ISSN 0370-8799 (Print)
ISSN 2658-462X (Online)

Volume 53 No 5 2023

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

No 5
Volume 53

MAY 2023

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

THE SCIENTIFIC JOURNAL

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

FOUNDERS: SIBERIAN FEDERAL SCIENTIFIC CENTRE OF AGRO-BIOTECHNOLOGIES
OF THE RUSSIAN ACADEMY OF SCIENCES
SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES

ESTABLISHED IN 1971 — 12 ISSUES PER YEAR

Volume 53, No 5 (294)
DOI: 10.26898

2023
May

www. sibvest.elpub.ru

Editors *E.M. Isaevich, E.V. Mosunova, G.N. Yagupova.* Corrector *V.E. Selianina.*
Desktop Publisher *N.U. Borisko.* Translator *M.Sh. Gacenko.*
Certificate PI FS77-64832 issued by the Federal Service for Supervision of Media,
Communications and Information Technologies on February 2, 2016
Publisher: Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Editorial and publisher's address: PO Box 463, office 456, SFSCA RAS Building, Krasnoobsk, Novosibirsk District, Novosibirsk Region, 630501, Russia.
Printing house address: room 156, SRI of Fodder Crops building, Krasnoobsk, Novosibirsk district, Novosibirsk region, 630501, Russia.
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НАУЧНЫЙ ЖУРНАЛ

СИБИРСКИЙ ВЕСТНИК СЕЛЬСКОХОЗЯЙСТВЕННОЙ НАУКИ

SIBIRSKII VESTNIK SEL'SKOKHOZYAISTVENNOI NAUKI

УЧРЕДИТЕЛИ: СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ НАУЧНЫЙ ЦЕНТР АГРОБИОТЕХНОЛОГИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК
СИБИРСКОЕ ОТДЕЛЕНИЕ РОССИЙСКОЙ АКАДЕМИИ НАУК

ОСНОВАН В 1971 г. ВЫХОДИТ 12 РАЗ В ГОД

Том 53, № 5 (294) **2023**

DOI: 10.26898 **май**

www. sibvest.elpub.ru

Редакторы *Е.М. Исаевич, Е.В. Мосунова, Г.Н. Ягупова.* Корректор *В.Е. Селянина*.
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Свидетельство о регистрации средств массовой информации ПИ ФС77-64832 выдано Федеральной службой по надзору в сфере связи, информационных технологий и массовых коммуникаций 2 февраля 2016 г.
Издатель: Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Адрес редакции и издателя: 630501, Новосибирская обл., Новосибирский р-н, р.п. Краснообск, здание СФНЦА РАН, к. 456, а/я 463
Адрес типографии: 630501, Новосибирская обл., Новосибирский р-н, р.п. Краснообск, здание СибНИИ кормов, к. 156
Тел./факс: (383)348-37-62; e-mail: sibvestnik@sfsca.ru, vestnik.nsk@ngs.ru; https://sibvest.elpub.ru/jour

Вышел в свет 20.06.2023. Формат 60 × 84 1/8. Бумага тип. № 1. Печать офсетная. Печ. л. 14,25
Уч.-изд. л. 14,25. Тираж 300 экз. Цена свободная.

Отпечатано в Сибирском федеральном научном центре агробиотехнологий Российской академии наук

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https://doi.org/10.26898/0370-8799-2023-5-1
УДК: 633.11:631.582
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ ДЛИНЫ РОТАЦИИ СЕВООБОРОТОВ И ПОГОДНЫХ УСЛОВИЙ НА ПРОДУКТИВНОСТЬ ОЗИМОЙ ПШЕНИЦЫ

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Представлены результаты исследования изменения урожайности зерна озимой пшеницы в зависимости от длины ротации севооборотов в условиях Нижнего Поволжья. В результате 12-летних исследований (2008–2019) выявлено, что максимальная урожайность получена в четырех- и пятипольном севооборотах с включением зернобобовых культур – 2,73 и 2,79 т/га соответственно. В ходе дисперсионного анализа отмечено различное воздействие условий вегетации и длины ротации севооборота на урожайность озимой пшеницы. Доля влияния условий вегетации составила 98,6%. Также значимым было влияние ротации севооборота (0,6%). Урожайность зерна озимой пшеницы существенно зависела от погодных условий, что позволило оценить в полной мере потенциал использования звена озимая пшеница – пар в севооборотах с короткой ротацией. При возделывании озимой пшеницы в четырех- и пятипольных севооборотах с включением зернобобовых культур урожайность повышалась как во влажные, так и в средние по увлажнению годы. При ГТК больше 0,9 в пятипольном севообороте урожайность зерна составила 4,40 т/га, в четырехпольном – 4,31, в трехпольном – 4,02 т/га. При ГТК от 0,6 до 0,9 в четырех- и пятипольном севооборотах урожайность варьировала в пределах 2,78–2,84 т/га, в трехпольном – 2,52 т/га. В засушливые годы не выявлено существенной разницы в урожайности озимой пшеницы между севооборотами, которая варьировала в пределах 0,98–1,07 т/га. Можно сделать вывод об эффективности возделывания озимой пшеницы на втором поле короткоротационных севооборотов по паровому предшественнику в условиях недостаточного увлажнения.

Ключевые слова: озимая пшеница, урожайность, севооборот, ротация, гидротермический коэффициент

THE EFFECT OF ROTATION LENGTH OF CROP ROTATIONS AND WEATHER CONDITIONS ON THE PRODUCTIVITY OF WINTER WHEAT

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The results of the study of changes in winter wheat grain yield depending on the rotation length of crop rotations in the Lower Volga region are presented. As a result of 12 years of research (2008-2019) it was found that the maximum yield was obtained in four- and five-field crop rotations with the inclusion of leguminous crops - 2.73 and 2.79 t/ha, respectively. During the analysis of variance, different effects of growing conditions and rotation length on winter wheat yields were noted. The influence of vegetation conditions accounted for 98.6%. The effect of crop rotation was also significant (0.6%). Winter wheat grain yield significantly depended on the weather conditions, which allowed to

fully evaluate the potential of winter wheat - fallow in crop rotations with a short rotation. When winter wheat was cultivated in four- and five-field crop rotations with the inclusion of leguminous crops, the yield increased both in wet and moderately wet years. With HTC greater than 0.9 in the five-field crop rotation the grain yield was 4.40 t/ha, in four-field - 4.31, in three-field - 4.02 t/ha. With HTC of 0.6 to 0.9 in four- and five-field crop rotations, the yield ranged from 2.78-2.84 t/ha, and in three-field crop rotations it was 2.52 t/ha. In dry years, no significant difference in winter wheat yield between crop rotations was found, which ranged from 0.98-1.07 t/ha. It can be concluded that winter wheat cultivation on the second field of short rotational crop rotations on fallow preceding crop in conditions of insufficient moisture is effective.

Keywords: winter wheat, yield, crop rotation, rotation, hydrothermal coefficient

Для цитирования: *Плаксина В.С., Асташов А.Н.* Влияние длины ротации севооборотов и погодных условий на продуктивность озимой пшеницы // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 5–12. https://doi.org/10.26898/0370-8799-2023-5-1

For citation: Plaksina V.S., Astashov A.N. The effect of rotation length of crop rotations and weather conditions on the productivity of winter wheat. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 5–12. https://doi.org/10.26898/0370-8799-2023-5-1

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

The complex of factors determining the yield of agricultural crops is associated with the bioclimatic potential, phytosanitary condition of crops, and other factors influencing plant productivity [1-3]. Winter wheat is one of the main strategic cereal crops, covering the largest cultivation area worldwide, which amounts to 240.4 million hectares, with grain gross harvests of 560 million tons [4, 5]. It exhibits high winter hardiness and resistance to edaphic stress, making it suitable for cultivation in various soil and climatic conditions[1].

In the Volga region, the cultivation area of winter wheat has significantly increased. This growth is closely related to climate change [6, 7]. Over the past ten years, the average annual air temperature in the Saratov region has risen by 0.36°C, and the winter season temperature has increased by 0.6°C, indicating that the rate of temperature rise in winter is nearly twice as high as the annual average. The total average annual precipitation in the last 30 years has increased by 24 mm, while the precipitation during May to July has decreased by 3 mm [8]. Global warming and its tendency to alter major agrometeorological characteristics have led to a rise in air temperature over the last three decades and a reduction in the duration of the winter period, creating favorable conditions for the overwintering of winter crops [9].

In the Lower Volga region, winter soft wheat significantly outperforms early spring crops in terms of yield [10]. The advantage of winter soft wheat is particularly evident during dry and drought-prone years, when the yield of winter crops surpasses that of spring crops [11, 12]. Previous studies indicate that including a fallow link, such as winter wheat, is a necessary condition to ensure sustainable productivity in arid conditions due to the low value of the hydrothermal coefficient[2].

It is essential to conduct comprehensive research to improve a scientifically-based agricultural system by studying the influence of rotation length on the productivity of winter wheat

[1]*Zhuchenko A.A.* Adaptive plant growing. Theory and practice. Moscow: Agrorus, 2002. vol. 1. 814 p.

[2]*Plaxina V., Astashov A., Bochkareva Ju., Azizov Z., Safronov A.* Improvement of the ecological sustainability of short-term rotation under the aridization conditions // IOP Conference Series: Earth and Environmental Science. Development of the Agro-Industrial Complex in the Context of Robotization and Digitalization of Production in Russia and Abroad: International Scientific and Practical Conference. DAICRA, 2022. DOI: 10.1088/1755-1315/949/1/012135.

as one of the ways to mitigate the consequences of unfavorable climatic changes.

The purpose of this research is to establish the influence of rotation length and weather conditions on the yield of winter wheat.

MATERIAL AND METHODS

The research was conducted from 2008 to 2019 at the experimental field of the Russian Research, Design and Technology Institute of Sorghum and Corn (RosNIISK "Rossorgo") in stationary crop rotations, established over time and space:

– three-field rotation: autumn fallow – winter wheat – mixed field (spring soft wheat, spring barley, corn, grain sorghum);

– four-field rotation: autumn fallow – winter wheat – soybean – mixed field (spring soft wheat, spring barley, corn, grain sorghum);

– Five-field rotation: autumn fallow – winter wheat – mixed field (grain sorghum, corn, spring barley, spring soft wheat) – chickpea – mixed field (spring soft wheat, spring barley, corn, grain sorghum).

The variety of winter soft wheat "Levoberezhnaya 3" was used as the subject of the research. Field experiments followed common practices for the region and did not involve pesticide application. The experiments were repeated three times, and systematic placement of plots was ensured. Sowing was done in optimal periods using the row method with SZ-3.6 seeders. The experiments were set up and yield measurements were conducted following standard methodologies[3]. The obtained data were statistically processed using the analysis of variance method with the AGROS software version 2.09[4, 5].

The soil of the experimental field is weakly alkaline, medium loamy chernozem of the southern type. In the plowed layer, the humus content ranged from 3.5% to 4.2%, available phosphorus from 2.4 to 12.0 mg/100 g soil, hydrolyzable nitrogen from 10 to 15, exchangeable potassium from 21 to 32, and calcium up to 8 mg/100 g.

The region has a sharply continental climate with cold and snowless winters, long springs, and dry summers. The territory of the Lower Volga region within Saratov, Volgograd, and Astrakhan regions possesses considerable radiation and thermal resources (the sum of active temperatures ranges from 2900 to 4000°C, the sum of effective temperatures from 2700 to 3600°C), a prolonged period of active vegetation but low moisture supply (P = 243–400 mm with evaporation of 800–1200 mm).

The hydrothermal coefficient is 0.6-0.7. According to the data from the Saratov AMS, the average incoming solar energy during the warm period is 356 KJ/cm, and the total radiation for the experimental zone is relatively stable. The duration of the frost-free period is 153–184 days, and the duration of the period with temperatures above 10°C is on average 150 days.

The main source of moisture is atmospheric precipitation, with an average annual norm of 391 mm. The productive moisture reserve in the soil layer of 0-100 cm during the spring, at the time of the average monthly temperature reaching 5°C, is 125–150 mm. During the period of vegetation cessation, 70–80 mm of precipitation falls. The snow cover is established in the third ten-day period of November, with a height of 27–32 cm.

