fruit after apples. The high export potential of this industry enables increases of up to 20% in fruit and vegetable exports annually (FAOSTAT, n.d.). According to Tridge (n.d.), fresh apricot production in Kyrgyzstan has fluctuated between 20,000 and 30,000 t over the past decade, ranking 29th globally. About 20% of apricots in Kyrgyzstan are consumed fresh, and about 55% are dried. Less than 1% of the total crop is processed into jams and nectar. From a young age, apricot trees yield 31-40 kg per tree (Ergashova, 2018). According to FAOSTAT (n.d.), fresh apricot production in Kyrgyzstan has remained relatively stable in recent years, amounting to approximately 26,067 tonnes in 2022 and 26,849 tonnes in 2023. Yield averaged around 4,000-5,000 kg per ha, depending on regional conditions and orchard management (with harvested area typically exceeding 8,000 ha). Apricot plantations in 2025 are estimated to cover more than 8,329 ha in Kyrgyzstan (FAOSTAT, n.d.). More than 80% of them is located in the country's southwest, in Batken (Kadyrov, 2023). The Batken region has a hot climate; therefore, it is renowned for its sweet apricots. In Kyrgyzstan, apricots are also grown in the Jalal-Abad, Osh, and Issyk-Kul regions. The Issyk-Kul region, in northern Kyrgyzstan, is a notable area for apricot cultivation. In this region, apricots mostly ripen in late summer and early autumn, extending the fresh apricot season.

Only a few manufacturers produce dried fruit and vegetables in Kyrgyzstan. Most dried fruit and vegetables are produced by individual entrepreneurs using sun drying. Kyrgyz companies have limited financial resources and therefore prefer to use solar energy. According to trade data for 2024, key export markets for Kyrgyz dried apricots include Russia (USD 991 thousand), the United States (USD 73.7 thousand), Kazakhstan (USD 24.8 thousand), Iraq (USD 18.2 thousand), China (USD 16.5 thousand), and Uzbekistan (USD 11.0 thousand) (OEC, n.d.). The share of fruit and vegetable processing in the republic remains low, not exceeding 13-14%. Generally, Kyrgyzstan exports more fresh fruit and vegetables than processed goods. Among Central Asian countries, Kyrgyzstan has the smallest harvested area of apricot orchards; nevertheless, Kyrgyz farmers have periodically ranked among the top exporters of dried apricots in the region.

The authors' assessment of Kyrgyzstan's fruit processing sector reveals substantial transformation over the past three decades. Historically, the main challenges included an outdated technical base and processing technologies, insufficient financial resources for enterprises, and underdeveloped storage, transportation, and logistics infrastructure. More recently, however, new large and small workshops equipped with modern machinery, as well as the first fruit logistics centres, have been established across the country. Enterprises in Kyrgyzstan have been increasingly investing in the processing of apricots into value-added products, such as apricot jam, apricot nectar, and apricot oil. These processed apricot products are not only sold domestically but are also exported to international markets. Nevertheless, limited human capacity and the seasonal nature of work continue to constrain production volume expansion. Although enterprises in the industry cannot compete with neighbouring countries in the volume of conventionally dried apricots, they possess competitive advantages in producing organic, sulphur-free, and freeze-dried apricots, which offer higher nutritional value and command higher prices.

Tajikistan. Apricots account for a significant share of Tajikistan fruit production, often alongside apples and grapes as leading crops by harvested tonnage (Qureshi, 2022; Murzakulova, 2024). This country has a strong tradition of apricot cultivation, and dried apricots are considered a form of alternative currency (EastFruit, 2020). According to trade data for 2025, the country has established approximately 100,000 hectares of apricot orchards (FAOSTAT, n.d.). The main apricot orchards in Tajikistan are located in the Sughd, Zeravshan, Khatlon, and Gissar valleys, as well as in mountainous regions. The Ashat district of the Sughd region is a well-known fruit-producing region in Tajikistan. There are 16,018 ha of apricot orchards in this area, in which up to 3 t of apricots are harvested from each hectare (CentralAsia, 2017). However, in Tajikistan, prices in 2023 were USD 0.79-1.06 per kg, i.e., 3-5 times lower than in Uzbekistan. In addition to a good harvest, another factor affecting apricot prices in Tajikistan is the complete closure of the border with Kyrgyzstan, through which exports are usually conducted.

Apricots make up a significant portion of the total fruit production, with 63.5% contributed by farmers, 25.1% by the general population, and 11.4% by public enterprises. According to FAOSTAT (n.d.) data for 2025, apricot production in Tajikistan has shown strong growth: the total apricot production in 2020 was 87,671 tonnes, in 2024 – 313,052 tonnes, this is due to the significant growth of the apricot orchard areas from 30,238 ha to 102,928 ha. Estimates for 2025 suggest that total apricot output reached 348,000 tonnes, representing an increase of more than 24% compared to previous years (Asia-Plus, 2025). According to TAJSTAT (n.d.), 20 small- and medium-sized enterprises are engaged in dried fruit processing and packaging. In 2023, these enterprises produced 3,642 tonnes of products, including 293 tonnes of apricots, 29 tonnes of prunes, 104.6 tonnes of dried apples, 1,663.6 tonnes of assorted dried fruit, 160.9 tonnes of rosehips, and 1,219.5 tonnes of dried apricots. The fruit harvest in Tajikistan was higher in 2024 than in 2020, and prices have increased by 20-100%. Dried apricots continued to be the leading exported product; core enterprises comprised the majority of exports, totalling 20,854 tonnes in 2022, valued at USD 15.119 million, and increasing to USD 17.2 million in 2024 (OEC, n.d.). About 45% of fruit exports go to Russia, followed by Kazakhstan and Iraq (Qureshi, 2022). The main consumers of Tajik dried fruit in 2024 were Kazakhstan, Turkey, Azerbaijan, Ukraine, and Poland.

While production volumes have been rising, labour shortages – especially during peak harvest seasons – have become a concern in some apricot-growing districts due to out-migration and workforce constraints. Price fluctuations and market access can influence farmer profitability, as local markets sometimes absorb large harvests at low prices. Enhanced processing (e.g., dried fruit production), improved logistics, and export market diversification are key opportunities to strengthen the sector's economic performance (EastFruit, 2023). In conclusion, Tajikistan is one of the leading apricot producers in Central Asia, benefiting from favourable agro-climatic conditions, extensive orchard areas, and a strong tradition of dried apricot production for export. Apricots play a strategic role in rural livelihoods and agro-exports, with growing opportunities in value-added processing despite challenges related to labour and market volatility.

Analysis of apricot drying technologies

Drying, or dehydration, is the process of removing excess moisture from food to reduce microbial activity and spoilage (Arslan & Alibaş, 2024). Drying is used

to extend the shelf life of fruit and vegetables; as a result, the moisture content is reduced to below 20%. Typically, dried foods have a water activity of less than 0.06, which prevents microbial growth (Karabulut *et al.*, 2007; Akter *et al.*, 2022). In the production of dried apricots and other fruits, traditional (solar) drying, convective drying (hot air drying), freeze-drying, and infrared drying are used (Gao *et al.*, 2024). Pre-treatment significantly influences drying efficiency and final product quality. C. Ertekin *et al.* (2023) showed that sulphur dioxide (SO_2) treatment increases heat and mass transfer rates during drying by disintegrating the cellular matrix, whilst preserving the characteristic orange colour. However, growing demand for organic certification has prompted research into SO_2-free alternatives using natural acidulants and controlled atmosphere techniques.

Drying technologies play a pivotal role in realising the economic potential of apricot production in Central Asia, where fresh fruit has a very short shelf life and is highly susceptible to post-harvest losses (often exceeding 30-50% due to inadequate handling, weather exposure, and limited cold-chain infrastructure). Effective drying not only extends shelf life to 12-24 months, reduces moisture content below 20-25% to inhibit microbial growth, but also significantly enhances export competitiveness by enabling access to distant high-value markets (Russia, EU, USA, China) with stable demand for premium dried products. In Kyrgyzstan, Uzbekistan, and Tajikistan – countries with small to medium-scale orchards and seasonal surpluses – modernisation of drying practices (from traditional sun drying to infrared or freeze-drying) can substantially increase farmer incomes, reduce sulphur dioxide dependency for organic certification, improve product quality (colour, nutritional retention, and safety), and help capitalise on the post-2025 global supply gap caused by the Turkish frost crisis. Thus, the choice of drying method directly influences ROI, gross margins, and the overall contribution of the apricot sector to rural livelihoods and national export revenues in the region.

Sun drying. Natural sun drying in the open air is widely used in Central Asia and other countries with hot, and tropical climates. Food is exposed to sunlight for several days to remove moisture (Adeyeye *et al.*, 2022). With sun drying, according to İ. Toğrul & D. Pehlivan (2003), significant savings are achieved since the energy source is free and renewable. However, sun drying is a relatively slow process that can take several days or even weeks, resulting in substantial losses (Toğrul, 2005). Also, as mentioned by S. Vijayavenkataraman *et al.* (2012), insect infestations, enzymatic reactions, microbial growth, and mycotoxin development decrease the product quality. Traditional drying techniques of apricot involve manually removing the pit and collecting the fruit flesh on the ground in the garden or near the drying area. Fruit is laid out in inaccessible places, on flat stones, large boulders, and grass. During the drying process, fruit accumulates dust and becomes black, particularly when it rains (Hussain *et al.*, 2012). Figure 7 describes the traditional sun drying technology used in dried apricot production in Kyrgyzstan.