Data from the reference weather station "Saratov YUVES" were used to assess weather conditions (see Table 1). The total precipitation from April to July varied from 56 mm in 2010 to 331 mm in 2017, with an average multi-year value of 251 mm. The sum of active temperatures ranged from 2970°C in 2017 to 3595°C in 2012, with an average multi-year value of 2988°C.

The Selyaninov hydrothermal coefficient for the vegetative period of winter wheat (from the beginning of spring vegetation to wax ripeness) during the years of the study ranged from 0.16 to 1.12, with an average multi-year value of 0.84. Out of the 12 years, 2008, 2013, and 2017 were favorable in terms of moisture (HTC ≥ 1.0);

[3] *Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of research results). Moscow: Book on Demand, 2012. 352 p.

[4] *Kazantsev V.P.* Field experience and basic methods of statistical analysis. Omsk: OmSAU Publishing House, 2010. 209 p.

[5] *Martynov S.P.* Statistical and biometric-genetic analysis in crop production and breeding. Program package AGROS 2.09. Tver, 1999.

Табл. 1. Характеристика погодных условий в годы исследований (от начала возобновления весенней вегетации до полной спелости)

Table 1. Characteristics of weather conditions during the years of research (from the beginning of the resumption of spring vegetation to full ripeness)

Year of research											
2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sum of active temperatures, deg.											
3137	3002	3502	3285	3595	3309	3147	3270	3271	2970	3239	3324
Total precipitation, mm											
318	156	56	133	220	289	178	416	265	331	221	182
HTC											
1,02	0,52	0,16	0,41	0,40	1,01	0,51	0,84	0,81	1,12	0,72	0,61

2009, 2014–2016, 2018, and 2019 were moderate ($0.6 \leq HTC \leq 1.0$); and 2010–2012 were dry and hot ($HTC < 0.6$). Thus, the influence of the factors under study was examined in different agrometeorological conditions, allowing for a comprehensive assessment of their impact on the yield of winter wheat.

RESULTS AND DISCUSSION

The grain yield of winter wheat varied significantly and was significantly influenced by weather conditions. The highest yield was recorded in 2017: 5 tons per hectare in the three-field rotation, 5.64 and 5.66 tons per hectare in the four- and five-field rotations, respectively. The lowest yield was observed in 2010, ranging from 0.50 to 0.52 tons per hectare, depending on the rotation. On average over the years of the study, the highest yield was obtained in the four- and five-field rotations with the inclusion of leguminous crops, amounting to 2.73 and 2.79 tons per hectare, respectively. The yield in these variants was higher by 0.22–0.28 tons per hectare compared to the three-field rotation (see Table 2).

Formation of the biological yield of any crop largely depends on the conditions of vegetation and its place in the crop rotation. The analysis of variance showed different effects of the mentioned factors on the winter wheat yield. The factor "years of the study" accounted for 98.6% of the variation in yield. The length of the crop rotation had a significant influence, accounting for 0.6%. The share of influence of the factor interaction amounted to 0.8%.

When considering the results of the research in the four- and five-field rotations, a significant increase in the performance compared to the three-field rotation was also noted. In wet years ($HTC > 0.9$), the highest yields were obtained over the average of three years for all experiment variants. The five-field rotation with chickpea showed the highest grain yield of winter wheat – 4.40 tons per hectare, while the four-field rotation with soybean had a slightly lower productivity – 4.31 tons per hectare, and the three-field rotation yielded 4.02 tons per hectare. In moderately humid years ($0.6 \leq HTC \leq 0.9$), the yield in the four- and five-field rotations ranged from 2.78 to 2.84 tons per hectare, respectively. In the three-field rotation, the yield decreased to 2.52 tons per hectare.

In dry years ($HTC < 0.6$), the average yield of winter wheat over three years varied from 0.98 to 1.07 tons per hectare, and the difference in yield between the rotations was insignificant, within the experimental error (see Table 3).

In the course of the long-term studies, it was revealed that the maximum yield of winter wheat was formed in four- and five-field crop rotations. In addition to the impact of the cropping pattern, this factor was significantly influenced by a large variety of crops, which affected the agrophysical properties of the soil and the content of basic nutrition elements. According to our long-term obser-

Табл. 2. Урожайность озимой пшеницы в экспериментальных севооборотах, т/га
Table 2. Yield of winter wheat in experimental crop rotations, t/ha

Year (factor A)	Crop rotation (factor B)			Average for factor A
	three-field	four-field	five-field	
2008	4,37	4,32	4,76	4,48j
2009	3,52	3,72	3,82	3,69i
2010	0,52	0,50	0,51	0,51a
2011	1,30	1,39	1,45	1,38c
2012	1,12	1,21	1,25	1,19b
2013	2,68	2,98	2,79	2,82g
2014	1,63	1,80	2,06	1,83d
2015	2,10	2,29	2,27	2,22f
2016	1,94	1,97	2,01	1,97e
2017	5,00	5,64	5,66	5,43k
2018	2,90	3,60	3,61	3,37
2019	3,04	3,29	3,25	3,31h
Average for factor B	2,51a	2,73b	2,79c	

Experimental error (P) = 2,29%

$LSD_{05(A)}$ = 0,100, $LSD_{05(B)}$ = 0,050, $LSD_{05(AB)}$ = 0,173

$F_{fact\ (A)}$ = 1651,682*, $F_{factr\ (B)}$ = 53,499*, $F_{fact\ (AB)}$ = 6,883*

Note. Data labeled with different letters are significantly different according to Duncan's multiple comparisons test at $p \leq 0,05$.

vations, the amount of productive moisture under winter crops in the soil layer 0-100 cm in spring (annual maximum) in most years (more than 75%) did not reach the field moisture capacity.

Spring melt water did not have a significant effect on nitrate nitrogen content by flushing it through the soil profile. Thus, in spring in winter wheat crops in the phase of the booting start in the soil layer 0-50 cm in three-field crop rotation remained 3.3 mg/kg of nitrogen, in five-field crop rotation 3.6 mg/kg, in the layer 50-100 cm - 7.1 and 9.1 mg/kg, respectively. It should be noted that in all the layers of the soil profile the nitrate nitrogen content in the five-field rotation was higher than in the three-field rotation. As for other macroelements, for example, mobile phosphorus, unlike nitrate nitrogen, during the period of soil assimilation of spring melt water 80-90% of its content in the studied profile of 0-100 cm did not shift and was in the 0-50 cm layer. Exchangeable potassium was more mobile than phosphorus, so its content in the 0-50 cm soil layer was 40-45%. When considering this regularity in relation to different types of crop rotations, the following should be noted. In the three-field grain and fallow crop rotation the soil layer of 0-50 cm contained a greater amount of mobile phosphorus and exchangeable potassium (46.5 and 365 mg/kg, respectively) compared to the five-field grain and fallow crop rotation (42.8 and 357 mg/kg). It was found that in the conditions of the steppe zone of the Volga region due to uneven precipitation during the year and a number of years plant residues do not have time to decompose completely. In dry years their accumulation in the soil occurs, in humid years, on the contrary, their decrease is observed due to the increase in the intensity of decomposition.

Табл. 3. Урожайность озимой пшеницы в разные по увлажнению годы, т/га
Table 3. Winter wheat yields in different moisture years, t/ha

Moisture content on average by years	Crop rotation		
	three-field	four-field	five-field
Wet (2008, 2013, 2017)	4,02	4,31	4,40
P (experimental error) = 3,03%, F_{fact} = 106,124*, $LSD_{0,05}$ = 0,123			
Medium (2009, 2014–2016, 2018, 2019)	2,52	2,78	2,84
P (experimental error) = 2,01%, F_{fact} = 8,631*, $LSD_{0,05}$ = 0,180			
Dry (2010–2012)	0,98	1,03	1,07
P (experimental error) = 2,54%, F_{fact}=3006, $LSD_{0,05}$ = ns			

*$p \leq 0,05$.

Thus, it has been revealed that with a decrease in the rotation length due to an increase in the share of fallow in the cropping structure, the amount of poorly hydrolyzable organic residues that enter the fallow field increases, leading to a decrease in the yield of winter wheat in wet years. On average over the last 12 years, its yield in the three-field rotation was 2.51 tons per hectare. In the four- and five-field rotations, where leguminous crops with soil-improving potential were present, the yield was 2.73 and 2.79 tons per hectare, respectively.

CONCLUSION

As a result of the comparative assessment of winter wheat yield depending on the weather conditions and the length of crop rotations in the Lower Volga region, it was found that stable yields were achieved in all rotations, and growing winter wheat as the second crop in short-rotation crop systems after fallow was justified. However, the data obtained during the research showed that the grain yield of winter wheat varied significantly and depended on the weather conditions, allowing for a comprehensive evaluation of the potential use of the winter wheat - fallow link in short rotations. The highest grain yield was obtained in the years with HTC greater than 0.9, and slightly lower yields were observed in the years with HTC from 0.6 to 0.9. In these years, the highest yields were obtained in the four- and five-field rotations with the inclusion of leguminous crops, which facilitate nitrogen fixation and accumulation, providing a prolonged effect. In dry years, no significant difference in the yield of winter wheat was observed between rotations.

СПИСОК ЛИТЕРАТУРЫ

1. *Лихацевич А.П.* Риски в земледелии: оценка влияния погодных условий на урожайность зерновых культур в Белорусском Полесье // Известия Национальной академии наук Беларуси. Серия аграрных наук. 2022. Т. 60. № 3. С. 279–295. DOI: 10.29235/1817-7204-2022-60-3-279-295.
2. *Кардашина В.Е., Николаева Л.С.* Влияние агрометеорологических условий на урожайность и развитие овса // Пермский аграрный вестник. 2018. № 1 (21). С. 69–76.
3. *Яроменко Н.Н., Кулак А.А., Овсиенко А.А.* Эконометрический анализ факторов, влияющих на урожайность зерновых (на примере сельскохозяйственных организаций центральной зоны Краснодарского края) // Естественно-гуманитарные исследования. 2020. № 4 (30). С. 269–274. DOI: 10.24411/2309-4788-2020-10428.
4. *Федорова В.А.* Экологическая пластичность и стабильность перспективных сортов озимой мягкой пшеницы в зоне Северного Прикаспия // Аграрный научный журнал. 2021. № 6. С. 39–42. DOI: 10.28983/asj.y2021i6pp39-42.
5. *Скворцова Ю.Г., Филенко Г.А., Фирсова Т.И., Черткова Н.Г., Калинина Н.В.* Оценка урожайности и посевных качеств у сортов озимой мягкой пшеницы селекции ФГБНУ АНЦ «Донской» в первичном семеноводстве // Зер-

новое хозяйство России. 2021. № 5. С. 24–28. DOI: 10.31367/2079-8725-2021-77-5-24-28.
6. *Левицкая Н.Г., Демакина И.И.* Агрометеорологические особенности засухи 2018 года и ее влияние на урожайность зерновых культур в Саратовской области // Аграрный вестник Юго-Востока. 2019. № 2. С. 19.
7. *Ермошкина Н.Н., Артемова Г.В., Степочкин П.И., Сурначев А.С., Мусинов К.К.* Влияние условий осенней вегетации на перезимовку озимой ржи и пшеницы при разных сроках посева // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 2. С. 30–39. DOI: 10.26898/0370-8799-2021-2-4.
8. *Левицкая Н.Г., Демакина И.И.* Современные изменения климата Саратовской области и стратегия адаптации к ним селекции и агротехнологий // Успехи современного естествознания. 2019. № 10. С. 7–12. DOI: 10.17513/use.37206.
9. *Солодовников А.П., Уполовников Д.А., Линьков А.С., Полетаев И.С., Лёвкина А.Ю.* Обоснование влияния агрофизических факторов и климатических условий на урожайность и качество зерна озимой пшеницы в Нижнем Поволжье // Аграрный научный журнал. 2022. № 4. С. 48–52. DOI: 10.28983/asj.y2022i4pp48-52.
10. *Азизов З.М.* Урожайность озимой пшеницы, проса, яровой пшеницы в севообороте по мере удаления от лесополосы по приемам основной обработки почвы и азотных удобрений // Аграрный научный журнал. 2019. № 4. С. 4–9. DOI: 10.28983/asj.y2019i4pp4-9.
11. *Сайфуллина Л.Б., Азизов З.М., Имашев И.Г., Архипов В.В., Бажан Г.Н.* Влияние систем основной обработки почвы на реализацию биологического потенциала сорта озимой пшеницы Калач 60 // Аграрный вестник Юго-Востока. 2019. № 2 (22). С. 27–32.
12. *Азизов З.М., Архипов В.В., Имашев И.Г.* Устойчивость производства зерна в севооборотах степи Нижнего Поволжья // Аграрный научный журнал. 2020. № 7. С. 4–9. DOI: 10.28983/asj.y2020i7pp4-9.

REFERENCES

1. Lixacevich A.P. Risks in agriculture: assessment of influence of weather conditions on the grain crops yield in Belarusian Polesye. *Izvestiya Nacional`noj akademii nauk Belarusi. Seriya agrarny`x nauk = Proceedings of the National Academy of Sciences of Belarus. Agrarian series*, 2022, vol. 60, no. 3, pp. 279–295. (In Belarus). DOI: 10.29235/1817-7204-2022-60-3-279-295.
2. Kardashina V.E., Nikolaeva L.S. Influence of agro-meteorological conditions on yield capacity and development of oats. *Permskij agrarny`j vestnik = Perm Agrarian Journal*, 2018, no. 1 (21), pp. 69–76. (In Russian).
3. Yaromenko N.N., Kulak A.A., Ovsienko A.A. Econometric analysis of factors affecting grain yield (on the example of agricultural organizations in the central zone of the Krasnodar Territory). *Estestvenno-gumanitarny`e issledovaniya = Natural-Humanitarian Research*, 2020, no. 4 (30), pp. 269–274. (In Russian). DOI: 10.24411/2309-4788-2020-10428.
4. Fedorova V.A. Ecological plasticity and stability of promising varieties of winter soft wheat in the Northern Caspian region. *Agrarny`j nauchny`j zhurnal = Agrarian Scientific Journal*, 2021, no. 6, pp. 39–42. (In Russian). DOI: 10.28983/asj.y2021i6pp39-42.
5. Skvortsova Yu.G., Filenko G.A., Firsova T.I., Chertkova N.G., Kalinina N.V. Estimation of productivity and sowing qualities of the winter bread wheat varieties of the FSBSI “ARC “Donskoy” in the primary seed production. *Zernovoe xozyajstvo Rossii = Grain Economy of Russia*, 2021, no. 5, pp. 24–28. (In Russian). DOI: 10.31367/2079-8725-2021-77-5-24-28.
6. Levitskaya N.G., Demakina I.I. Agrometeorological features of the drought of 2018 and its impact on the yield of grain crops in the Saratov region. *Agrarny`j vestnik Yugo-Vostoka = Agrarian Reporter of South-East*, 2019, no. 2, p. 19. (In Russian).
7. Ermoshkina N.N., Artemova G.V., Stepochkin P.I., Surnachev A.S., Musinov K.K. Effect of autumn vegetation conditions on overwintering of winter rye and wheat with different sowing dates. *Sibirskij vestnik sel`skoxozyajstvennoj nauki = Siberian Herald of Agricultural Science*, 2021, vol. 51, no. 2, pp. 30–39. (In Russian). DOI: 10.26898/0370-8799-2021-2-4.
8. Levitskaya N.G., Demakina I.I. Modern climate changes in the Saratov region and the strategy of adaptation of breeding and agrotechnologies to them. *Uspehi sovremennogo estestvoznaniya = Advances in Current Natural Sciences*, 2019, no. 10, pp. 7–12. (In Russian). DOI: 10.17513/use.37206.
9. Solodovnikov A.P., Upolovnikov D.A., Linkov A.S., Poletaev I.S., Levkina A.Yu. Sub-

stantiation of the influence of agrophysical factors and climatic conditions on the yield and quality of winter wheat grain in the Lower Volga region. *Agrarny`j nauchny`j zhurnal = Agrarian Scientific Journal*, 2022, no. 4, pp. 48–52. (In Russian). DOI: 10.28983/asj.y2022i4pp48-52.
10. Azizov Z.M. Yield of winter wheat, millet, spring wheat in the crop rotation from distance of forest shelterbelt by basic soil tillage method and nitrogen fertilizer. *Agrarny`j nauchny`j zhurnal = Agrarian Scientific Journal*, 2019, no. 4, pp. 4–9. (In Russian). DOI: 10.28983/asj.y2019i4pp4-9.
11. Sayfullina L.B., Azizov Z.M., Imashev I.G., Arkhipov V.V., Bazhan G.N. Influence of tillage treatments on realization of biological potential of winter wheat variety Kalach 60. *Agrarny`j vestnik Yugo-Vostoka = Agrarian Reporter of South-East,* 2019, no. 2 (22), pp. 27–32. (In Russian).
12. Azizov Z.M., Arkhipov V.V., Imashev I.G. Stability of grain production in crop rotations in the steppe conditions of the Lower Volga region. *Agrarny`j nauchny`j zhurnal = Agrarian Scientific Journal*, 2020, no. 7, pp. 4–9. (In Russian). DOI: 10.28983/asj.y2020i7pp4-9.

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Дата поступления статьи / Received by the editors 22.08.2022
Дата принятия к публикации / Accepted for publication 12.10.2022
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-2
УДК: 634.34:631.67
Тип статьи: оригинальная
Type of article: original

РЕАКЦИЯ РАСТЕНИЙ СОИ НА ИНОКУЛЯЦИЮ СЕМЯН И РЕЖИМЫ ОРОШЕНИЯ СВЕТЛО-КАШТАНОВЫХ ПОЧВ В УСЛОВИЯХ НИЖНЕГО ПОВОЛЖЬЯ

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Цель исследования – выявить реакцию растений сои на инокуляцию семян при разных режимах орошения (влажность не ниже 80% НВ в слоях 0,4 и 0,6 м, дифференцированный по фазам роста и развития водный режим на уровне 70–80–70% НВ в слоях 0,4 и 0,6 м) в условиях Нижнего Поволжья. Объект исследования – посевы сои сорта Волгоградка 2 селекции Всероссийского научно-исследовательского института орошаемого земледелия (ВНИИОЗ). Эксперимент проводили в 2021 и 2022 гг. на опытном поле ВНИИОЗ. В качестве инокулянта использовали препарат Геостим Фит Г производства компании Биотехагро (г. Тимашевск, Краснодарский край) в концентрации 5–10 л/га. Для внекорневой подкормки применяли биопрепараты, природный минерал билатор и фунгицид Колосаль Про. На основании полученных данных установлено, что максимальный прирост продуктивности (132%) получен при инокуляции семян перед посевом на варианте с уровнем влажности почвы 80% НВ. При дифференцированном водном режиме продуктивность составила 129% по сравнению с необработанным контролем. Из средств, применяемых в период вегетации для борьбы с патогенами, предпочтение следует отдать биопрепаратам. Объем собранного зерна был максимальным (3,87 т/га) в контрольном варианте при влажности почвы 80% НВ и использовании инокуляции семян. Второй результат по продуктивности показал вариант с применением природного минерала билатор (3,38 т/га), минимальная урожайность (2,86 т/га) зафиксирована в случае использования химического препарата Колосаль Про. Расчет экономической эффективности показал выгодность обработки посевов сои биопрепаратами. Научная новизна исследования состоит в том, что в ходе его проведения впервые для условий Нижнего Поволжья определена эффективность возделывания сои с учетом влияния сразу нескольких факторов: водный режим почвы, предпосевная обработка семян инокулянтами, обработка растений в период вегетации для борьбы с патогенами.

Ключевые слова: соя, режимы орошения, сорт Волгоградка 2, инокуляция, продуктивность, биопрепараты, билатор, химические средства защиты растений

REACTION OF SOYBEAN PLANTS TO SEED INOCULATION AND DIFFERENT IRRIGATION REGIMES OF LIGHT CHESTNUT SOILS OF THE LOWER VOLGA REGION

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The purpose of the research is to find out the reaction of soybean plants to seed inoculation under different irrigation regimes (humidity not lower than 80% MWC (minimum water capacity) in the layers 0,4 and 0,6 m, differentiated by stages of growth and development water regime at the level of 70-80-70% MWC in the layers 0,4 and 0,6 m) in the Lower Volga region conditions. The object of the study is soybean crops of the Volgogradka 2 variety selected by the All-Russian Scientific Research Institute of Irrigated Agriculture (VNIIOZ). The experiment was conducted in 2021 and 2022 on the experimental field of VNIIOZ. Geostim Fit G produced by Biotechagro (Timashevsk, Krasnodar Territory) was used as

an inoculant at a concentration of 5-10 l/ha. For foliar feeding biopreparations, natural mineral bilator and fungicide Kolosal Pro were used. Based on the data obtained, it was found that the maximum increase in productivity (132%) was obtained by seed inoculation before sowing in the variant with a soil moisture level of 80% MWC. With differentiated water treatment, the productivity was 129% compared to the untreated control. Of the agents used during the growing season to control pathogens, preference should be given to biopreparations. The volume of the harvested grain was maximum (3.87 t/ha) in the control variant with soil moisture of 80% MWC and the use of seed inoculation. The second result in terms of productivity showed the variant with the use of natural mineral bilator (3.38 t/ha), the minimum yield (2.86 t/ha) was recorded in the case of using the chemical agent Kolosal Pro. The calculation of economic efficiency showed the profitability of soybean crops treatment with biological preparations. The scientific novelty of the study is that in the course of its implementation for the first time for the conditions of the Lower Volga region the efficiency of soybean cultivation was determined taking into account the influence of several factors at once: soil water regime, seed pre-sowing treatment with inoculants, treatment of plants during vegetation to control pathogens.

Keywords: soybeans, irrigation regimes, Volgogradka 2 variety, inoculation, productivity, biologics, bilator, chemical plant protection products

Для цитирования: *Москвичев А.Ю., Агапова С.А.* Реакция растений сои на инокуляцию семян и режимы орошения светло-каштановых почв в условиях Нижнего Поволжья // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 13–21. https://doi.org/10.26898/0370-8799-2023-5-2

For citation: Moskvichev A.Yu., Agapova S.A. Reaction of soybean plants to seed inoculation and different irrigation regimes of light chestnut soils of the Lower Volga region. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 13–21. https://doi.org/10.26898/0370-8799-2023-5-2

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

In current economic conditions, great importance is given to resource-saving cultivation technologies of agricultural crops [1]. One of the most economical and accessible methods of providing plants with nitrogen during the vegetation period is symbiotic nitrogen fixation from the air [2]. In this regard, the development of agronomic practices that increase the activity of symbiotic nitrogen fixation and enhance the yield and protein productivity of leguminous crops is of theoretical and practical interest [3]. For example, new soybean varieties grown using innovative agronomic techniques can produce at least 3 tons of seeds per hectare [4]. One of the main agronomic practices used in soybean cultivation is seed inoculation with nitrogen-fixing bacteria [5, 6].

Currently, there is a growing demand worldwide for the quality of agricultural products [7], leading to the adoption of environmentally safe methods for obtaining these products, such as seed bacterization with nitrogen-fixing bacteria [8, 9].

Soybean is one of the most important protein and oil crops used in the food and technical industries, as well as in feed production and livestock farming [10, 11]. The oil content in its seeds is over 20%, and the protein content is not less than 40%. Soybean protein is characterized by high physiological value and a rich amino acid composition[1]. Due to these properties, soybeans are a complete product for meeting the energy and protein needs of humans and animals [12, 13].

The research aims to determine the effectiveness and impact of seed inoculation

[1]*Ibragimov A.D.* Soybean - a unique protein-oilseed crop // Innovative approach in the strategy of development of agro-industrial complex of Russia: collection of materials of the scientific works of the All-Russian scientific and practical conference. Makhachkala, 2018. pp. 40-44.

on soybean plants under different soil irrigation regimes in the conditions of the Lower Volga region.

MATERIAL AND METHODS

The research was conducted in 2021 and 2022 at the experimental field of the All-Russian Research Institute of Irrigated Agriculture. The object of the study was the crops of early-maturing soybean variety Volgogradka 2[2] [14].

The experiment involved studying two soil irrigation regimes:

1. Maintaining a differentiated 70-80-70% MWC level (minimum water capacity) at a moisture depth (h) of 0.4 and 0.6 meters with the following scheme: from sowing to the end of plant branching - 70% MWC in the 0.4-meter layer, from the beginning of flowering to the end of grain filling - 80% MWC in the 0.4-meter layer, from the end of grain filling to full maturity - not less than 70% MWC in the 0.6-meter layer.