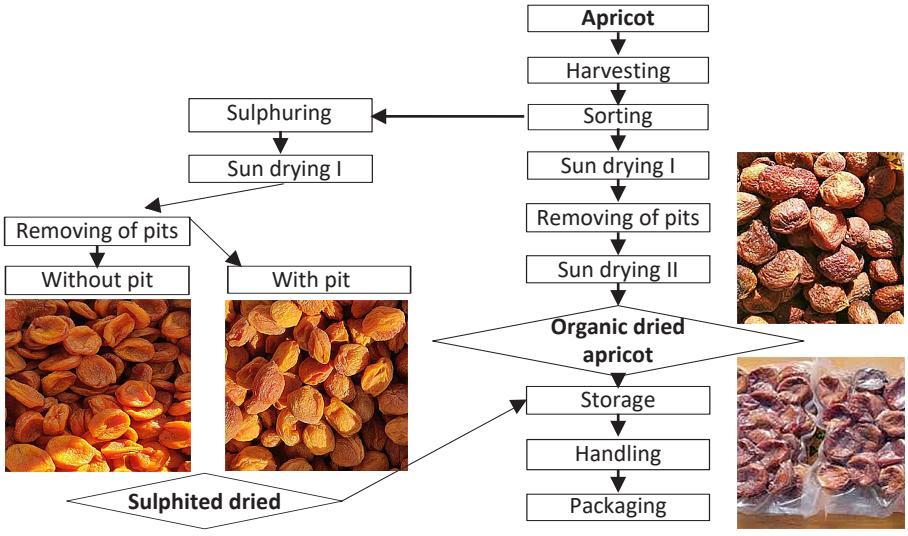

Figure 7. Home technology scheme for drying apricots

Source: created by the authors

According to farmers in Kyrgyzstan, there are two stages in the production of dried apricots. In the first stage, sulphur dioxide (SO_2) treatment of fresh apricots, which is known as sulphitation, preserves colour and prevents the growth of microbes that cause decay. As a result of sulphur dioxide treatment, apricots retain their natural reddish-yellow or intense orange colour with good stickiness during drying, processing, and storage (Elmaci *et al.*, 2008; Igual *et al.*, 2012). SO_2 fumigation is carried out in rooms of approximately 2.4 × 2.4 × 2.2 m dimensions; the duration of fumigation is about 8-12 h, and the average sulphur consumption in this process

is 1.6-1.8 kg/t of material. The second stage consists of two drying operations, in which the apricots are traditionally dried in the open air before and after pit removal. In addition to sun drying of apricots, shade drying and stem stacking methods are used in this region.

There are three terms used to describe dried apricots, depending on the presence of the pit. Kuraga is a dried, pitless half-apricot. Ashtak is a whole dried fruit from which the stone has been removed before drying and put back into the apricot. Kaisa is a whole dried apricot without a stone, which is removed through a recess at the stalk's point of attachment. The drying period varies with pit removal: 6-10 days for Kuraga, 13-17 days for Ashtak and 10-20 days for Kaisa. For export, apricot quality must meet specified standards and requirements. The United Nations Economic Commission for Europe (UNECE) developed the quality standards concerning the marketing and commercial quality control for fresh (FFV-02) and sun-dried apricots (DDP-15) (UNECE, 2017). According to this standard, the moisture content of untreated dried apricots should not exceed 25.0%. For dried apricots treated with preservatives or otherwise preserved (e.g., pasteurised), the moisture content should be above 25.0% but not exceed 40.0%. Products with a moisture content between 32.0 and 40.0% should be labelled as high moisture or an equivalent designation.

Hot air drying. Hot air drying (HAD) has several advantages over sun drying, including reduced microbial contamination, more controlled drying parameters, less adverse effects of weather conditions, shorter drying times, and lower labour costs (Karabulut *et al.*, 2007). Convective drying relies on heat transfer from a heated drying agent (air or a vapour-gas mixture) to the product. Conductive drying relies on heat transfer from a hot surface to the product being dried. HAD is a common method for drying foods, although it often yields a medium-quality product (Fig. 8).

Figure 8. Hot air-dryer used for apricot drying in Batken region, Kyrgyzstan, and dried apricot in hot air-drier (pre-treated with 1% citric acid solution)

Source: photo by the authors

The drying temperature and pre-treatment methods affect the colour and nutritional value of dried fruit. As stated by D. Nowak & E. Jakubczyk (2020), shrinkage is a notable example of such changes. The selection of chemicals, dipping temperature, time, and their concentrations has previously been described in the literature. Hot air flow is also recommended for desulphiting over-fumigated and dried apricots (Güçlü *et al.*, 2006). For apricots, a hot air circulating oven is recommended; however, depending on production capacity, manufacturer the cost of a hot air dryer for a daily input of 1,000 kg is USD 13,500-21,000 (Fruit and Vegetable Dryer, 2025).

Infrared drying. Infrared drying technology is used as an alternative drying method for many agricultural products. According to D. Zhang *et al.* (2023), during infrared drying, water molecules in wet materials directly absorb infrared radiation and convert it into thermal energy, thereby heating and drying the material. Infrared energy is transferred to the product surface from the heating element without heating the surrounding air, resulting in a high-quality final product and a stable drying temperature (Adak *et al.*, 2017; Ye *et al.*, 2021). Advantages of infrared drying: the material is heated directly, drying is fast, and it consumes significantly less energy than hot air convective drying (El-Mesery *et al.*, 2023). Infrared drying with a daily input capacity of 1,000 kg is USD 10,110.

Freeze-drying. Freeze-drying is the process of removing moisture from a frozen product under high vacuum conditions. This method is regarded as one of the most effective drying techniques for preserving vitamins and other bioactive components of dried foods. Conversely, freeze-drying has been identified as the costliest dehydration process, with the sublimation stage accounting for approximately 50% of the total energy consumption (Ratti, 2001). Freeze-drying is used to produce high-quality food powders and solids (Bhatta *et al.*, 2020). It is essential to select appropriate conditions for the freeze-drying process to ensure that the water does not melt (Fig. 9).

Figure 9. Freeze-dryer used for apricot drying (Namangan region, Uzbekistan) and freeze-dried apricots

Source: photo by the authors

However, freeze dryers are more expensive than hot air dryers, for example, freeze-dryer with a daily input capacity of 1,000 kg is USD 134,614-2,880,000 (KEMOLO, n.d.).

Comparison of different drying methods. Table 2 presents the return-on-investment (ROI) and gross profitability calculation for different drying methods for apricots with a volume of 50 tonnes of dried apricots per year. Traditional sun drying is characterised by very low capital expenditure (CAPEX), enabling small-scale entry, exhibits the lowest margin and a high vulnerability to price fluctuations. Convective drying requires moderate CAPEX and allows for industrial-scale production, with economically viable returns achievable provided that minimum market selling prices are met. Infrared (IR) drying involves slightly lower CAPEX and yields superior product quality, making it suitable for premium market segments. The exceptionally high ROI for infrared drying is primarily driven by very low capital expenditure assumptions and should be interpreted as an indicative upper-bound estimate. Freeze-drying is associated with very high CAPEX and elevated OPEX. Infrared and freeze-drying provide more stable gross margins; however, their economic viability depends on access to premium markets. Table 3 shows comparison of apricot drying technologies.

Table 2. Return-on-investment (ROI) and gross profitability calculation for different drying methods

Indicator	Sun drying	Hot air	Infrared	Freeze-drying
Selling price (USD/kg)	4.5	6.5	7.5	10.3
Annual revenue (USD)	225,000	325,000	375,000	515,000
Raw material cost (USD)	67,000	67,000	67,000	67,000
Energy + labour + packaging (USD)	140,000	180,000	200,000	260,000
CAPEX (USD)	15,000	21,000	10,110	134,614
Amortisation (10%) (USD)	1,500	2,100	1,011	13,461
Total OPEX (USD)	208,500	249,100	268,011	340,461
Net profit/year (USD)	16,500	75,900	106,989	174,539
ROI (%/year)	110%	361%	1,059%	130%
Simple payback	<1 year	<1 year	<1 year	~0.8 year
Gross profitability	7.3%	23.4%	28.5%	33.9%

Source: calculated by the authors

Table 3. Comparison of apricot drying technologies

Parameter	Traditional (sun drying)	Convective (hot air drying)	Infrared (IR) drying	Freeze-drying (lyophilisation)
Drying principle	Natural moisture evaporation using sun and wind	Heated air circulation (50-75°C)	Infrared radiation heats the water molecules	Freezing → vacuum → sublimation of ice
Capital expenditure (CAPEX)	Very low	Low-medium	Medium-high	Very high
Operating costs (OPEX)	Minimal	Medium (electricity/gas)	Medium (electricity)	Very high (energy + maintenance)
Drying time	7-15 days	12-36 hours	4-12 hours	18-36 hours
Dependence on climate	Very high	Low	Low	None
Process control	Very limited	Good	Very good	Full, automated
Colour retention	Low-medium (browning possible)	Medium	High	Very high (near fresh appearance)
Nutrient retention	Medium	Medium	High	Maximum (90-95%)
Product texture	Dense, chewy	Classic dried fruit texture	Softer, more uniform	Light, porous, crispy
Quality uniformity	Low	Medium-high	High	Very high
Hygiene and food safety	Low-medium	High	High	High (if pretreated with hot water blanching)

Table 3. Continued

Parameter	Traditional (sun drying)	Convective (hot air drying)	Infrared (IR) drying	Freeze-drying (lyophilisation)
Compliance with export standards (EU, USA)	Limited	Yes	Yes	Premium
Typical export market segment	Low to mid-price	Mid-price	Mid-to-high	Premium/functional foods
Export price potential	Low	High	Medium	Low-medium
Production scalability	Low	High	Medium	Low-medium
Applicability in Central Asia – advantages	Low investment, traditional, suitable climate	Best price-quality balance	High value-added export potential	Niche markets, high margins
Applicability in Central Asia – limitations	Quality risks, difficult certification	Energy costs, competition	Higher entry barrier, market required	High CAPEX, limited demand

Source: compiled by the authors

Based on the comparison of apricot drying technologies, clear trade-offs emerge between investment cost, operating expenses, and market positioning. Traditional sun drying requires minimal capital investment but offers limited quality control and export potential, making it suitable mainly for local or small-scale markets. Convective drying represents a balanced option, with moderate CAPEX and scalable production, and can achieve positive returns if minimum selling prices are secured. Infrared drying provides improved product quality and access to premium markets at the cost of higher capital and operating requirements. Freeze-drying delivers the highest quality product but involves high CAPEX and OPEX, restricting its economic viability to niche, high-margin markets with stable long-term demand.