2. Maintaining the pre-irrigation moisture threshold at a level not less than 80% MWC in the 0.4-meter layer from sowing to the end of plant branching and 0.6 meters from the beginning of flowering to full grain maturity[3].

Based on these irrigation regimes, the effectiveness of soybean seed inoculation with a mixture of biological components was studied. The mixture consisted of Geostim Fit G - 5-10 liters/ha, Improver - 20 ml/ton, and Helios Super - 1-2 liters/ton. The control group included non-inoculated seeds and non-treated vegetating plants, as well as inoculated seeds without treatment. In addition to seed inoculation and the described irrigation regimes, the possibility of foliar application of various nature-based preparations was considered. These included biopreparations (Geostim Fit Zh - 1-2 liters/ha + BFTIM - 2-4 liters/ha + Improver - 50 ml/100 liters of solution + Humel Lux - 1 liter/ha + Helios Bor Molybdenum - 0.7-2.0 liters/ha), natural mineral bilator, and fungicide Colossal Pro.

Geostim Fit G is a microbiological biodegrader of plant residues with powerful fungicidal properties, used to accelerate the decomposition of plant residues in the soil's surface layer, suppress the development of phytopathogens, and stimulate plant growth and development. The preparation contains saprophytic fungus Trichoderma viride, associative nitrogen-fixing bacteria Azomonas agilis, and Azotobacter chroococcum. Advantages of the Geostim preparation include:

1) protects plants from a wide range of fungal diseases;

2) improves soil structure;

3) increases yield;

4) safe for plants, animals, and humans;

5) does not lead to soil, air, and water pollution;

6) facilitates better absorption of mineral nutrients by plants.

BFTIM Bactericide contains Bacillus amyloliquefaciens KC-2 bacteria and their metabolites. The product is used for seed treatment. The working solution is prepared immediately before use, and it can be combined with herbicides, insecticides, chemical fungicides, and micronutrients. Advantages of BFTIM:

1) effectively protects against fungal and bacterial diseases;

2) has growth-stimulating effects and strengthens the plants' immune status;

3) can be combined with chemical pesticides in tank mixtures in integrated plant protection systems;

4) does not lead to phytopathogen resistance;

5) does not cause soil, air, and water pollution;

6) can be applied at any stage of plant development, with a waiting period of 1 day;

7) harmless to humans, animals, birds, fish, and insects.

[2]Pat. No. 11288, Russian Federation. Breeding achievement "Soybean variety Volgogradka 2" / Tolokonnikov V.V., Kantser G.P., Kruzhilin I.P., Melikhov V.V., Taranov M.I., Ovchinnikov A.S., Novikov A.A., Koshkarova T.S., Ileneva S.V., Chamurliev G.O.; applicants Volgograd State Agrarian University, All-Russian Research Institute of Irrigated Agriculture; published 20.10.2020.

[3]*Ivanov A.L., Kulik K.N.* System of adaptive-landscape farming of Volgograd region for the period up to 2015. Volgograd, 2009. 302 p.

Bilator is an innovative and highly effective complex agent that stimulates plant growth and development. The product is a water-suspension concentrate of nanoscale structured magnesium chloride. It is used for seed encrustation and foliar treatment of leguminous, cereal, and oil crops. Bilator contributes to:

1) increased crop yield of agricultural crops;

2) improved germination and seedling vigor;

3) formation of a robust root system;

4) suppression of the development of disease-causing agents;

5) enhanced drought and frost resistance of plants;

6) increased resistance to pests.

Colossal Pro is a two-component systemic fungicide that provides long-lasting protection for cereals, sugar beets, grapes, rapeseed, soybeans, peas, and other crops against a wide range of diseases. The product contains tebuconazole (200 g/l) and propiconazole (300 g/l). Advantages of Colossal Pro are:

1) broad spectrum of controlled pathogens;

2) high penetrating ability;

3) quick fungicidal action;

4) excellent systemic properties;

5) extended protection period.

These products were used when diseases and pests were detected on soybean plants before the bean ripening period.

The total area of the plots was 2363 m^2, with 1182 m^2 for first-order plots, 393 m^2 for second-order plots, and 98.25 m^2 for third-order plots. The soil of the experimental plot was light chestnut heavy loamy, with a relatively thin humus layer (0-0.28 m) and a humus content of 1.3-1.4%. The soil had a weakly alkaline reaction, with a pH of 7.2-7.7 in a water extract. The soil showed low nitrogen content, moderate available phosphorus, and increased exchangeable potassium levels. The natural soil bulk density for the calculated layers of 0-0.4 m and 0-0.6 m was 1.38 and 1.43 g/cm^3, respectively. Porosity ranged from 46.64 to 51.59% in different layers. The planting method was wide-row planting with inter-row spacing of 0.7 m. The seeding was done in the second decade of May using the Mater Makk seeder with a seeding rate of 600,000 viable seeds/ha.

RESULTS AND DISCUSSION

Before the combine (mass) harvesting of the crop, sheaves were selected, and the biological yield per 1 m^2 was recorded. The analysis of the selected sheaves allowed determining the main parameters of the crop structure: grain weight per plant, weight of 1000 grains, height of the attachment of the lowest pod (see Table 1), as well as the number of pods per plant, number of grains in the pods, and the weight of a single plant.

The data presented in Table 1 demonstrate the advantage of maintaining soil moisture levels not below 80% of minimum water capacity (MWC) at the depths of 0.4 and 0.6 meters.

Moreover, two selected water regimes showed the superiority of the seed treatment with inoculant compared to non-inoculated variants. Differences in crop structure parameters were observed in the second-order plots when using plant protection products during the vegetation period. For instance, in the variant with differentiated soil moisture regime (70-80-70% MWC at the depths of 0.4 and 0.6 meters) without inoculation and foliar treatment, the grain weight per plant was minimal and averaged 3.79 g, and the weight of 1000 grains was 102.5 g. The best results (5.48 g and 133.03 g, respectively) were obtained when using bio-preparations, slightly lower results were achieved with bilator (4.85 g and 124.03 g) and fungicide (4.34 g and 111.50 g). A similar trend was observed in the variant with differentiated irrigation and seed inoculation. The highest values of grain weight per plant and the weight of 1000 grains were recorded when using a bio-preparation (8.22 g and 144.03 g), and the lowest values were achieved with the fungicide (5.58 g and 118.75 g).

When maintaining the pre-irrigation moisture threshold at the level of not less than 80% MWC in the layers of 0.4 and 0.6 m in the control variant (without inoculation and without treatment), the weight of grains from one plant was equal to 6.03 g, the weight of 1 thousand grains - 116.85 g. When using different

Табл. 1. Влияние изучаемых факторов на структуру урожая сои сорта Волгоградка 2
Table 1. The influence of the studied factors on the structure of the soybean crop of the Volgogradka 2 variety

Experiment option			Grain weight per plant, g			Weight of 1 thousand grains, g			Lower bean attachment height, m		
			2021	2022	Average	2021	2022	Average	2021	2022	Average
70–80–70% MWC, h = 0,4 and 0,6 m	Without inoculation	Control	3,80	3,78	3,79	101,20	103,80	102,50	0,10	0,13	0,12
		Biopreparation	5,52	5,44	5,48	131,80	134,25	133,03	0,12	0,16	0,14
		Bilator	4,88	4,82	4,85	122,70	125,35	124,03	0,11	0,15	0,13
		Fungicide	4,36	4,31	4,34	110,50	112,50	111,50	0,10	0,13	0,12
	With inoculation	Control	5,46	5,31	5,39	110,30	113,20	111,75	0,11	0,14	0,13
		Biopreparation	8,19	8,24	8,22	141,95	146,10	144,03	0,13	0,17	0,15
		Bilator	6,74	6,69	6,72	130,60	134,30	132,45	0,12	0,15	0,14
		Fungicide	5,60	5,56	5,58	115,20	122,30	118,75	0,11	0,14	0,13
80% MWC, h = 0,4 and 0,6 m	Without inoculation	Control	6,00	6,05	6,03	119,10	114,60	116,85	0,11	0,15	0,13
		Biopreparation	8,30	8,29	8,30	149,00	144,90	146,95	0,13	0,18	0,16
		Bilator	7,10	7,02	7,06	138,60	133,80	136,20	0,13	0,16	0,15
		Fungicide	6,80	6,65	6,73	126,90	120,45	123,68	0,11	0,15	0,13
	With inoculation	Control	7,20	7,29	7,25	132,90	131,25	132,08	0,11	0,16	0,14
		Biopreparation	10,30	10,21	10,26	157,00	155,90	156,45	0,14	0,19	0,17
		Bilator	9,00	8,96	8,98	148,10	144,95	146,53	0,12	0,18	0,15
		Fungicide	7,60	7,49	7,55	139,70	137,90	138,80	0,11	0,17	0,14

preparations during the growing season, these indicators were slightly higher compared to the control values. In the control variant with inoculation, the average value of the above parameters of the yield structure amounted to 7.25 and 132.08 g, respectively. Inoculation and treatment were the highest in the variant with the use of the biopreparations - 10.26 and 156.45 g. Treatment of crops with natural mineral bilator and chemical plant protection agents gave intermediate results between the control and the use of biopreparations.

The height of the lower bean attachment also differed among the experiment variants, but still the difference was insignificant and was within the range of 0.12-0.17 m.

The result of any research in agricultural practice is the determination of the most important parameter - productivity of the crop under study. It is by its value that the effectiveness of any factors is evaluated.

Table 2 shows that in the variant with differentiation of water regime and soil moisture depth by phases of growth and development of soybean plants (70-80-70% MWC, h = 0.4 and 0.6 m) without seed inoculation and leaf treatment the minimum yield was observed, which averaged 1.43 t/ha for two years of research. When the seeds were treated with the inoculant and vegetative plants with the biopreparation, productivity increased, reaching 2.78 t/ha.

When soil water regime was maintained at 80% MWC in 0.4 and 0.6 m layers and seed inoculation was combined with foliar fertilization with the biopreparation, maximum

Табл. 2. Продуктивность сои сорта Волгоградка 2 на различных вариантах
Table 2. Volgogradka 2 soybean variety productivity on different options

Experiment option			Yield, t/ha			Gain	
			2021	2022	Average	t/ha	%
70–80–70% MWC, *h* = 0,4 and 0,6 m	Without inoculation	Control	1,44	1,42	1,43	–	–
		Biopreparation	2,12	1,99	2,06	0,63	44,10
		Bilator	1,87	1,76	1,82	0,39	27,30
		Fungicide	1,66	1,61	1,64	0,21	14,70
	With inoculation	Control	1,95	1,86	1,91	–	–
		Biopreparation	2,71	2,85	2,78	0,87	45,60
		Bilator	2,49	2,38	2,44	0,53	27,70
		Fungicide	2,09	2,01	2,05	0,14	7,30
80% MWC, *h* = 0,4 and 0,6 m	Without inoculation	Control	2,15	2,14	2,15	–	–
		Biopreparation	2,93	2,78	2,86	0,71	33,00
		Bilator	2,61	2,53	2,57	0,42	19,50
		Fungicide	2,29	2,31	2,30	0,15	7,00
	With inoculation	Control	2,77	2,67	2,72	–	–
		Biopreparation	3,90	3,84	3,87	1,15	42,30
		Bilator	3,42	3,34	3,38	0,66	24,30
		Fungicide	2,91	2,81	2,86	0,14	5,10

Note. 2021: LSD_{05} A = 0,19, LSD_{05} B = 0,11, LSD_{05} C = 0,09, LSD_{05} ABC = 0,16; 2022: LSD_{05} A = 0,20, LSD_{05} B = 0,12, LSD_{05} C = 0,10, LSD_{05} ABC = 0,16

yield was obtained, which averaged 3.87 t/ha over two years, which was 1.15 t/ha more compared to the untreated control.