Conclusions

The growing global demand for healthy, natural fruit-based products underscores the promising prospects for apricot processing, particularly in Central Asia, where favourable agro-climatic conditions, genetic diversity, and proximity to major export markets (Russia, EU, Middle East, China) provide a strong competitive foundation. The analysis revealed that global apricot production reached approximately 4.5 million tonnes in 2024, with Turkey historically dominating both fresh and dried segments. However, the catastrophic spring frosts of 2025 in Turkey created a significant supply gap, offering Central Asian producers – especially Uzbekistan (~526-540 thousand tonnes), Tajikistan (~313-348 thousand tonnes), and Kyrgyzstan (~57 thousand tonnes in recent years) – a unique window to increase market share in dried apricots. ROI calculations for drying technologies at a scale of 50 tonnes of dried product per year demonstrated clear advantages of modern methods: sun drying yielded 7.3%, convective drying 23.4%, infrared drying 28.5%, and freeze-drying 33.9%. Infrared and freeze-drying not only delivered superior product quality (better colour retention, nutritional value, and safety without sulphur dioxide), but also ensured higher and more stable gross margins, making them particularly suitable for small- and medium-scale operations in Kyrgyzstan and similar regions with limited harvest volumes.

To capitalise on these opportunities, farmers and processors in Central Asia should prioritise the adoption of infrared drying for mid-premium segments and freeze-drying for high-value organic and export-oriented markets, while governments and development agencies should support targeted investments in modern equipment, training in quality standards (UNECE, organic certification), and improved logistics infrastructure to minimise post-harvest losses and enhance export competitiveness. Further research should focus on conducting region-specific techno-economic feasibility studies that incorporate local energy tariffs, labour costs, and actual smallholder supply chain constraints; performing full-scale pilot trials of infrared and freeze-drying technologies under Kyrgyz and Tajik conditions; investigating the long-term sensory and nutritional stability of sulphur-free dried apricots during extended storage and transport; and assessing the impact of new early-ripening cultivars on extending the harvest window and reducing climate-related risks in the post-2025 market environment.

Acknowledgements

None.

Funding

This work was supported by the German Federal Ministry of Education and Research (BMBF) [FKZ: 01LZ2201B].

Conflict of Interest

No potential conflict of interest was reported by the authors.

References

[1] Adak, N., Heybeli, N., & Ertekin, C. (2017). Infrared drying of strawberry. *Food Chemistry*, 219, 109-116. doi: 10.1016/j.foodchem.2016.09.103.

[2] Adeyeye, S.A.O., Ashaolu, T.J., & Babu, A.S. (2022). Food drying: A review. *Agricultural Reviews*, 1(8), 1-8. doi: 10.18805/ag.R-2537.

[3] Ahmed, A., Raza, A., Khalid, N., Malik, A.M., Asghar, M., & Abid, H.M.R. (2020). Development of apricot (*Prunus armeniaca* L.) powder and its food application. *Journal of Pure and Applied Agriculture,* 5(2), 26-33.
[4] Akter, F., Muhury, R., Sultana, A., & Deb, U.K. (2022). A comprehensive review of mathematical modeling for drying processes of fruits and vegetables. *International Journal of Food Science*, 2022, article number 6195257. doi: 10.1155/2022/6195257.
[5] Al-Soufi, M.H., *et al.* (2022). A review with updated perspectives on nutritional and therapeutic benefits of apricot and the industrial application of its underutilized parts. *Molecules*, 27(15), article number 5016. doi: 10.3390/molecules27155016.
[6] Arslan, A., & Alibaş, İ. (2024). Assessing the effects of different drying methods and minimal processing on the sustainability of the organic food quality. *Innovative Food Science & Emerging Technologies*, 94, article number 103681. doi: 10.1016/j.ifset.2024.103681.
[7] Asia-Plus. (2025). *Tajikistan's fruit production exceeds expectations*. Retrieved from.https://asiaplustj.info/en/news/tajikistan/economic/20251226/tajikistans-fruit-production-surpasses-expectations.
[8] Azarov, A., Maurer, M.K., Weyerhaeuser, H., & Darr, D. (2019). The impact of uncertainty on smallholder farmers' income in Kyrgyzstan. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 120(2), 183-195. doi: 10.17170/kobra-20191127816.
[9] Bhatta, S., Stevanovic Janezic, T., & Ratti, C. (2020). Freeze-drying of plant-based foods. *Foods*, 9(1), article number 87. doi: 10.3390/foods9010087.
[10] CentralAsia. (2017). *Life in Central Asia: Dried fruit production from the famous Asht apricots (photo report)*. Retrieved from https://centralasia.media/print:1397055.
[11] EastFruit. (2020). *Who ate the Tajik apricot, or why is the area of orchards growing while the export of dried apricots and dried fruit is rapidly declining?* Retrieved from https://east-fruit.com/novosti/kto-sel-tadzhikskiy-abrikos-ili-pochemu-ploshchad-sadov-rastet-a-eksport-kuragi-i-sukhofruktov-bystro-padaet/.
[12] EastFruit. (2022a). *Gardeners in Uzbekistan continue to harvest and export apricots*. Retrieved from https://east-fruit.com/novosti/sadovody-uzbekistana-prodolzhayut-sbor-i-eksport-abrikosov/.
[13] EastFruit. (2022b). *Uzbekistan: New apricot harvest exports have begun from southern regions*. Retrieved from https://east-fruit.com/novosti/uzbekistan-iz-yuzhnykh-regionov-nachalsya-eksport-abrikosa-novogo-urozhaya-foto/.
[14] EastFruit. (2023). *Apricot of Tajikistan: Harvest pleases, prices disappoint*. Retrieved from https://east-fruit.com/en/news/apricot-of-tajikistan-harvest-pleases-prices-disappoint-photo/.
[15] Elmaci, Y., Altug, T., & Pazir, F. (2008). Quality changes in unsulfured sun dried apricots during storage. *International Journal of Food Properties*, 11(1), 146-157. doi: 10.1080/10942910701279945.
[16] El-Mesery, H.S., Ashiagbor, K., Hu, Z., & Alshaer, W.G. (2023). A novel infrared drying technique for processing of apple slices: Drying characteristics and quality attributes. *Case Studies in Thermal Engineering*, 52, article number 103676. doi: 10.1016/j.csite.2023.103676.
[17] Ergashova, M.A. (2018). Genetic fund of apricots and prospects of its use in Tajikistan. *Pomiculture & Small Fruits Culture in Russia*, 54, 200-204. doi: 10.31676/2073-4948-2018-54-200-204.
[18] Ertekin, C., Aktas, T., Alibas, I., & Essalhi, H. (2023). Drying of fruits and vegetables. In S.M. Jafari & N. Malekjani (Eds.), *Drying technology in food processing: Unit operations and processing equipment in the food industry* (pp. 491-542). Amsterdam: Elsevier. doi: 10.1016/B978-0-12-819895-7.00004-3.
[19] Expana. (2025). *Apricot market: Severe Türkiye frost slashes output, sends global prices soaring*. Retrieved from https://surl.li/xnqefh.
[20] FAOSTAT. (n.d.). *Crops and livestock products*. Retrieved from https://www.fao.org/faostat/en/#data/QCL/visualize.
[21] Fruit and Vegetable Dryer. (2025). Retrieved from https://hnybjixie.en.made-in-china.com/product/jmlpUqMGuTra/China-Fruit-and-Vegetable-Dryer-Hot-Air-Dryer-for-Fruit-and-Vegetable-Apricot-Dryer.html.
[22] Gao, J.-R., Li, M.-Y., Cheng, Z.-Y., Liu, X.-Y., Yang, H., Li, M.-T., He, R.-Y., Zhang, Q., & Yang, X.-H. (2024). Effects of different drying methods on drying characteristics and quality of small white apricot (*Prunus armeniaca* L.). *Agriculture*, 14(10), article number 1716. doi: 10.3390/agriculture14101716.
[23] Güçlü, K., Altun, M., Özyürek, M., Karademir, S.E., & Apak, R. (2006). Antioxidant capacity of fresh, sun- and sulphited-dried Malatya apricot (*Prunus armeniaca*) assayed by CUPRAC, ABTS/TEAC and folin methods. *International Journal of Food Science and Technology*, 41(S1), 76-85. doi: 10.1111/j.1365-2621.2006.01347.x.
[24] Hussain, A., Ishfaq Akbar, P., & Lamo, K. (2012). Apricot drying: Preservation technique currently practiced in Ladakh, India. *Stewart Postharvest Review*, 8(3), 1-6. doi: 10.2212/spr.2012.3.1.
[25] Igual, M., García-Martínez, E., Martín-Esparza, M.E., & Martínez-Navarrete, N. (2012). Effect of processing on the drying kinetics and functional value of dried apricot. *Food Research International*, 47(2), 284-290. doi: 10.1016/j.foodres.2011.07.019.

[26] Kadyrov, A.A. (2023). *Final report on the comprehensive assessment of the economic situation and competitiveness of agribusiness with the aim of building a value chain and productive partnerships in the Batken region*. Retrieved from https://www.batken.gov.kg/file/page/8_finalnyi-otchet_070823.pdf
[27] Karabulut, I., Topcu, A., Duran, A., Turan, S., & Ozturk, B. (2007). Effect of hot air drying and sun drying on color values and β-carotene content of apricot (*Prunus armenica* L.). *LWT – Food Science and Technology*, 40(5), 753-758. doi: 10.1016/j.lwt.2006.05.001.
[28] Karataş, N., & Şengül, M. (2020). Some important physicochemical and bioactive characteristics of the main apricot cultivars from Turkey. *Turkish Journal of Agriculture and Forestry*, 44(6), 651-661. doi: 10.3906/tar-2002-95.
[29] Kayran, S., & Doymaz, İ. (2021). Drying of Cataloglu apricots: The effect of sodium metabisulfite solution on drying kinetics, diffusion coefficient, and color parameters. *International Journal of Fruit Science*, 21(1), 270-283. doi: 10.1080/15538362.2021.1873218.
[30] KEMOLO. (n.d.). *FD-1000 food freeze dryer*. Retrieved from https://www.liofilizador.com/products/food_freeze_dryer.html.
[31] Kiralan, M., Özkan, G., Kucukoner, E., & Ozcelik, M.M. (2019). Apricot (*Prunus armeniaca* L.) oil. In M.F. Ramadan (Ed.), *Fruit oils: Chemistry and functionality* (pp. 505-519). Cham: Springer. doi: 10.1007/978-3-030-12473-1_25.
[32] Mirzabaev, A., Strokov, A., & Krasilnikov, P. (2023). The impact of land degradation on agricultural profits and implications for poverty reduction in Central Asia. *Land Use Policy*, 126, article number 106530. doi: 10.1016/j.landusepol.2022.106530.
[33] Mirzaeva, M.A., & Makhmudova, M.A. (2020). Drying technology of apricot varieties suitable for drying. *Universum: Technical Sciences: Electronic. Scientific Journal*, 12(81).
[34] Murzakulova, A. (2024). The power of apricot: Border disputes, land scarcity and mobility in the Isfara River Basin. In J. Feaux de la Croix & B. Penati (Eds.), *Environmental humanities in Central Asia* (pp. 245-261). Milton Park: Taylor & Francis. doi: 10.4324/9781003362364-16.
[35] Nowak, D., & Jakubczyk, E. (2020). The freeze-drying of foods – the characteristic of the process course and the effect of its parameters on the physical properties of food materials. *Foods*, 9(10), article number 1488. doi: 10.3390/foods9101488.
[36] OEC. (n.d.). Retrieved from https://oec.world/en.
[37] Polat, A.A., & Caliskan, O. (2013). Yield and fruit characteristics of various apricot cultivars under subtropical climate conditions of the Mediterranean Region in Turkey. *International Journal of Agronomy*, 2013(1), article number 687345. doi: 10.1155/2013/687345.
[38] Poyraz, S., & Gül, M. (2022). The development of apricot production and foreign trade in the world and in Turkey. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, 22(2), 601-616.
[39] Programme for the Development of the Food and Processing Industry of the Kyrgyz Republic for 2017-2021. (2017, March). Retrieved from https://cbd.minjust.gov.kg/53-290/edition/851186/ru.
[40] Qureshi, T.A. (2022). *Identifying the potential of horticulture exports to China from Pakistan, Tajikistan, Kyrgyzstan, and Uzbekistan*. Urumqi: CAREC Institute.
[41] Ratti, C. (2001). Hot air and freeze-drying of high-value foods: A review. *Journal of Food Engineering*, 49(4), 311-319. doi: 10.1016/S0260-8774(00)00228-4.
[42] Su, F., Liu, Y., Chen, L., Orozbaev, R., & Tan, L. (2024). Impact of climate change on food security in the Central Asian countries. *Science China Earth Sciences*, 67, 268-280. doi: 10.1007/s11430-022-1198-4.
[43] TAJSTAT. (n.d.). Retrieved from https://www.stat.tj/en/.
[44] Toğrul, İ.T. (2005). Convective heat transfer coefficient of apricots under open sun drying conditions. *Chemical Engineering Communications*, 192(8), 1036-1045. doi: 10.1080/009864490522579.
[45] Toğrul, İ.T., & Pehlivan, D. (2003). Modelling of drying kinetics of single apricot. *Journal of Food Engineering*, 58(1), 23-32. doi: 10.1016/S0260-8774(02)00329-1.
[46] Tridge. (n.d.). Retrieved from https://www.tridge.com/about/data-analytics/trade?next=%252Ftrades.
[47] Tynarbekova, M., Smanalieva, J., Novoslavskij, A., Liaudanskas, M., Žvikas, V., Jakštas, V., & Henle, T. (2025). Effects of pre-treatment methods on the physical properties, phenolic composition, antioxidant capacity in vitro, and microbiological safety indicators of dried apricot (*Prunus armeniaca* L.). *Journal of Food Measurement and Characterization*, 19, 9976-9986. doi: 10.1007/s11694-025-03588-w.
[48] U.S. Department of Agriculture. (2022). *Prune, dried*. Retrieved from https://surl.li/xxdage.
[49] UNECE. (2017). *UNECE standard FFV-02 concerning the marketing and commercial quality control of apricots*. Geneva: United Nations Economic Commission for Europe.
[50] Vijayavenkataraman, S., Iniyan, S., & Goic, R. (2012). A review of solar drying technologies. *Renewable and Sustainable Energy Reviews*, 16(5), 2652-2670. doi: 10.1016/j.rser.2012.01.007.
[51] World Integrated Trade Solution (WITS). (2024). *Dried apricots exports by country in 2024*. Retrieved from https://surl.li/irkmnr.

[52] World Trade Organization (WTO). (n.d.). Retrieved from https://www.wto.org/.
[53] Ye, L., EL-Mesery, H.S., Ashfaq, M.M., Shi, Y., Zicheng, H., & Alshaer, W.G. (2021). Analysis of energy and specific energy requirements in various drying process of mint leaves. *Case Studies in Thermal Engineering*, 26, article number 101113. doi: 10.1016/j.csite.2021.101113.
[54] Zhang, D., Huang, D., Zhang, Y., Lu, Y., Huang, S., Gong, G., & Li, L. (2023). Ultrasonic assisted far infrared drying characteristics and energy consumption of ginger slices. *Ultrasonics Sonochemistry*, 92, article number 106287. doi: 10.1016/j.ultsonch.2022.106287.
[55] Zhang, Y., Li, T., Hu, Q., He, L., & Li, X. (2025). Food security changes in Central Asia during 1992-2019 and potential assessment in different scenarios based on self-sufficiency. *Environmental Impact Assessment Review*, 114, article number 107900. doi: 10.1016/j.eiar.2025.107900.

Борбордук Азияда өрүктү өстүрүү жана кайта иштетүү потенциалы

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Аннотация. Өрүк (*Prunus armeniaca* L.) мелүүн зоналардын негизги жемиштеринин бири бойдон калууда, Борбордук Азия анын келип чыгышынын жана генетикалык ар түрдүүлүгүнүн маанилүү борбору болуп саналат. Изилдөө дүйнө жүзү боюнча, өзгөчө Борбордук Азия өлкөлөрүндө жаңы жана кургатылган өрүктү өндүрүү менен соодалоонун экономикалык потенциалын баалоого, ошондой эле ар кандай кургатуу технологияларынын натыйжалуулугун талдоого багытталган. FAOSTAT, WITS, Tridge жана WTO маалыматтары (2020-2025-жылдар), илимий адабияттардын системалуу карап чыгуусу (Scopus, Web of Science ж.б.) колдонулду; жыл сайын 50 тонна кургатылган өрүк өндүрүү шартында салттуу күн кургатуу, конвективдүү, инфракызыл жана сублимациялык (freeze-drying) ыкмалар үчүн инвестициянын кайтарымдуулугу (ROI) жана дүң киреше эсептелди. Аныкталгандай, 2024-жылы дүйнөлүк өрүк өндүрүшү болжол менен 4,5 млн тоннага жеткен; Түркия, Өзбекстан жана Иран лидер болуп калууда, бирок 2025-жылы Түркияда (айрыкча Малатья облусунда) катуу жазгы үшүккө байланыштуу өндүрүш чейин кыскарган, бул жаңы жана кургатылган өрүктүн дүйнөлүк бааларынын кескин өсүшүнө алып келген. Борбордук Азияда Өзбекстан (~526-540 миң т 2024-ж.), Тажикстан (~313-348 миң т 2024-2025-жж.) жана Кыргызстан (~57 миң т 2023-2024-жж.) олуттуу экспорттук потенциалды көрсөтүүдө; Түркия 2024-жылы кургатылган өрүктү 404,5 млн АКШ долларына экспорттогон, бирок 2025-жылы регионалдык жеткирүүчүлөр (айрыкча Өзбекстан жана Тажикстан) атаандаштык артыкчылыкка ээ болууда. ROI эсептөөлөрү: күн кургатуу – 7,3 %, конвективдүү – 23,4 %, инфракызыл – 28,5 %, сублимациялык – 33,9 %; инфракызыл жана сублимациялык ыкмалар эң жогорку сапатты камсыз кылат. Жыйынтыктар Борбордук Азиянын (негизинен Кыргызстандын) фермерлери, кайра иштетүүчүлөрү жана инвесторлору тарабынан кургатуу технологияларын тандоодо, түшүм жыйналгандан кийинки жоготууларды азайтууда жана премиум-экспорттук рынокторго (ЕБ, АКШ, Россия) чыгууда колдонулушу мүмкүн

Негизги сөздөр: жыйноо аянты; түшүмдүүлүк; кургатуу технологиясы; жабдуу; инвестициянын кирешелүүлүгү; эксплуатациялык чыгымдар

Потенциал выращивания и переработки абрикосов в Центральной Азии

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Аннотация. Абрикос (*Prunus armeniaca* L.) остается одним из ключевых фруктов умеренных зон, а Центральная Азия является важным центром его происхождения и генетического разнообразия. Целью работы была оценка экономического потенциала производства и торговли свежими и сушеными абрикосами в мире с акцентом на страны Центральной Азии, а также анализ эффективности различных технологий сушки. Для анализа использовались данные FAOSTAT, WITS, Tridge и WTO за 2020-2025 гг., а также систематический обзор научной литературы по технологиям сушки (Scopus, Web of Science и др.); выполнен расчет рентабельности инвестиций (ROI) и валовой прибыли для традиционной солнечной, конвективной, инфракрасной и сублимационной (freeze-drying) сушки при производстве 50 т сушеных абрикосов в год. Было установлено, что мировое производство абрикосов в 2024 г. составило около 4,5 млн т; Турция, Узбекистан и Иран остаются лидерами, однако в 2025 г. из-за катастрофических заморозков в Турции (особенно в Малатье) производство там сократилось, что привело к резкому росту мировых цен на свежие и сушеные абрикосы. В Центральной Азии Узбекистан (~526-540 тыс. т в 2024 г.), Таджикистан (~313-348 тыс. т в 2024-2025 гг.) и Кыргызстан (~57 тыс. т в 2023-2024 гг.) демонстрируют значительный экспортный потенциал; Турция в 2024 г. экспортировала сушеные абрикосы на 404,5 млн долл., однако в 2025 г. региональные поставщики (особенно Узбекистан и Таджикистан) получили конкурентные преимущества. Расчет ROI показал: солнечная сушка – 7,3 %, конвективная – 23,4 %, инфракрасная – 28,5 %, сублимационная – 33,9 %; при этом инфракрасная и сублимационная сушка обеспечивают наивысшее качество продукта. Результаты могут быть использованы фермерами, переработчиками и инвесторами Центральной Азии (прежде всего Кыргызстана) для выбора технологий сушки, снижения послеуборочных потерь и выхода на премиум-сегменты экспортных рынков (ЕС, США, Россия)

Ключевые слова: площадь сбора урожая; урожайность; технология сушки; оборудование; окупаемость инвестиций; операционные расходы

Received: 25.09.2025. Revised: 06.02.2026. Accepted: 10.03.2026.