Next, let's consider the economic efficiency of the studied agricultural technique. Economic efficiency is the result of the impact of the studied factors in monetary terms, determined by comparing the total costs with the value of the entire crop (increment). When calculating economic efficiency, the following indicators should be taken into account: the cost of the obtained crop, the expenses for purchasing, delivering, and applying plant protection products. The total costs should also include the costs of harvesting and processing the additional crop obtained as a result of using plant protection products. In our case, the cost of the crop obtained in 2022 was 35 rubles per kilogram, the price of bio-preparations was 905 rubles, bilator was 150 rubles, and the fungicide was 1391 rubles.

Analysis of economic efficiency showed that the use of seed inoculation in the studied variants of soil moisture is an economically beneficial agricultural technique (see Table 3). Thus, at 70-80-70% MWC at the depths of 0.4 and 0.6 meters, the profitability ranged from 98.2% to 148.1%, without inoculation, the indicators were lower - from 33.5% to 84.0%. In the control variant, the value of this parameter varied from 148.3% to 238.3% and from 96.5% to 150.2%, respectively.

All of this affected the production cost. With a differentiated water regime and no seed inoculation, it ranged from 19.0 to 26.2 thousand rubles per ton, while in the inoculated variant, it ranged from 14.1 to 19.3 thousand rubles per ton. With 80% MWC at the depths of 0.4 and 0.6 meters, the production cost in the variants without inoculation varied from 14.0 to 17.8 thousand rubles per ton, while in the variants with inoculation, it ranged from 10.3 to 14.1 thousand rubles per ton.

Табл. 3. Оценка экономической эффективности использования изучаемых режимов орошения и препаратов при возделывании сои сорта Волгоградка 2 (2021, 2022 гг.)

Table 3. Assessment of economic efficiency of the studied irrigation regimes and preparations in the cultivation of the Volgogradka 2 soybean variety (2021, 2022)

Indicator	Without inoculation				With inoculation			
	Control	Bio-preparation	Bilator	Fungicide	Control	Bio-preparation	Bilator	Fungicide
Differentiated soil water regime: 70–80–70% MWC, h = 0,4 and 0,6 m								
Yield, t/ha	1,43	2,06	1,82	1,64	1,91	2,78	2,44	2,05
Sales price, kg/roubles	35,0	35,0	35,0	35,0	35,0	35,0	35,0	35,0
Cost of gross output, thousand rubles/ha	50,05	72,1	63,7	57,4	66,85	97,3	85,4	71,75
Expenses of funds, thousand rubles/ha	37,48	39,11	38,40	39,38	37,52	39,22	38,44	39,42
Cost price of grain, thousand rubles/t	26,2	19,0	21,1	24,0	19,3	14,1	15,8	19,2
Net income, thousand rubles/ha	12,57	32,99	25,30	18,03	29,33	58,08	46,96	32,33
Profitability level, %	33,5	84,4	65,9	45,8	78,2	148,1	122,1	82,0
Control soil water regime: 80% MWC, h = 0,4 and 0,6 m								
Yield, t/ha	2,15	2,86	2,57	2,3	2,72	3,87	3,38	2,86
Sales price, kg/roubles	35,0	35,0	35,0	35,0	35,0	35,0	35,0	35,0
Cost of gross output, thousand rubles/ha	75,25	100,1	89,95	80,5	95,2	135,45	118,3	100,1
Expenses of funds, thousand rubles/ha	38,3	40,0	39,22	40,2	38,3	40,0	39,3	40,2
Cost price of grain, thousand rubles/t	17,8	14,0	15,3	17,5	14,1	10,3	11,6	14,1
Net income, thousand rubles/ha	36,95	60,10	50,72	40,30	56,86	95,41	79,03	59,86
Profitability level, %	96,5	150,2	129,3	100,3	148,3	238,3	201,3	148,8

CONCLUSIONS

1. In the conditions of the Lower Volga region, pre-sowing seed inoculation and treatment of the growing soybean plants with biological preparations contribute to reducing disease and pest damage.

2. Based on the results of the conducted research, the following variant should be considered as the best: soil moisture regime at 80% minimum water capacity (MWC) at the depths of 0.4 and 0.6 meters + seed inoculation before sowing (Geostim Fit G, concentration 5-10 liters/hectare + Improver, 20 ml/ton + Helios Super, 1-2 liters/ton) + foliar treatment with bio-preparations (Geostim Fit Z, concentration 1-2 liters/hectare + BFTIM, 2-4 liters/hectare + Improver, 50 ml/100 liters of solution + Gumel Lux, 1 liter/hectare + Helios Bor Molybdenum, 0.7-2.0 liters/hectare). Based on this variant, a maximum yield of 3.87 tons per hectare was achieved with a profitability of 238.0%.

СПИСОК ЛИТЕРАТУРЫ

1. *Гайдученко А.Н., Сюмак А.В., Коротенко Б.А.* Экономическая эффективность возделывания сои в зависимости от применяемых технологий // Земледелие. 2017. № 2. С. 23–25.
2. *Niewiadomska A., Sulewska H., Wolna-Maruwka A., Ratajczak K., Waraczewska Z., Budka A.* The influence of biostimulants and foliar fertilizers on the process of biological nitrogen fixation and the level of soil biochemical activity in soybean (Glycine max L.) cultivation // Applied ecology and environmental research. 2019. N 17 (5). P. 12649–12666.
3. *Белышкина М.Е.* Проблема производства растительного белка и роль зерновых бобовых культур в ее решении // Природообустройство. 2018. № 2. С. 65–73.
4. *Кирсанова Е.В., Цуканова З.Р., Васильчиков А.Г., Чекалин Е.И.* Оценка влияния инокуляции семян на урожайность сои в Орловской области // Вестник аграрной науки. 2017. № 4 (67). С. 62–68. DOI: 10.15217/48484.

5. *Васильчиков А.Г., Акулов А.С.* Управление вегетацией перспективных сортообразцов сои путем применения высокоэффективных инокулянтов // Земледелие. 2018. № 4. С. 19–22.
6. *Saranraj P., Al Tawaha A., Sivasakthivelan P.* Diversity and evolution of Bradyrhizobium communities relating to Soybean cultivation: A review // IOP Conference Series: Earth and Environmental Science. Krasnoyarsk: IOP Publishing Ltd, 2021. T. 788. N 1. P. 12208.
7. *Муравьев А.А., Демидова А.Г.* Урожай и качество семян сортов сои в лесостепи Центрально-Черноземного региона на разноудобренных фонах // Земледелие. 2018. № 3. С. 22–25. DOI: 10.24411/0044-3913-2018-10304.
8. *Бутовец Е.С., Лукьянчук Л.М., Васин Е.А.* Взаимодействие ризобиальных бактерий с растениями сои сортов приморской селекции // Вестник Дальневосточного отделения Российской академии наук. 2019. № 3 (205). С. 48–54.
9. *Васин В.Г., Саниев Р.Н., Васин А.В., Бурунов А.Н., Просандеев Н.А., Трифонов Д.И.* Применение микроудобрительных смесей и биопрепаратов при возделывании сои // Агрохимический вестник. 2019. № 2. С. 47–52. DOI: 10.24411/0235-2516-2019-10027.
10. *Шабалкин А.В., Дубинкина Е.А.* Соя – перспективная высокорентабельная культура // Сахарная свекла. 2022. № 1. С. 34–37.
11. *Шабалкин А.В., Дубинкина Е.А., Беляев Н.Н.* Влияние обработки семян и вегетирующих растений сои микробиологическими удобрениями на урожайность и качество продукции в условиях Центрально-Черноземного региона // Аграрная Россия. 2020. № 9. С. 12–16.
12. *Васильчиков А.Г., Гурьев Г.П.* Изучение эффективности различных форм микробных препаратов для инокуляции сои // Земледелие. 2017. № 3. С. 3–4.
13. *Петровский А.С., Каракотов С.Д.* Микробиологические препараты в растениеводстве: альтернатива и партнерство // Защита и карантин растений. 2017. № 2. С. 14–18.
14. *Толоконников В.В., Кошкарова Т.С.* Новый сорт сои Волгоградка 2 // Научный журнал Российского научно-исследовательского института проблем мелиорации. 2021. Т. 11. № 1. С. 14–23. DOI: 10.31774/2222-1816-2021-11-1-14-23.

REFERENCES

1. Gaiduchenko A.N., Sumak A.V., Korotenko B.A. Economic efficiency of soybean cultivation depending on applied technologies. *Zemledeliye = Zemledelie*, 2017, no. 2, pp. 23–25. (In Russian).
2. Niewiadomska A., Sulewska H., Wolna-Maruwka A., Ratajczak K., Waraczewska Z., Budka A. The influence of biostimulants and foliar fertilizers on the process of biological nitrogen fixation and the level of soil biochemical activity in soybean (Glycine max L.) cultivation. *Applied ecology and environmental research*, 2019, no. 17 (5), pp. 12649–12666.
3. Belyshkina M.E. Problem of production of vegetable protein and role of grain legumes in its decision. *Prirodoobustroystvo = Environmental Engineering*, 2018, no. 2, pp. 65–73. (In Russian).
4. Kirsanova E.V., Tsukanova Z.R., Vasilchikov A.G., Chekalin E.I. Evaluation of the effect of seed inoculation on soybean yields in the Orel region. *Vestnik Agrarnoi Nauki = Bulletin of Agrarian Science*, 2017, no. 4 (67), pp. 62–68. (In Russian). DOI: 10.15217/48484.
5. Vasil'chikov A.G., Akulov A.S. Management of the growing season of promising soybean varieties by using highly effective inoculants. *Zemledeliye = Zemledelie*, 2018, no. 4, pp. 19–22. (In Russian).
6. Saranraj P., Al Tawaha A., Sivasakthivelan P. Diversity and evolution of Bradyrhizobium communities relating to Soybean cultivation: A review. *IOP Conference Series: Earth and Environmental Science*, Krasnoyarsk: IOP Publishing Ltd, 2021, vol. 788, no. 1, p. 12208.
7. Murav'ev A.A., Demidova A.G. Yield and grain quality of soybean varieties in the forest-steppe of the central chernozem region against backgrounds with different fertilization. *Zemledeliye = Zemledelie*, 2018, no. 3, pp. 22–25. (In Russian). DOI: 10.24411/0044-3913-2018-10304.
8. Butovets E.S., Lukyanchuk L.M., Vasin E.A. Interaction of rhizobial bacteria with plants of soybean varieties developed in Primorsky Krai. *Vestnik Dal'nevostochnogo otdeleniya Rossiyskoy akademii nauk = Vestnik of Far Eastern Branch of the Russian Academy of Sciences*, 2019, no. 3 (205), pp. 48–54. (In Russian).
9. Vasin V.G., Saniev R.N., Vasin A.V., Burunov A.N., Prosandeev N.A., Trifonov D.I. Mi-

crofertilizers and biopreparations application for soya cultivation. *Agrokhimicheskiy vestnik = Agrochemical Herald*, 2019, no. 2, pp. 47–52. (In Russian). DOI: 10.24411/0235-2516-2019-10027.
10. Shabalkin A.V., Dubinkina E.A. Soybeans is a perspective high cost-effective culture. *Sakharnaya sviokla = Sugar beet*, 2022, no. 1, pp. 34–37. (In Russian).
11. Shabalkin A.V., Dubinkina E.A., Belyaev N.N. Influence of processing of soybean seeds and vegetating plants with microbiological fertilizers on yield and product quality in the Central Black Earth region. *Agrarnaya Rossia = Agrarian Russia*, 2020, no. 9, pp. 12–16. (In Russian).
12. Vasilchikov A.G., Guryev G.P. Investigation of efficiency of different forms of microbial preparations for soybean inoculation. *Zemledeliye = Zemledelie*, 2017, no. 3, pp. 3–4. (In Russian).
13. Petrovsky A.S., Karakotov S.D. Microbiological preparations in crop production: Alternative and partnership. *Zaschita i karantin rasteniy = Plant Protection and Quarantine*, 2017, no. 2, pp. 14–18.
14. Tolokonnikov V.V., Koshkarova T.S. New soya variety Volgogradka 2. *Nauchniy zhurnal Rossiyskogo NII problem melioratcii = Land Reclamation and Hydraulic Engineering*, 2021, vol. 11, no. 1, pp. 14–23. (In Russian). DOI: 10.31774/2222-1816-2021-11-1-14-23.