Bulletin of the Kyrgyz National Agrarian University

Vol. 24, No. 1. 2026

Journal homepage: https://knau-bulletin.com/en

UDC 637.5.043 (571.56)

DOI: 10.63621/bknau./1.2026.77

Technological properties of Yakut horse fat

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Abstract. The relevance of this study is due to the need for scientific justification of the technological potential of Yakut horse fat as a unique source of meat for children, formed in the conditions of extremely low temperatures of the Far North and possessing distinctive physicochemical properties. The aim of the work was to comprehensively assess the physicochemical and technological characteristics of Yakut horse fat in terms of its potential use in the food industry and in the development of certain food products. During the research, gas-liquid chromatography methods were used to analyse the fatty acid composition, standard physical and chemical methods were used to determine the melting point, iodine and acid numbers, and instrumental methods were used to assess the consistency and plasticity of the fat. As a result, it was established that the fat of the Yakut horse contains the necessary proportion of unsaturated fatty acids, with the content of oleic acid being 42.3-45.7% and linoleic acid being 9.8-11.6%, which allows for the calculation of indicators for the growth of other horse breeds. The melting point of the samples was mainly 28.5-31.2°C, which indicates high plasticity and good digestibility of the product. The iodine value was 78-86 g I_2/100 g of fat, and the acid value was 1.2-1.6 mg KOH/g, which indicates

Suggested Citation: Pak, M., Vasilyeva, V., Ivanov, R., Makhatov, B., & Rakhmanov, S. (2026). Technological properties of Yakut horse fat. *Bulletin of the Kyrgyz National Agrarian University*, 24(1), 77-87. doi: 10.63621/bknau./1.2026.77.

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the high quality and stability of the fat during storage. It has been established that the combination of these indicators provides the fat with pronounced emulsifying properties and technological stability during processing. The practical value of the work lies in the possibility of using the results by meat processing and confectionery enterprises in the northern regions when developing technologies for processing horse fat and obtaining effective food products with increased biological value

Keywords: horse meat; foal meat; adipose tissue; secondary raw materials from slaughter products; polyunsaturated fatty acids

Introduction

The Yakut horse is a unique indigenous breed that developed in the extremely low temperatures of the Far North and is characterised by exceptional adaptive qualities. Breeding Yakut horses in herds and using them for riding in harsh climatic conditions has contributed to the development of specific physiological mechanisms, including the ability to accumulate significant fat reserves and use them sparingly during the long winter period. The relevance of research into Yakut horse fat is due to the growing interest in the use of non-traditional types of animal raw materials with high biological and technological value, especially in the context of global climate change, the intensification of food technologies and increasing demands on food quality.

In recent years, the scientific community has paid particular attention to the study of livestock products formed in extreme natural and climatic conditions. The extreme climatic conditions of the Far North have a significant impact on the formation of adaptive mechanisms in animals, which directly affects the quality characteristics of livestock products. One of the key adaptive qualities of the Yakut horse is its ability to accumulate significant fat reserves during the favourable season and to use them sparingly during the long winter. The total amount of adipose tissue in the body of a Yakut horse ranges from 6 to 11 kg, which significantly exceeds the indicators for breeds from temperate climatic zones (Pak, 2020).

Modern research shows that the fats of northern animal breeds have a specific lipid profile, characterised by an increased content of biologically active components. Thus, M. Aroua *et al.* (2024) found that the use of horse meat in traditional meat products improves their physicochemical characteristics due to the favourable composition of fatty acids. Research by L. Beldarrain *et al.* (2021) showed that horse adipose tissue is characterised by a specific fatty acid composition, depending on the anatomical and topographical location and the conditions in which the animals are kept. N. Čobanović *et al.* (2023) noted in their review the existing gaps in knowledge about the quality of horse meat and highlighted the need for further research into the technological properties of horse fat. The work of A. Ivanković *et al.* (2025) is of great importance, emphasising the potential of local horse breeds for meat production in the context of sustainable development and the conservation of genetic resources. R. Stanisławczyk *et al.* (2023) demonstrated the influence of horse age on carcass tissue composition and meat quality, which is directly related to the characteristics of adipose tissue.

Despite the existence of individual studies devoted to the biological characteristics of the Yakut horse and the general characteristics of horse fat, there is insufficient systematic data in the modern scientific literature on the comprehensive assessment of the physicochemical and technological properties of fat from the Yakut horse breed in particular. The lack of such data limits the possibilities for the rational use of this valuable raw material and hinders the development of processing technologies adapted to the conditions of the North. The aim of the study was to establish the physicochemical indicators and technological characteristics of fat from Yakut horses of different anatomical and topographical locations and age groups in order to determine the optimal directions for its use in the food industry of the northern regions.

Literature Review

Studies show that extreme climatic conditions contribute to the formation of a special lipid profile, ensuring high energy density and biological value of fats. Studies on the lipid composition of meat and fat from horses in northern regions indicate an increased content of mono- and polyunsaturated fatty acids, which has a positive effect on the nutritional value and digestibility of the products (Ashakayeva *et al.*, 2022). According to research by M. Pak (2020), young horses of the Yakut breed were found to contain 30.8% to 43.4% saturated fatty acids, 22.0% to 38.8% monounsaturated fatty acids, and polyunsaturated fatty acids (PUFAs) of 10.2-16.4%, with the native type characterised by a higher PUFA content of 32.5-40.9%. Compared to horses of other breeds, Yakut horses have the thickest skin (4.4 ± 0.05 mm in winter in the area of the last rib), under which subcutaneous fat is located. In various breeds of domestic horses, there is a significant variation in the thickness of subcutaneous fat at anatomical points of the body. Measurements of subcutaneous fat thickness (SFT) using ultrasound in the work of T. Martin-Gimenez *et al.* (2016) showed that higher fat layer values are observed on the tail and ribs than on other areas, and that these measurements correlate with the overall

assessment of fatness. Fat is also deposited around the internal organs of horses. A significant amount of adipose tissue accumulates on top of the fibrous capsule and in the renal sinus, forming a fat capsule. Significant amounts of fat can accumulate in the longitudinal and coronary sulci of the heart.

According to N. Abilmazhinova (2025), horse fat is characterised by a significantly lower melting point (17-28°C) and a higher iodine value (59-102) compared to other livestock fats, such as beef or mutton. These parameters indicate a high concentration of unsaturated fatty acids, which makes the physicochemical properties of horse fat comparable to those of vegetable oils. This unique composition highlights the high biological value of lipids obtained from horse fat, in contrast to more saturated animal fats.

Recent publications have examined the influence of natural and climatic factors on the stability of animal-derived lipids. K. Petrov *et al.* (2020) found that the high biological value of Yakut horse fat is due to the consumption of cereal cryofodder, in which, during autumn cold hardening, the concentration of fatty acids reaches 75% of the total lipid composition. The study showed that these acids are distributed specifically in the horses' bodies: while the liver is rich in linoleic acid, muscle and fat tissues mainly accumulate alpha-linolenic acid, which makes horse meat a unique dietary product adapted to extreme winter conditions. The fat of the Yakut horse requires special treatment during technological and culinary processing due to its particularly delicate structure, otherwise it quickly oxidises and loses its organoleptic properties (Slobodchikova *et al.*, 2019). In fat raw materials during its accumulation and long-term storage, as well as in ready-made rendered fat, due to the presence of moisture, glyceride molecules are cleaved from glycerol and dissolve in the fat mass. Hydrolytic and oxidative processes primarily occur with unsaturated acids, which are abundant in the fat of the Yakut horse.

Despite data on fatty acid composition and some technological studies, specific technological indicators (crystallisation temperature, phase transitions, fat rheology, storage stability, oxidative stability) for fat from Yakut horses are insufficiently described or systematised. There is little data on the effect of processing (melting temperature, transesterification, fat deodorisation) and its use in food products with specific technological characteristics. A more detailed comparison with fats from other animals using a uniform methodological approach is rare – some of the data is given for "horse fat" in general, without breaking it down by breed. The question of the influence of age, sex, and season of selection on the technological properties of Yakut breed fat needs further research. Processing technologies should take into account the specificity of the raw material (low temperatures during slaughter and processing), extraction and purification methods. M. Slobodchikova *et al.* (2015) considered the fat of young Yakut horses as a raw material for functional foods and food supplements. However, comprehensive studies aimed at systematising knowledge about the technological properties of Yakut horse fat, taking into account the requirements of the modern food industry, remain a pressing task.

Materials and Methods

The research was conducted between July 2023 and March 2024 at the laboratory for agricultural production and bioanalysis of the M.G. Safronov Yakut Scientific Research Institute of Agriculture (YANIISH) using equipment from the Shared Use Centre of the Federal Research Centre "Yakut Scientific Centre of the Siberian Branch of the Russian Academy of Sciences". The object of the study was the fat of Yakut horses obtained from animals of various age groups. To analyse the physicochemical indicators and fatty acid composition, fat samples were taken from horses under 3 years of age and from adult animals over 10 years of age. All animals were kept in year-round pasture (tambun-tebenovka) conditions without the use of concentrated feed. The diet in winter consisted of tebenovka (natural pasture feed obtained from under the snow cover), and in summer – meadow and tundra grasses. Watering was carried out from natural water bodies in summer and by eating snow in winter. The total number of samples analysed was 27, including materials collected in different seasons of the year and from different anatomical and topographical locations of adipose tissue. Some of the analyses (anatomical-topographical and seasonal differences) were performed on a sample of 10 clinically healthy animals of the Yakut Prilensky breed, including 6 adult horses and 4 foals, selected as part of an experimental slaughter. The animals were slaughtered in accordance with current veterinary and sanitary requirements and animal welfare standards in accordance with Council Directive 2010/63/EU (2010).

Subcutaneous and internal adipose tissue selected from the abdominal wall, ribs and perirenal area was used for analysis. Additionally, samples of cervical and visceral fat were selected for comparative analysis of anatomical and topographical features. The weight of each sample ranged from 300 to 500 g. After collection, the fat samples were thoroughly cleaned of connective tissue, muscle fibres, and blood vessels, packed in sealed polyethylene containers labelled (animal number, location, date of collection), and stored at -18°C until analysis. The storage period for samples did not exceed 30 days.

To assess the effect of the slaughter season on the physicochemical properties of fat, a series of samples were taken at different times of the year. Autumn slaughter was carried out after the end of grazing (October 2023), winter slaughter was carried out during a period of sustained sub-zero temperatures

(February 2024), and summer slaughter was carried out in conditions of above-zero temperatures (July 2023). The ambient air temperature at the time of slaughter was recorded using a digital thermometer and ranged from +10 to +15°Cin summer, from -5 to -10°C in autumn, and from -32 to -38°C in winter. For each season, samples were taken from 3-4 animals of similar age groups. It was necessary to take seasonal conditions into account because a decrease in the external temperature activates the enzymatic processes of lipid metabolism, in particular the activity of dehydrogenases, which leads to a change in the content of saturated and unsaturated fatty acids in adipose tissue.

The melting point of fat was determined by the capillary method in accordance with the requirements of GOST 8285-91 (1992). The fat was pre-melted in a water bath at a temperature of 60-70°C for 15-20 minutes, after which it was collected in transparent glass capillaries with a diameter of 1.5 mm, forming a column 5-7 mm high. The capillaries were cooled at a temperature of +4°C for 2 hours for complete crystallisation of the fat. The capillary was then fixed on a mercury thermometer with a scale of 0.1°C and placed in a water bath with gradual heating (heating rate 1°C/min) with constant stirring. The melting point was recorded at the moment when the fat became completely transparent and began to move up the capillary. All measurements were performed five times for each sample, and the results were expressed as the arithmetic mean.

The acid number was determined in accordance with GOST R 50457-92 (1994). A 3-5 g sample of fat (weighed to an accuracy of 0.01 g on analytical scales) was dissolved in 50 ml of a neutralised ether-alcohol mixture (diethyl ether and 96% ethyl alcohol in a 1:1 ratio by volume). The mixture was neutralised by adding 0.1 N potassium hydroxide (KOH) solution until a pale pink colour appeared in the presence of phenolphthalein. A 1% solution of phenolphthalein in ethanol (3-4 drops added) was used as an indicator. Titration was carried out with a 0.1 N potassium hydroxide solution until a stable pale pink colour appeared that did not disappear within 30 seconds. The acid number (X, mg KOH/g) was calculated using formula (1):

$$X = \frac{5.61 \times V \times K}{g}, \quad (1)$$

where 5.61 is the titre of the 0.1 N KOH solution, mg/cm^3; V is the volume of the titrant, cm^3; K is the correction factor for the normality of the solution; g is the weight of fat, g. Each determination was performed in triplicate.

The iodine number was determined using a method based on the Wijs reagent (iodine monochloride) with titration of excess iodine with sodium thiosulphate solution in the presence of a starch indicator according to ISO 3961:2024 (2024). A 0.15-0.20 g (±0.0001 g) sample of fat was dissolved in acetic acid/chloroform, Wijs reagent was added, and the mixture was kept at room temperature with periodic stirring. After the reaction was complete, a potassium iodide solution and water were added, after which the excess reagent was titrated with a 0.1 N sodium thiosulphate solution until the colour disappeared in the presence of a starch indicator; a blank test was also performed. The determinations were performed in triplicate.

The fatty acid composition was determined by gas-liquid chromatography on an Agilent 7890B gas chromatograph (USA) equipped with a flame ionisation detector (FID). Sample preparation included methylation of fatty acids by transesterification using a methanol solution of sodium hydroxide according to the standard method ISO 12966-2:2017 (2017). A 100 m long HP-88 capillary column with an internal diameter of 0.25 mm and a stationary phase thickness of 0.20 µm was used. The temperature programme was set as follows: initial temperature 140°C with a holding time of 5 minutes, then an increase to 240°C at a heating rate of 4°C/min, final isotherm at 240°C for 10 minutes. The injector temperature was 250°C, and the detector temperature was 260°C. Helium was used as the carrier gas at a flow rate of 1.0 ml/min. The sample volume was 1 µl, the split ratio was 1:50, and the ionisation energy was 70 eV. Fatty acids were identified using Supelco 37 Component FAME Mix standards (Sigma-Aldrich, USA) and the NIST database. Quantitative analysis was performed using internal normalisation, and the content of individual fatty acids was expressed as a percentage of the sum of the areas of all identified peaks. Chromatograms were processed using Agilent ChemStation software, version E.02.02. The vitamin A content in fat samples was determined by spectrophotometry after alkaline saponification and extraction of the unsaponifiable fraction with an organic solvent, followed by measurement of the optical density at a wavelength of 325 nm. Quantitative assessment was performed using a calibration curve constructed according to the retinol standard. The saponification number was determined by titrimetric method in accordance with ISO 3657:2023 (2023), based on the amount of potassium hydroxide required for fat saponification.

Statistical processing of the results was performed using Statistica 13.5 software (TIBCO Software Inc., USA). The normality of distribution was checked using the Shapiro-Wilk criterion. For data corresponding to a normal distribution, the arithmetic mean (M) and standard error of the mean (m) were calculated. The reliability of differences between sample groups (depending on anatomical location, animal age, and slaughter season) was assessed using one-way analysis of variance (ANOVA) followed by Tukey's test for pairwise comparisons. Differences were considered statistically significant at a significance level of $p < 0.05$. The tables show the F-statistics and p-values for assessing the influence of the factors studied. The analysis methods were

validated using certified standard fatty acid samples and reference materials.

Results and Discussion

During the research, data were obtained characterising the main physicochemical and technological properties of Yakut horse fat that are important for its industrial processing. It was found that Yakut horse fat has a pronounced variability of indicators depending on the anatomical and topographical location of fat deposits. The melting point of fat varied significantly depending on the location of the adipose tissue. The melting point of fat varied significantly depending on the anatomical and topographical location and ranged from 24.2 to 29.2°C. The minimum values were characteristic of perirenal fat, while higher values were observed for visceral and abdominal fat. The identified differences are manifested in the originality of the physical structure of fat and determine the peculiarities of its biological formation.

The acid number values in the samples studied ranged from 0.37 to 1.6 mg KOH/g, with the lowest values characteristic of cervical fat and higher values characteristic of abdominal fat, which meets the requirements for high-quality animal fat and indicates a low degree of hydrolytic lipid content. The lowest acid values are characteristic of internal and perirenal fat, as slightly higher values are observed in subcutaneous fat deposits, which may be associated with the periodic progression of oxidative processes. The iodine component values are 78-86 g I_2/100 g of fat, with the highest values recorded in the internal part of the fat. This indicates a high content of unsaturated fatty acids and confirms the pronounced biological and technological value of Yakut horse fat. The increased iodine value correlates with a lower melting point and establishes the standard digestibility of the product.

The results of gas chromatographic analysis showed that unsaturated fatty acids predominate in the fat composition. The proportion of oleic acid is 42.3-45.7%, linoleic acid – 9.8-11.6%, while the total content of saturated fatty acids did not exceed 38-41%. The direct ratio of fatty acids determines the low melting point of the fat and its similarity in technological properties to poultry fats and vegetable oils. The identified physicochemical characteristics indicate the high technological adaptability of Yakut horse fat for processing. The low melting point, resulting from the content of unsaturated fatty acids, and satisfactory acid and iodine composition indicators allow this type of liquid ingredient to be considered a promising component for the production of food products and specialised fat compositions. The melting point of fat is one of the main indicators determining its technological properties and potential for use in the food industry. To assess the anatomical and topographical location of fat deposits based on this indicator, the melting point of fat from various parts of the carcass of a Yakut Prilensky breed was determined (Table 1).

Table 1. Melting point of fat from Yakut Prilensky horses

Type of fat	Melting point, °C
Neck	27.75 ± 0.63
Abdominal	28.40 ± 0.66
Subcutaneous internal	27.30 ± 0.52
Visceral internal	29.20 ± 0.20
Perirenal	24.20 ± 1.30

Note: internal fat is subdivided into subcutaneous internal and visceral internal depending on the anatomical location of sampling
Source: developed by the authors based on their own experimental studies

The data presented indicate a pronounced dependence of the melting point of fat on its anatomical and topographical location. The lowest values are characteristic of perirenal fat, which indicates its increased plasticity and low melting point. Internally located fat is characterised by more stable thermophysical properties, while subcutaneous fat deposits demonstrate slightly higher melting point values. The differences identified reflect the heterogeneity of the lipid structure and are of practical importance when choosing the technological processing of Yakut horse fat. At lower ambient temperatures, the action of enzymes – dehydrogenases – is activated, resulting in an increase in the percentage of highly unsaturated fatty acids in adipose tissue. The acid number also varies depending on the anatomical and topographical location. The highest acid number is observed in abdominal fat and is 1.31 mg/g, while the lowest is in neck fat and is 0.37 mg/g.

The acid number is a consequence of the quality of fat, reflecting the degree of hydrolytic influence of lipids and the stability of the original source during storage and processing. To assess the anatomical and topographical localisation of fat according to this indicator, acid number values were established for various fat deposits of the Yakut Prilensky breed (Table 2).

Table 2. Acid number of fat in Yakut Prilensky horses

Type of fat	Acid number, mg KOH/g
Neck	0.3
Abdominal	1.3

Table 2. Continued

Type of fat	Acid number, mg KOH/g
Subcutaneous internal	0.7
Visceral internal	0.6
Perirenal	0.56

Note: internal fat is subdivided into subcutaneous internal and visceral internal depending on the anatomical location of sampling
Source: developed by the authors based on their own experimental studies

Analysis of the data presented shows that the acid number values of Yakut horse fat depend on the anatomical and topographical location of the adipose tissue. Higher values are characteristic of abdominal adipose tissue, which may be associated with the peculiarities of its metabolic activity, while internal and perirenal localisation are characterised by a lower degree of hydrolytic lipid breakdown. The results obtained indicate the high quality of the raw ingredient and its stability during technological processing. The taste and technological qualities of horse meat strongly depend on the nature of the adipose tissue. In adult horses, the fat is soft and yellowish, while in young horses it is usually almost white; when melted, it is greasy and yellow in colour. The chemical composition and organoleptic properties of horse adipose tissue are comparable to those of other slaughter animals. Fatty acid profile analyses in the work of X. Belaunzaran *et al.* (2017) showed that horse fat is characterised by a high proportion of polyunsaturated fatty acids, in particular linolenic and linoleic acids, which reflects the influence of a grass-based diet and fatty acid metabolism in monogastric animals; at the same time, the content of n-3 PUFA in subcutaneous fat can reach relatively high values, significantly exceeding those in other meat products (e.g., linolenic acid up to 18-28% PUFA in fat deposits).