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Дата поступления статьи / Received by the editors 28.12.2022
Дата принятия к публикации / Accepted for publication 10.02.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-3
УДК: 632.3.01:635.44
Тип статьи: оригинальная
Type of article: original

БИОУДОБРЕНИЕ И ОСВЕЩЕНИЕ КАК ФАКТОРЫ, ВЛИЯЮЩИЕ НА РОСТ, РАЗВИТИЕ И БИОХИМИЧЕСКИЙ СОСТАВ ТОМАТОВ

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Проведено комплексное исследование роста и биохимического состава растений томатов сорта Благодатный, выращенного с использованием спор бактерий *Bacillus cereus* (штамм 96) при непрерывном светодиодном освещении на основе полного спектра фотонов в пропорции B : G : R : FR ~ 17 : 23 : 43 : 17. В качестве контроля использованы растения, выращенные с помощью натриевых ламп высокого давления (HPS) без действия бактериальной культуры. Изучен ряд параметров, отражавших рост растений и качество плодов томатов, – содержание фотосинтетических пигментов, сухих веществ и органических кислот. Показано, что в течение вегетационного периода томаты, выращиваемые под светодиодным освещением, отличались большей длиной побега по сравнению с растениями в натриевом варианте. Действие бактерий проявилось при созревании плодов с достоверно значимыми различиями как при натриевом, так и при светодиодном освещениях. Влияние сухих веществ под действием бактерий на растения, выращенные с использованием натриевого освещения, не отличалось от контрольного варианта. Наблюдаемые различия стали более выраженными и достоверно значимыми у растений при светодиодном освещении. Применение бактериальной культуры *B. cereus* способствовало увеличению концентрации хлорофиллов *a, b* и каротиноидов по сравнению с контролем. При оценке действия разных типов светового освещения и использования бактерий *B. cereus* на накопление органических кислот в плодах установлено, что светодиодное освещение оказывало лучшее воздействие на синтез органических кислот. Растения томатов, обработанные *B. cereus,* отличались формированием плодов с большим содержанием янтарной, яблочной и лимонной кислот с натриевым типом освещения. При анализе плодов томатов, выращенных под светодиодным освещением, отмечено изменение в накоплении только янтарной кислоты. Использование разных источников освещения и биоудобрений вызвало изменения в развитии растений томатов в условиях климатических камер.

Ключевые слова: томаты, микроорганизмы, гидропоника, освещение, пигменты, органические кислоты

BIOFERTILIZER AND LIGHTING AS FACTORS AFFECTING TOMATO GROWTH, DEVELOPMENT AND BIOCHEMICAL COMPOSITION

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A comprehensive study of growth and biochemical composition of the Blagodatny variety tomato plants grown with the use of bacterial spores *Bacillus cereus* strain 96 under continuous LED lighting

based on full spectrum photons in the proportion B: G: R: FR ~ 17: 23: 43: 17 was conducted. Plants grown with high-pressure sodium lamps (HPS) without bacterial culture action were used as controls. A number of parameters reflecting plant growth and quality of tomato fruits were studied - the content of photosynthetic pigments, dry matter and organic acids. It was shown that during the growing season, tomato plants grown under LED illumination had a longer shoot length compared to the plants in the sodium variant. The action of the bacteria manifested itself during fruit ripening with significant differences under both sodium and LED lighting. The effect of dry matter under the influence of bacteria on the plants grown with sodium lighting did not differ from the control variant. The observed differences became more pronounced and reliably significant in the plants under LED lighting. Application of *B. cereus* bacterial culture increased the concentration of chlorophylls a, b and carotenoids compared to the control. When evaluating the effect of different types of lighting and the use of *B. cereus* bacteria on the accumulation of organic acids in fruits, it was found that LED lighting had a better effect on the synthesis of organic acids. Tomato plants treated with B. cereus were distinguished by the formation of fruits with a high content of succinic, malic and citric acids with a sodium type of lighting. When analyzing the fruits of tomato plants grown under LED lighting, a change in the accumulation of only succinic acid was noted. The use of different lighting sources and biofertilizers caused changes in the development of tomato plants under climate chamber conditions.

Keywords: tomatoes, microorganisms, hydroponics, lighting, pigments, organic acids

Для цитирования: *Князева И.В., Вершинина О.В., Титенков А.В., Джос Е.А.* Биоудобрение и освещение как факторы, влияющие на рост, развитие и биохимический состав томатов // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 22–30. https://doi.org/10.26898/0370-8799-2023-5-3

For citation: Knyazeva I.V., Vershinina O.V., Titenkov A.V., Jos E.A. Biofertilizer and lighting as factors affecting tomato growth, development and biochemical composition. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2023, vol. 53, no. 5, pp. 22–30. https://doi.org/10.26898/0370-8799-2023-5-3

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Modern hydroponic vegetable cultivation focuses on creating new environmentally friendly and energy-saving technologies [1]. In closed-type vertical farms (PFAL – Plant Factory with Artificial light), lighting plays a crucial role in providing the necessary environmental conditions for plant growth. It serves not only as an energy source for photosynthesis but also as a signal for various physiological reactions, exerting significant influence on plant morphology, growth rate, fruiting, flowering, taste, color, nutrient content, metabolites, and overall plant health [2]. Currently, LED lighting has become the optimal choice due to numerous advantages, including narrow wavelength bands, long lifespan, and high light efficiency. Compared to the commonly used high-pressure sodium (HPS) and fluorescent lamps in agriculture, LEDs provide a high level of spectral tuning [3, 4].

Various studies have shown that controlled light intensity improves post-harvest product quality and shelf life by stimulating the production of nutrients and bioactive compounds. These bioactive compounds, known as primary or secondary metabolites, contribute to the aroma, color, and taste of plants [5]. Meng et al. [6] observed that lettuce grown in a controlled spectrum LED environment on a closed farm exhibits a sweeter, more aromatic, and more appealing taste compared to lettuce grown under natural sunlight in greenhouses.

The application of endophytic bacteria, known as Plant Growth-Promoting Rhizobacteria (PGPRB), offers an ecological approach by partially replacing (25–50%) NPK mineral fertilizers to improve agricultural production, increase yields, and obtain high-quality crops for human consumption [7]. The use of bacterial biofertilizer mixtures, including *Bacillus sp.*,

reduces the recommended dosage of chemical fertilizers and enhances physicochemical parameters for various vegetable crops. Bio-preparations based on organic acids or bacteria are applied to seed pre-treatment and directly introduced into the soil/substrate based on the specific requirements of the cultivated crop and the form of the fertilizer [8–11].

According to the research by Alaaeldin A. Helaly et al. [12], the application of the AP-51 *Bacillus cereus* strain on cabbage plants resulted in significant differences in vegetative growth, including plant length, number of leaves, and leaf area, compared to the control and two other bacterial strains, AP-28 *Pseudomonas koreensis* and AP-29 *Ralstonia pickettii.*

Optimizing lighting systems, developing light formulas, and implementing environmental management strategies can enhance biomass accumulation by maximizing photosynthesis efficiency and significantly increasing the production of photosynthesis products, which is crucial for crop yield and quality [13].

The purpose of this research is to study the influence of *Bacillus cereus* bacteria on the development and accumulation of bioactive substances in tomato plants grown under LED and sodium lighting.

MATERIAL AND METHODS

The experiments to study the effects of lighting and bacterial culture on the growth of tomato plants and fruit quality were conducted in 2021 and 2022 at the Department of Closed Artificial Agroecosystems for Plant Production at the Federal Scientific Agroengineering Center VIM (Moscow, Russia).

The chosen subject of the study was the "Blagodatny" variety selected by the Federal Scientific Center for Vegetable Production. This variety is characterized by medium-early development, with a growth period from germination to ripening taking 98-107 days. It is a determinate type of tomato with a dry matter content of up to 6% and total sugar content of 3.5%. It is recommended for fresh consumption, canning, and pickling.

Spores *of Bacillus* cereus bacteria were obtained from the State Unitary Enterprise "Moscow City Center for Disinfection." The acquired material consisted of dried spores of the strain 96. Under sterile conditions, 0.5 ml of nutrient medium was added to a 1.5 ml Eppendorf tube containing the bacterial spores, and the mixture was incubated in a thermostat for 24-48 hours at 37°C until the medium's color changed completely. The resulting suspension was used as a biofertilizer.

The biofertilizer was applied exogenously once during the vegetative period of tomatoes at the early stages of plant development (formation of 3-4 leaves). The suspension of *B. cereus* spores was introduced into the root zone of tomato plants at a concentration of 10^3 CFU (colony-forming units). Plants without the addition of bacterial culture served as the control. The experiment included 4 variants, each consisting of 16 plants (see Table 1).

Tomato plants were grown hydroponically using low-volume technology with drip irrigation in a climate chamber at VIM production facilities (Russia). During the experiment, the following conditions were maintained in the chamber: daytime temperature ranged from 22-24°C, nighttime temperature ranged from 14-16°C, with a 16-hour photoperiod and relative air humidity of 60-65%.

For the research, a spectrum of LED lighting was used with an illuminance at the plant level of 13,900 lux and a total photosynthetic active radiation (PAR) of 278 μmol/(m²·s): blue (47.9 μmol/(m²·s)), green (62.5 μmol/(m²·s)), red (119.3 μmol/(m²·s)), far-red (48.3 μmol/(m²·s)), in a B:G:R:FR ratio of approximately 17:23:43:17 (see Figure 1).

As a control light source, two sodium tubular lamps (DNAT-600, yellow light) and one met-

Табл. 1. Схема эксперимента
Table 1. Scheme of the experiment

№	Experiment option	Lighting type
1	Control - without treatment of plants with bacteria	Sodium (hereinafter referred to as Na)
2	Plants treated with bacteria	
3	Control - without treatment of plants with bacteria	Light-emitting diode (hereinafter referred to as LED)
4	Plants treated with bacteria	

al halide lamp (DRI-600/4K, white light) were used. The illuminance at the plant level was 13,900 lux, and the PAR was 270 μmol/(m²·s).

Photon flux density and spectral composition measurements were performed using the MK350D Compact Spectrometer from UPRtek Corp. (Miaoli County, Taiwan). The quantitative content of major pigments (chlorophyll a, b, and carotenoids) in tomato leaves was determined using a spectrophotometer, Spex SCP-705M (Russia). Pigment concentrations were calculated for 100% acetone using the Holm-Vettschnein equation. Determination of dry matter content was done by drying samples to constant weight in a Memmert UN-450 drying oven (Germany) following the GOST 28561-90 standard. The total titratable acidity in tomato fruits was determined according to the GOST ISO 750-2013 standard. The Brix index in tomato fruits was measured using the Atago Pal-1 refractometer (Japan). The content of organic acids in tomato fruits was determined by capillary electrophoresis on the "Kapel-205" instrument (Russia).

The obtained results were statistically processed using ANOVA (analysis of variance) with STADIA 8.0 software (Russia). Significant differences between means were calculated using Duncan's test at a probability level of $p \leq 0.05$.

RESULTS AND DISCUSSION

The intensity of linear growth of plants depends on the varietal characteristics of the crop, growing conditions and nutrition regime. Fig. 2 shows the diagram of shoot length growth of tomato plants by development phases. Observations in the experiment showed that during the growing season tomato plants grown under LED lighting were characterized by a greater shoot length compared to the sodium variant. In the phase of 4-6 true leaves the length of tomato shoots was up to 20 cm in the chamber with LED lighting and up to 16 cm - with Na (the sodium variant) lighting. In the phase of flowering initiation, tomato plants had an average main shoot length of 33.6 cm. The tallest plants were observed in the chamber with LED lighting (36.0 cm), regardless of the action of bacteria.

During the ripening phase, the shoot length varied from 84.0 to 101.5 cm depending on the experimental variant. At this stage of plant development, the effect of the bacterial culture *B. cereus* on growth rates was evident, with significant differences observed under both sodium and LED lighting. In several studies, the presence of *Pseudomonas* sp. 2.4.1 rhizobacteria in the rhizosphere resulted in accelerated growth and increased dry leaf biomass accumulation in tomatoes [14]. When a mixture of *Bacillus* strains was used, there was an increase in the number of clusters, flowers, and fruits in tomatoes [15].