It has been shown that the chemical composition of meat and fat in horses varies depending on age and diet: adult animals have a higher fat content, while young animals have a lower fat content, despite a more favourable fatty acid profile in both cases. According to P. Seong *et al.* (2015), the age and husbandry methods of animals affect the physicochemical qualities of fat and its distribution in tissues, as well as indicators that may be related to the technological suitability and organoleptic properties of the final product. In this study, a comparative analysis of indicators characterising polyunsaturated fatty acids and the physicochemical properties of fat in Yakut horses of different age groups was carried out to determine age-related textures (Table 3).

Table 3. Characteristics of polyunsaturated fatty acids and physicochemical indicators of fat in horses of the Yakut breed (M ± m)

Indicators	Up to 3 years (n = 18)	10-20 years (n = 9)
Acid number, mg KOH/g	1.54 ± 0.07	1.09 ± 0.05
Saponification number	203.0 ± 1.1	199.8 ± 1.4
Iodine number, g I_2/100 g	91.1 ± 1.0	82.5 ± 1.9
Melting point, °C	28.2 ± 1.0	29.2 ± 0.7
Linoleic acid, %	6.8 ± 1.0	5.6 ± 0.5
Linolenic acid, %	13.3 ± 0.6	10.1 ± 0.6
Vitamin A, IU/g	5.7 ± 0.6	11.0 ± 0.7

Note: data are presented as mean values and standard errors (M ± m); n – number of samples studied in the corresponding age group
Source: developed by the authors based on their own experimental studies

The data presented indicate age-related differences in the fatty acid composition and physicochemical properties of fat in Yakut horses. The fat of animals in the younger age group is characterised by higher iodine values and increased content of linoleic and linolenic acids, which indicates a higher proportion of polyunsaturated fatty acids and more pronounced biological activity. At the same time, horses in the older age group have a higher concentration of vitamin A and a slightly higher melting point, which is within the limits of statistical variability, which may be associated with age-related features of lipid metabolism and the accumulation of fat-soluble vitamins. The identified differences are important when choosing the direction of technological processing of fat depending on the age of the animals.

The iodine number, which determines the total unsaturation of fats, varies slightly by age category: in young horses up to 3 years old, the iodine number is 91.1 g, while in adult horses it is 82.6 g. In addition, the fats of Kazakh horses are observed during the spring grazing period (up to 100 in young horses) and lower in the fats of horses after autumn grazing and during the wintering period (82-90). The saponification number characterises the total amount of fatty acids in fat. It does not change significantly depending on the season. This indicates the stability of the average molecular weight of triglycerides in the fat of wild horses and the absence of significant amounts of low-molecular-weight acids such as butyric acid, which increase the saponification number, regardless of the season.

The fat of adult horses contains more vitamin A in all seasons than the fat of young animals. The highest amount of vitamin A is found in the fat of horses slaughtered after autumn grazing. In winter, the vitamin A content in fat is significantly lower. After spring feeding, vitamin A reserves in stored fats are partially restored, but do not reach autumn levels, despite a significant intake of carotenoids with feed. The amount of vitamin A in autumn fats is higher than in spring fats, as a result of the biologically acquired ability to withstand harsh winter conditions. According to R. Álvarez *et al.* (2015), the amount of vitamin A in fats increases with age. The fat of adult horses contains more vitamin A and carotenoids than the fat of young animals. Their amount depends on the conditions in which the horses are kept: maximum in herd conditions and minimum in stable conditions. The content of highly unsaturated essential fatty acids (linoleic and linolenic) in fats varies depending on a number of factors, according to P. Seong *et al.* (2016). The highest amount is found in the fat of horses after autumn grazing. During the winter, there is an intensive expenditure of these acids, and during spring grazing, only a small part of them is replenished. With age, the content of linoleic and linolenic acids in fats decreases, which is a general biological pattern.

The composition of fatty acids in different anatomical and topographical parts of the carcass of the Yakut horse varies significantly. Thus, the highest proportion of atherogenic saturated acids is concentrated in the abdominal fat of the Yansk type of Yakut horse – 38.65% and in the native type of horse – 37.18%, while the lowest proportion is found in the neck fat of the Yansk type of Yakut horse (33.22%) and in the subcutaneous fat of the native type of Yakut horse (32.82%). According to M. Pak *et al.* (2025), palmitic acid predominates among them, especially in the subcutaneous (19.34%) and abdominal (20.82%) parts of the carcass. The internal fat of the Yakut horse exceeds the PUFA indicators of subcutaneous fats, with the exception of abdominal fat. The results confirm that the fat of the Yakut horse is characterised by a combination of physicochemical and technological properties, formed as a result of the long-term adaptation of animals to the extreme climatic conditions of the Far North. The high content of unsaturated fatty acids and relatively low melting point identified in modern development are consistent with the data of a number of recent studies on the lipid composition of northern breeds of animals. Thus, studies by K. Petrov *et al.* (2020) have shown that the fat content of horses raised in cold climates is characterised by an increased proportion of oleic and linoleic acids compared to the fat content of animals from temperate zones. This phenomenon is associated with adaptive mechanisms of lipid metabolism aimed at maintaining the plasticity of fat deposits at low ambient temperatures. Similar patterns were found in the present study, where high iodine values correlated with low fat melting points.

The relationship between diet and lipid profile of fat is also confirmed by the results of J. Smanalieva *et al.* (2019). The authors demonstrated that grazing promotes the accumulation of polyunsaturated fatty acids due to the direct intake of linoleic and linolenic acids from plant feed. The data obtained are consistent with the conclusions that natural and climatic factors and the type of feeding play a decisive role in the formation of the qualitative characteristics of fat raw materials. Thus, a comparison of the results of this study with data from modern scientific publications allows for concluding that the fat of the Yakut horse is a promising type of raw ingredient, combining natural biological value and favourable technological characteristics. At the same time, further research aimed at studying the rheological properties, crystallisation behaviour and stability of fat under various processing methods is necessary for the development of scientifically sound technologies for its industrial use.

Conclusions

The studies conducted have made it possible to comprehensively characterise the physicochemical and technological properties of Yakut horse fat as a specific type of animal raw material formed in the extreme climate of the Far North. It has been established that the fat of the Yakut horse breed has a favourable lipid profile due to its high content of unsaturated fatty acids: oleic acid – 42.3-45.7%, linoleic acid – 9.8-11.6%, with a total content of saturated fatty acids of no more than 38-41%. The melting point of the fat was 28.5-31.2°C, depending on the anatomical location, which determines its high plasticity and low melting point. Analysis of fat quality indicators showed that the iodine number values are at the level of 78-86 g I_2/100 g of fat, which indicates a significant proportion of polyunsaturated fatty acids and high biological value of the product. The acid number in all samples studied was 1.2-1.6 mg KOH/g, which indicates satisfactory fat quality and its resistance to hydrolytic processes when stored under optimal conditions. The differences in melting point depending on the anatomical and topographical location of adipose tissue (minimum values for perirenal fat – 24.20 ± 1.30°C, maximum for visceral internal fat – 29.20 ± 0.20°C) confirm the heterogeneity of the lipid structure and the need for a differentiated approach to their processing.

It has been established that the internal and perirenal fat of the Yakut horse is characterised by a higher content of unsaturated fatty acids compared to subcutaneous fat deposits, which makes them most promising for use in the food industry and in the creation of functional foods. Age characteristics also affect the properties of fat: in , young animals up to 3 years of

age have a higher iodine number (91.1 ± 1.0 g I_2/100 g) and an increased content of linoleic (6.8 ± 1.0%) and linolenic (13.3 ± 0.6%) acids compared to animals aged 10-20 years (iodine value 82.5 ± 1.9 g I_2/100 g, linoleic acid 5.6 ± 0.5%, linolenic acid 10.1 ± 0.6%), while in adult animals, the fat is more stable during storage and has a higher vitamin A content (11.0 ± 0.7 IU/g versus 5.7 ± 0.6 IU/g in young animals).

The results confirm the possibility of using Yakut horse fat as a dietary product, as well as a valuable raw material for the production of food supplements and fat compositions with increased biological activity. The practical significance of the study lies in expanding the raw material base of the food industry in northern regions by involving previously underutilised slaughter products. Prospects for further research are related to the study of the rheological and crystallisation properties of Yakut horse fat, the assessment of its oxidative stability under various processing methods, as well as the development and testing of optimal technological modes that ensure the preservation of biologically active components and increase the shelf life of finished products.

Acknowledgements

None.

Funding

The research was conducted as part of the state task FWRS-2024-0025, using the equipment of the Shared Use Centre of the Federal Research Centre "Yakut Scientific Centre of the Siberian Branch of the Russian Academy of Sciences".

Conflict of Interest

None.

References

[1] Abilmazhinova, N.K. (2025). Use of horse meat trimming in the production of meat semi-finished products. In E.N. Skorikova (Ed.), *XIII international scientific and practical conference "Development of science and education: Current issues, achievements, and development prospects"* (pp. 4-11). Anapa: Innova.

[2] Álvarez, R., Meléndez-Martínez, A.J., Vicario, I.M., & Alcalde, M.J. (2015). Carotenoids and fat-soluble vitamins in horse tissues: A comparison with cattle. *Animal*, 9(7), 1230-1238. doi: 10.1017/S1751731115000415.

[3] Aroua, M., Fehri, N.E., Ben Said, S., Quattrone, A., Agradi, S., Brecchia, G., Balzaretti, C.M., Mahouachi, M., & Castrica, M. (2024). The use of horse and donkey meat to enhance the quality of the traditional meat product (kaddid): Analysis of physico-chemical traits. *Foods*, 13(18), article number 2974. doi: 10.3390/foods13182974.

[4] Ashakayeva, R., Assenova, B., Tumenova, G., Nurgazezova, A., Zhumanova, G., Atambayeva, Z., Baikadamova, A., Il, D., & Dautova, A. (2022). A pumpkin-based emulsion gel as a texture improvement of mixed horsemeat semi-smoked sausages. *Foods*, 11(23), article number 3886. doi: 10.3390/foods11233886.

[5] Belaunzaran, X., Lavín, P., Barron, L.J.R., Mantecón, A.R., Kramer, J.K.G., & Aldai, N. (2017). An assessment of the fatty acid composition of horse-meat available at the retail level in northern Spain. *Meat Science*, 124, 39-47. doi: 10.1016/j.meatsci.2016.10.014.

[6] Beldarrain, L.R., Morán, L., Sentandreu, M.Á., Insausti, K., Barron, L.J.R., & Aldai, N. (2021). Muscle and subcutaneous fatty acid composition and the evaluation of ageing time on meat quality parameters of Hispano-Bretón horse breed. *Animals*, 11(5), article number 1421. doi: 10.3390/ani11051421.

[7] Čobanović, N., Grković, N., Suvajdžić, B., Vićić, I., & Karabasil, N. (2023). Horse carcass and meat quality – current knowledge and research gaps. *Meat Technology*, 64(2), 160-165. doi: 10.18485/meattech.2023.64.2.29.

[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://eur-lex.europa.eu/eli/dir/2010/63/oj/eng.

[9] GOST 8285-91. (1992). *Rendered animal fats. Acceptance rules and testing methods*. Retrieved from https://vsegost.com/Catalog/52/5269.shtml.

[10] GOST R 50457-92. (1994). *Animal and vegetable fats and oils. Determination of acid value and acidity*. Retrieved from https://vsegost.com/Catalog/23/2346.shtml.

[11] ISO 12966-2:2017. (2017). *Animal and vegetable fats and oils – gas chromatography of fatty acid methyl esters*. Retrieved from https://www.iso.org/standard/72142.html.

[12] ISO 3657:2023. (2023). *Animal and vegetable fats and oils – determination of saponification value*. Retrieved from https://www.iso.org/standard/85171.html.

[13] ISO 3961:2024. (2024). *Animal and vegetable fats and oils – determination of iodine value*. Retrieved from https://www.iso.org/standard/89081.html.

[14] Ivanković, A., Pećina, M., Bittante, G., Amalfitano, N., Konjačić, M., & Kelava Ugarković, N. (2025). Meat production potential of local horse breeds: Sustainable conservation through valorization. *Animals*, 15(13), article number 1911. doi: 10.3390/ani15131911.

[15] Martin-Gimenez, T., Aguirre-Pascasio, C.N., & de Blas Giral, I.D. (2016). Ultrasonographic assessment of regional fat distribution and its relationship with body condition in an easy keeper horse breed. *Journal of Equine Veterinary Science*, 39, 69-75. doi: 10.1016/j.jevs.2016.01.010.

[16] Pak, M.N. (2020). *Influence of polyunsaturated fatty acids in feed on metabolic indicators in free-roaming horses of Yakutia and development of technology for obtaining a concentrate with polyunsaturated fatty acids from the internal fat of foals*. (PhD dissertation, Federal State Budgetary Scientific Institution Federal Research Center "Yakut Scientific Center of the Siberian Branch of the Russian Academy of Sciences", Yakut Scientific Research Institute of Agriculture named after M.G. Safronov, Yakutsk, Russian Federation).
[17] Pak, M.N., Evsiukova, V.K., & Vinokurov, N. (2025). Prospects for the application of Yakut horse fat: Fatty acid composition of lipids in adipose tissue. *ResearchGate Preprint*. doi: 10.13140/RG.2.2.15363.41760.
[18] Petrov, K.A., Dudareva, L.V., Nokhsorov, V.V., Stoyanov, K.N., & Makhutova, O.N. (2020). Fatty acid content and composition of the Yakutian horses and their main food source: Living in extreme winter conditions. *Biomolecules*, 10(2), article number 315. doi: 10.3390/biom10020315.
[19] Seong, P., Park, K.M., Cho, S., Kang, G.H., Chae, H.S., Park, B.Y., & Van Ba, H. (2016). Effect of cut type and post-mortem ageing on technological quality, textural profile and sensory characteristics of horse meat. *Animal Production Science*, 56(9), 1551-1559. doi: 10.1071/AN14545.
[20] Seong, P.N., Park, K.M., Kang, G.H., Cho, S.H., Park, B.Y., Chae, H.S., & Van Ba, H. (2015). The differences in chemical composition, physical quality traits and nutritional values of horse meat as affected by various retail cut types. *Asian-Australasian Journal of Animal Sciences*, 29(1), 89-95. doi: 10.5713/ajas.15.0049.
[21] Slobodchikova, M.N., Ivanov, R.V., & Vasilyeva, V.T. (2019). Yakut horse fat: A promising raw material for the production of functional food products. *Arctic XXI Century*, 1(17), 36-47.
[22] Slobodchikova, M.N., Vasileva, V.T., Ivanov, R.V., Vasileva, R.E., Stepanov, K.M., & Permyakova, P.F. (2015). Possibility of using internal fat of young Yakut horse. *Biosciences Biotechnology Research Asia*, 12(2), 1281-1285. doi: 10.13005/bbra/1782.
[23] Smanalieva, J., Ozbekova, Z., Kulmyrzaev, A., & Fischer, P. (2019). Investigation of fatty acid composition, thermal and rheological behavior of yak, cow and horse fats. *Manas Journal of Engineering*, 7(1), 24-33.
[24] Stanisławczyk, R., Żurek, J., Rudy, M., & Gil, M. (2023). Influence of horse age on carcass tissue composition and horsemeat quality: Exploring nutritional and health benefits for gourmets. *Applied Sciences*, 13(20), article number 11293. doi: 10.3390/app132011293.

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Аннотация. Бул изилдөөнүн актуалдуулугу Крайний Түндүктүн өтө төмөн температура шарттарында калыптанган жана өзгөчө физика-химиялык касиеттерге ээ болгон якут жылкысынын майынын технологиялык потенциалын илимий негиздөө зарылдыгы менен шартталат. Иштин максаты – якут жылкысынын майынын физика-химиялык жана технологиялык мүнөздөмөлөрүн комплекстүү баалоо жана аны тамак-аш өнөр жайында жана айрым азык-түлүк продуктыларын иштеп чыгууда колдонуу мүмкүнчүлүктөрүн аныктоо. Изилдөөнүн жүрүшүндө май кислоталарынын курамын талдоо үчүн газ-суюктук хроматография ыкмасы, эригичтик температурасын, йоддук жана кычкылдык көрсөткүчтөрдү аныктоонун стандарттык физика-химиялык ыкмалары, ошондой эле майдын консистенциясын жана пластикалуулугун баалоонун инструменталдык ыкмалары колдонулду. Натыйжада якут жылкысынын майында каныкпаган май кислоталарынын жетиштүү үлүшү бар экени аныкталды: олеин кислотасынын курамы 42,3-45,7 %, линол кислотасыныкы 9,8-11,6 % түздү, бул башка жылкы тукумдарын өстүрүү үчүн көрсөткүчтөрдү салыштырууга мүмкүндүк берет. Үлгүлөрдүн эригичтик температурасы негизинен 28,5-31,2 °C болду, бул майдын жогорку пластикалуулугун жана жакшы сиңимдүүлүгүн көрсөтөт. Йоддук көрсөткүчтөр 78-86 г I_2/100 г майды, кычкылдык көрсөткүчтөр 1,2-1,6 мг KOH/г түзүп, майдын жогорку сапатын жана сактоо учурунда туруктуулугун тастыктайт. Көрсөтүлгөн көрсөткүчтөрдүн жыйындысы майдын айкын эмульгирлөөчү касиеттерин жана технологиялык иштетүүгө туруктуулугун камсыз кылаары аныкталды. Иштин практикалык мааниси – алынган натыйжаларды түндүк аймактардагы эт кайра иштетүүчү жана кондитердик өнөр жай ишканалары жылкы майын кайра иштетүү технологияларын иштеп чыгууда жана биологиялык баалуулугу жогору натыйжалуу азык-түлүк продуктыларын алууда колдоно алышында

Негизги сөздөр: жылкы эти; кулун эти; май ткани; союу продуктыларынын экинчи чийки заты; көп каныкпаган май кислоталары

Технологические свойства жира якутской лошади

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Аннотация. Актуальность данного исследования обусловлена необходимостью научного обоснования технологического потенциала жира якутской лошади как уникального исходного детского мяса, формирующегося в условиях экстремально низкой температуры Крайнего Севера и обладающего отличительными физико-химическими явлениями. Целью работы стала комплексная оценка физико-химических и технологических характеристик жира якутской лошади с точки зрения возможностей его использования в пищевой промышленности и при разработке определенных продуктов питания. В ходе исследований были использованы методы газожидкостной хроматографии для анализа жирнокислотного состава, стандартные физико-химические методы определения температуры плавления, йодного и кислотного чисел, а также инструментальные методы оценки консистенции и пластичности жира. В результате установили, что жир якутской лошади содержит необходимую долю ненасыщенных жирных кислот, при этом содержание олеиновой кислоты составило 42,3-45,7 %, линолевой – 9,8-11,6 %, что позволяет рассчитывать показатели для роста других пород лошадей. Температура плавления образцов составляла в основном 28,5-31,2 °С, что свидетельствует о высокой пластичности и хорошей усвояемости изделия. Значения йодного количества составили 78-86 г I_2/100 г жира, кислотное количество – 1,2-1,6 мг КОН/г, что свидетельствует о высоком качестве и выдержке жира при хранении. Установлено, что совокупность указанных показателей обеспечивает выраженные эмульгирующие свойства жира и его технологическую устойчивость к обработке. Практическая ценность работы заключается в возможности использования результатов предприятиями мясоперерабатывающей и кондитерской промышленности северных регионов при разработке технологий переработки конского жира и получения эффективных пищевых продуктов с повышенной биологической ценностью

Ключевые слова: конина; жеребятина; жировая ткань; вторичное сырье продуктов убоя; полиненасыщенные жирные кислоты

Bulletin of the Kyrgyz National Agrarian University

Scientific Journal

Vol. 24, No. 1, 2026

Signed for print 10.03.2026
Format 60*84/8
Conventional printed pages 10.5
Circulation 100 copies

Publishing Address:
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
E-mail: info@knau-bulletin.com
https://knau-bulletin.com/en

Кыргыз улуттук агрардык университетинин Жарчысы

Илимий журнал

Көлөм 24 №1 2026

Басмага 10.03.2026-ж кол коюлган
Форматы 60*84/8
Шарттуу басма табак 10,5
Тираж 100 нуска

Редакциянын дареги:
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
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Вестник Кыргызского национального аграрного университета

Научный журнал

Том 24 №1 2026

Подписано в печать 10.03.2026 г.
Формат 60*84/8
Условн. печать. лист. 10,5
Тираж 100 экз.

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