The application of the *B. cereus* bacterial culture increased the accumulation of dry matter up to 5.73% in tomatoes grown under LED lighting. However, there were no significant differences in dry matter content between the experimental variants under sodium lighting. The dry matter content in tomatoes grown under sodium light-

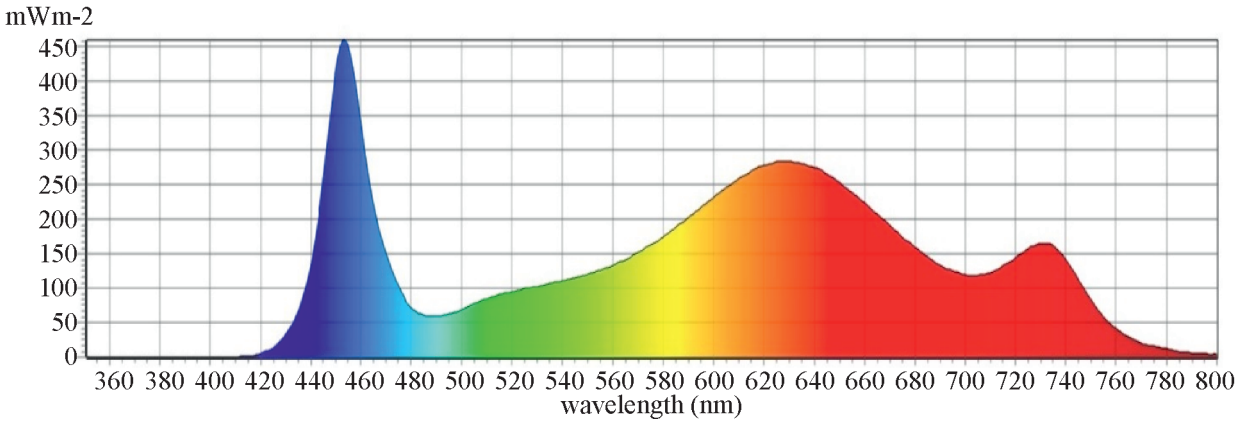
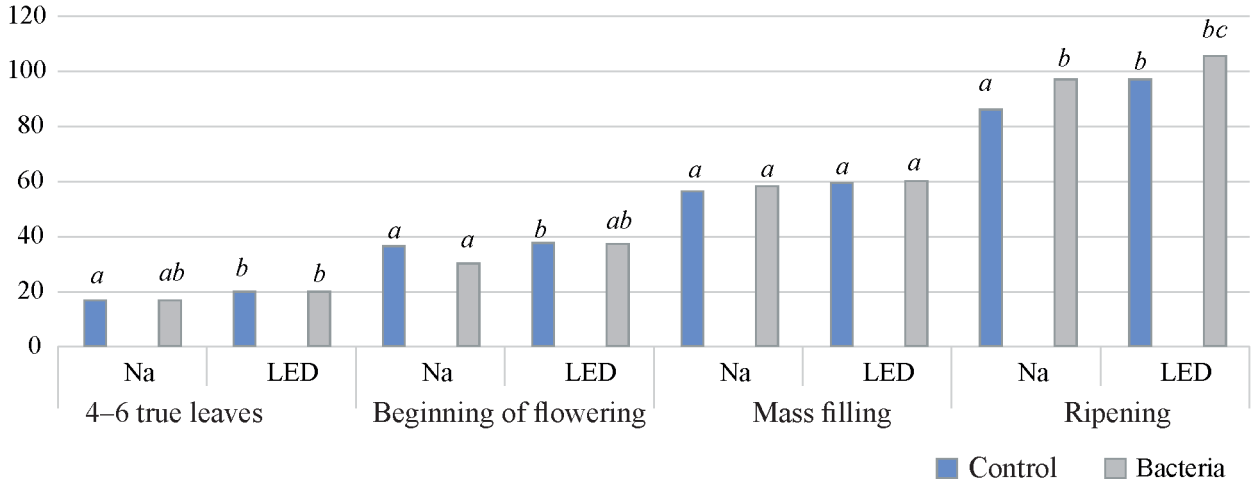


Рис. 1. Спектральный состав освещения

Fig. 1. Spectral composition of lighting



Puc. 2. Высота растений томатов сорта Благодатный, выращенного в условиях закрытой агроэкосистемы, см

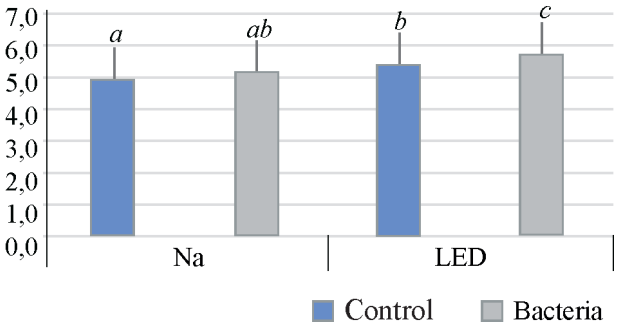
Fig. 2. Height of tomato plants of the Blagodatny variety grown in a closed agroecosystem, cm

ing with the application of bacteria was comparable to that of the control under LED lighting (see Figure 3).

In the sodium lighted chamber without bacteria application, the mass fraction of dry matter in tomato fruits was 4.93% compared to LED (5.41%).

The main components of the plant's photosynthetic system are pigments, which serve as primary photoreceptors in the process of photosynthesis. The adaptability of plants to specific light conditions is reflected in changes in the pigment composition. The conducted analyses showed that the ratios of photosynthetic pigments in the studied experimental variants were different (see Table 2). The application of the *B. cereus* bacterial culture led to an increase in the concentration of chlorophylls a, b, and carotenoids compared to the control. In tomato leaves grown under sodium (control) lighting with the application of *B. cereus*, the average content of chlorophyll a and b was 4.24 and 1.70 mg/g, respectively, compared to plants without the application of bacteria, which had 3.62 mg/g (chlorophyll a) and 1.27 mg/g (chlorophyll b).

A similar trend of increased accumulation of photosynthetic pigments was observed in the LED lighting experimental variant with the application of bacterial culture. The presence of bacteria led to a less pronounced accumulation



Puc. 3. Содержание сухих веществ в плодах томата сорта Благодатный, %

Fig. 3. Dry matter content in fruits of the Blagodatny tomato variety, %

of carotenoids in the biomass of tomato leaves compared to other pigments, with values ranging from 1.16 to 1.19 mg/g in the bacterial variant, compared to 0.83 to 0.97 mg/g in the control. The lighting source did not significantly affect the accumulation of photosynthetic pigments.

The total content of chlorophylls (a + b) was 5.94 mg/g (sodium lighting) and 6.25 mg/g (LED lighting), which exceeded the control variants without the presence of *B. cereus* by 21.5% and 25.8%, respectively. However, based on statistical analysis, no significant differences were observed between these data values.

The taste qualities of tomato fruits are influenced by the content of organic acids and the Brix index. When analyzing the Brix index in tomato fruits, it was noted that the content of

Табл. 2. Содержание основных фотосинтетических пигментов в растениях томата сорта Благодатный, мг/г (сырой массы)

Table 2. Contents of the main photosynthetic pigments in tomato plants of the Blagodatny variety, mg/g (wet weight)

Lighting type	Experiment option	*Хл. a*	*Хл. b*	*Хл.* (*a*+*b*)	Carotenoids
Na	Control	3,62 ± 0,3	1,27 ± 0,2	4,89 ± 0,3	0,97 ± 0,2
	Bacteria	4,24 ± 0,4	1,70 ± 0,3	5,94 ± 0,4	1,19 ± 0,3
LED	Control	3,55 ± 0,3	1,42 ± 0,3	4,97 ± 0,3	0,83 ± 0,2
	Bacteria	4,48 ± 0,4	1,77 ± 0,3	6,25 ± 0,5	1,16 ± 0,2

total sugars ranged from 2.2% to 3.5%, with the highest value observed in the variant where *B. cereus* was applied during plant cultivation under LED lighting conditions. The level of total titratable acidity among the studied variants ranged from 0.29% to 0.36%. Significant differences were observed between the control group with Na lighting (0.29%) and the variants with the application of bacterial suspension under different lighting conditions (see Table 3).

The sugar-acid index is one of the criteria for assessing fruit quality. This indicator characterizes the harmony of taste with regard to sugar and acidity. In our studies, this index ranged from 7.59 to 9.72, depending on the experimental variant. Higher values were observed in the variants with LED lighting (8.82–9.72), which significantly exceeded the control (7.59). Evaluating the impact of *B. cereus*-based biofertilizer on the taste qualities of tomato fruits, it should be noted that the effect of bacteria is neutralized in the case of Na lighting compared to plants grown under LED lighting.

Through chemical analysis using capillary electrophoresis, the composition of organic acids in the "Blagodatny" tomato variety was determined (see Figure 4). When evaluating the effect of different types of lighting and the application of *B. cereus* bacteria on the accumulation of bioactive substances in tomato fruits, certain patterns were identified. Lighting type promoted the accumulation of citric and malic acids in tomato fruits to a greater extent (see Figure 4).

Comparing control variants of tomato plants grown under different lighting sources, it was established that LED lighting had a more positive impact on the synthesis of the mentioned organic acids (see Figure 4). The content of malic acid in the chamber with LED lighting was 34.43 mg/100 g fresh weight compared to Na lighting (control) – 21.28 mg/100 g fresh weight of tomato fruits.

Tomato plants treated with *B. cereus* biofertilizer showed the formation of fruits with higher content of succinic, malic, and citric acids under Na lighting. When analyzing tomato fruits grown under LED lighting, changes were observed only in the accumulation of succinic acid. The synthesis of oxalic acid in tomato fruits was independent of the studied factors (lighting type

Табл. 3. Биохимические показатели плодов томата сорта Благодатный

Table 3. Biochemical parameters of the fruits of the Blagodatny tomato variety

Lighting type	Experiment option	Brix index, %	Titratable acidity, %	Sugar-acid index
Na	Control	2,20*a*	0,29*a*	7,59*a*
	Bacteria	2,70*b*	0,33*b*	8,18*ab*
LED	Control	3,00*b*	0,34*b*	8,82*b*
	Bacteria	3,50*c*	0,36*b*	9,72*c*

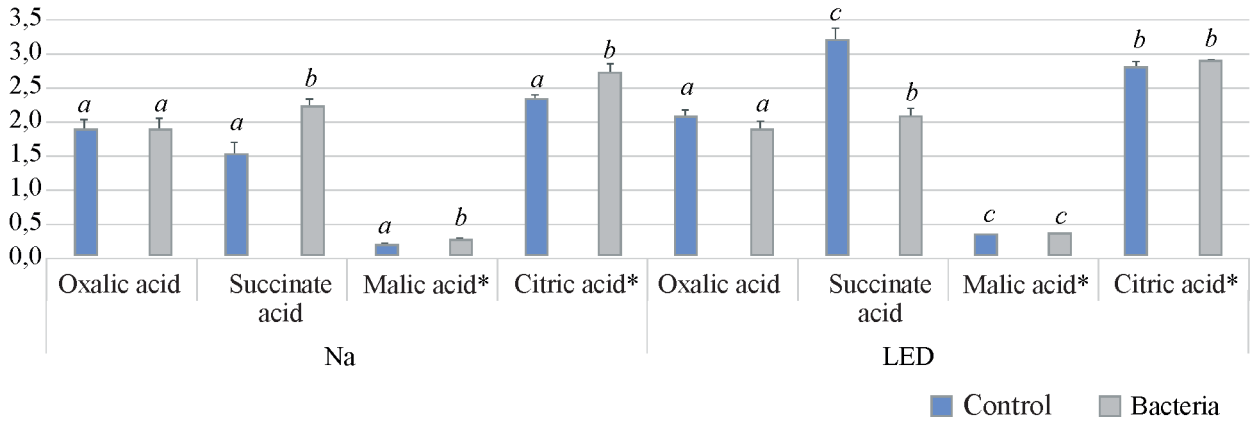


Рис. 4. Содержание органических кислот в плодах томата сорта Благодатный, мг/100 г сырой массы (*г/кг сырой массы)

Fig. 4. The content of organic acids in the fruit of the Blagodatny tomato variety, mg/100 g wet weight (*g/kg wet weight)

and the application of *B. cereus* bacteria). The concentration of oxalic acid in the experiment ranged from 1.87 to 2.08 mg/100 g fresh weight of tomato fruits, depending on the experimental variant.

The analysis of the obtained data in the experiment revealed that the key factor influencing tomato yield was the lighting source. Tomato yield under LED lighting was 1.89 kg per plant, while under Na lighting, this indicator was at the level of 1.53 kg per plant. The application of *B. cereus* biofertilizer during tomato cultivation did not significantly affect fruit yield.

CONCLUSION

The research results showed that the growth and development parameters of tomatoes under LED lighting differed in terms of longer shoot length compared to Na lighting. During the ripening phase, the effect of introducing *B. cereus* bacterial culture was evident with statistically significant differences in growth rates. The application of *B. cereus* bacterial culture promoted the accumulation of dry matter up to 5.73% in tomato fruits grown under LED lighting. No significant differences in dry matter content were observed between the experimental variants under Na lighting. Regarding the ratio of concentrations of all analyzed organic acids in the experiment, citric acid predominated, followed by malic acid. LED lighting allowed for a more active accumulation of organic acids in "Blagodatny" tomato fruits. The content of malic acid in the chamber with LED lighting was 34.43 mg/100 g fresh weight compared to Na lighting (control) – 21.28 mg/100 g fresh weight of tomato fruits.

СПИСОК ЛИТЕРАТУРЫ

1. *Журавлева Л.А.* Сити-фермерство как перспективное направление развития агропроизводства // Научная жизнь. 2020. Т. 15. № 4 (104). С. 492–503.
2. *Zhang X., Bian Z., Yuan X., Chen X., Lu C.A.* Review on the Effects of Light-Emitting Diode (LED) Light on the Nutrients of Sprouts and Microgreens. // Trends Food in Food Science & Technology. 2020. Vol. 99. P. 203–216. DOI: 10.1016/j.tifs.2020.02.031.
3. *Santin M., Ranieri A., Castagna A.* Anything New under the Sun? An Update on Modulation of Bioactive Compounds by Different Wavelengths in Agricultural Plants // Plants. 2021. Vol. 10. P. 1485. DOI: 10.3390/plants10071485.
4. *Xu Y.* Nature and source of light for plant factory. In Plant Factory Using Artificial Light // The Netherlands. Elsevier: Amsterdam. 2019. P. 47–69.
5. *Kozai T., Niu G., Takagaki M.* Plant Factory: An Indoor Vertical Farming System for Efficient Quality Food Production. Academic Press: Cambridge, MA, USA, 2019.
6. *Meng Q., Boldt J., Runkle E.S.* Blue Radiation Interacts with Green Radiation to Influence Growth and Predominantly Controls Quality Attributes of Lettuce // Journal of the American So-

ciety for Horticultural Science. 2020. Vol. 145. N 2. P. 75–87. DOI: 10.21273/JASHS04759-19.
7. *Abd-Elkader D.Y., Hassan S.M.* Influence of different fertilization and harvest time on growth, head characters and nutrition quality of endive under sandy soil // American Journal of Plant Physiology. 2016. Vol. 11. P. 23–32.
8. *Knyazeva I.V., Vershinina O.V., Gudimo V.V., Grishin A.A., Dorokhov A.S.* The effect of succin-ic acid on the productivity of Lactuca sativa L. in artificial agroecosystems // Agronomy Research. 2021. Vol. 19. N 2. P. 496–506. DOI: org/10.15159/AR.21.092.
9. *Knyazeva I.V., Dorokhov A.S., Vershinina O.V., Myachikova N.I., Grishin A.A., Gudimo V.B., Georgescu C.* The effect of amber acid on the productivity and chemical composition of tomatoes grown in a climatic chamber // Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry. 2021. Vol. 22. N 3. P. 311–319.
10. *Khan M.A., Asaf S., Khan A.L.* Thermotolerance effect of plant growth-promoting Bacillus cereus SA1 on soybean during heat stress // BMC Microbiol 20. 2020. Vol. 175. DOI: 10.1186/s12866-020-01822-7.
11. *Ahmed M.Ali, Mahrous Y.M. Awad, Sabry A. Hegab, Assem Mohamed Abd El Gawad & Mamdouh A. Eissa.* Effect of potassium solubilizing bacteria (Bacillus cereus) on growth and yield of potato // Journal of Plant Nutrition. 2021. Vol. 44 (3). P. 411–420. DOI: 10.1080/01904167.2020.1822399.
12. *Alaaeldin A. Helaly, Emad Mady, Emad A. Salem, Timothy O.* Randhir Stimulatory effects of growth-promoting bacteria on growth, nutritional composition, and yield of kale plants // Journal of Plant Nutrition. 2022. Vol. 45 (16). P. 2465–2477. DOI: 10.1080/01904167.2022.2046084.
13. *Масленникова Д.Р., Чубукова О.В., Вершинина З.Р., Емелина А.А., Насырова К.Р., Хакимова Л.Р., Михайлова Е.В.* Влияние ростостимулирующих бактерий на рост и содержание фотосинтетических пигментов в листьях растений томата // Биомика. 2021. Т. 13. № 3. С. 274–279.
14. *Масленникова В.С., Цветкова В.П.1, Петров А.Ф., Пастухова А.В.* Влияние бактерий рода *Bacillus* на рост и продуктивность томата сорта Спок // Вестник НГАУ (Новосибирский государственный аграрный университет). 2021. № 1 (58). С. 56–63. DOI: 10.31677/2072-6724-2021-58-1-56-63.
15. *Nicole C.C.S., Mooren J., Pereira Terra A.T., Larsen D.H., Woltering E.J., Marcelis L.F.M., Verdonk J., Schouten R., Troost F.* Effects of LED lighting recipes on postharvest quality of leafy vegetables grown in a vertical farm // Acta Horticulturae. 2019. 1256. P. 481–488. DOI: 10.17660/ActaHortic.2019.1256.68.

REFERENCES

1. Zhuravleva L.A. City farming as a promising direction for the development of agricultural production. *Nauchnaya zhizn' = Scientific Life,* 2020. T. 15. № 4 (104), pp. 492–503. (In Russian).
2. Zhang X., Bian Z., Yuan X., Chen X., Lu C.A. Review on the Effects of Light-Emitting Diode (LED) Light on the Nutrients of Sprouts and Microgreens. *Trends Food in Food Science & Technology*, 2020, vol. 99, pp. 203–216. DOI: 10.1016/j.tifs.2020.02.031.
3. Santin M., Ranieri A., Castagna A. Anything New under the Sun? An Update on Modulation of Bioactive Compounds by Different Wavelengths in Agricultural Plants. *Plants,* 2021, vol. 10, pp. 1485. DOI: 10.3390/plants10071485.
4. Xu Y. Nature and source of light for plant factory. In Plant Factory Using Artificial Light. *The Netherlands.* Elsevier: Amsterdam, 2019, pp. 47–69.
5. Kozai T., Niu G., Takagaki M. Plant Factory: *An Indoor Vertical Farming System for Efficient Quality Food Production*. Academic Press, Cambridge, MA, USA, 2019.
6. Meng Q., Boldt J., Runkle E.S. Blue Radiation Interacts with Green Radiation to Influence Growth and Predominantly Controls Quality Attributes of Lettuce. *Journal of the American Society for Horticultural Science*, 2020, vol. 145, no. 2, pp. 75–87. DOI: 10.21273/JASHS04759-19.
7. Abd-Elkader D.Y., Hassan S.M. Influence of different fertilization and harvest time on growth, head characters and nutrition quality of endive under sandy soil. *American Journal of Plant Physiology,* 2016, vol. 11, pp. 23–32.
8. Knyazeva I.V., Vershinina O.V., Gudimo V.V., Grishin A.A., Dorokhov A.S. The effect of succin-ic acid on the productivity of Lactuca sativa L. in artificial agroecosystems. *Agronomy Research,* 2021, vol. 19, no. 2, pp. 496–506. DOI: 10.15159/AR.21.092.
9. Knyazeva I.V., Dorokhov A.S., Vershinina O.V., Myachikova N.I., Grishin A.A., Gudimo V.B., Georgescu C. The effect of amber acid on the

productivity and chemical composition of tomatoes grown in a climatic chamber. *Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry*, 2021, vol. 22, no. 3, pp. 311–319.
10. Khan M.A., Asaf S., Khan A.L. Thermotolerance effect of plant growth-promoting Bacillus cereus SA1 on soybean during heat stress. *BMC Microbiol 20*. 2020, vol. 175. DOI: 10.1186/s12866-020-01822-7.
11. Ahmed M.Ali, Mahrous Y.M. Awad, Sabry A. Hegab, Assem Mohamed Abd El Gawad & Mamdouh A. Eissa Effect of potassium solubilizing bacteria (Bacillus cereus) on growth and yield of potato. *Journal of Plant Nutrition*, 2021, vol. 44 (93), pp. 411–420. DOI: 10.1080/01904167.2020.1822399.
12. Alaaeldin A. Helaly, Emad Mady, Emad A. Salem & Timothy O. Randhir Stimulatory effects of growth-promoting bacteria on growth, nutritional composition, and yield of kale plants. *Journal of Plant Nutrition*, 2022, vol. 45 (16), pp. 2465–2477. DOI: 10.1080/01904167.2022.2046084.
13. Maslennikova D.R., Chubukova O.V., Vershinina Z.R., Emelina A.A., Nasyrova K.R., Khakimova L.R., Mikhailova E.V. Effect of PGPR bacteria on growth and content of photosynthetic pigments the in leaves of tomato plants. *Biomika = Biomics,* 2021, vol. 13, no. 3, pp. 274–279. (In Russian).
14. Maslennikova V.S., Tsvetkova V.P.1, Petrov A.F., Pastukhova A.V. Influence of the bacillus genus bacteria on the growth and productivity of tomatoes of spok variety. *Vestnik NGAU (Novosibirskii Gosudarstvennyi Agrarnyi Universitet) = Bulletin of NSAU* (Novosibirsk State Agrarian University), 2021, vol. 1 (58), pp. 56–63. DOI: 10.31677/2072-6724-2021-58-1-56-63. (In Russian).
15. Nicole C.C.S., Mooren J., Pereira Terra A.T., Larsen D.H., Woltering E.J., Marcelis L.F.M., Verdonk J., Schouten R., Troost F. Effects of LED lighting recipes on postharvest quality of leafy vegetables grown in a vertical farm. *Acta Horticulturae*, 2019, vol. 1256. pp. 481–488. DOI: 10.17660/ActaHortic.2019.1256.68

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Дата поступления статьи / Received by the editors 01.09.2022
Дата принятия к публикации / Accepted for publication 20.01.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-4
УДК: 633.853.483:631.81
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ МИКРОУДОБРЕНИЙ СЕРИИ ИЗАГРИ НА ПРОДУКТИВНОСТЬ САФЛОРА (*CARTHAMUS TINCTORIUS*)

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Представлены результаты анализа влияния микроэлементных удобрений марки Изагри на продуктивность сафлора в условиях лесостепи Среднего Поволжья. Исследования проводили в 2020–2022 гг. на территории Пензенской области (опытное поле Пензенского научно-исследовательского института сельского хозяйства). Объектом изучения служил сафлор красильный сорта Ершовский 4. Опыт заключался в предпосевной обработке семян микроудобрениями серии Изагри. Установлено, что препараты Изагри увеличивают силу роста семян до 1,21–1,57 см, повышают всхожесть на 1,1–8,8%, сохранность растений к уборке – на 0,5–6,2%. На фоне применения удобрений продуктивность сафлора в среднем за 3 года составила 1,30–1,55 т/га, т.е. увеличилась на 0,06–0,25 т/га. Наибольший эффект дали препараты Изагри Форс и Изагри Вита, обработка которыми позволила получить прибавку урожая на 0,23–0,25 т/га. Наибольшая масличность семян отмечена в вариантах с использованием Изагри Азот (29,85%) и Изагри Бор (30,04%): прибавка составила 2,7 и 3,0% соответственно. Применение указанных препаратов снизило лузжистость семян до 37,7 и 37,9% соответственно. Наиболее крупные семена сформировались в варианте с Изагри Вита – масса 1 тыс. семян составила 39,16 г. Обработка Изагри Фосфор и Изагри Вита дала незначительное снижение содержания олеиновой кислоты (до 9,94 и 9,62%). При этом применение Изагри Вита максимально увеличило количество линолевой кислоты (до 83,63%). После использования препарата Изагри Форс концентрация данной кислоты снизилась до 81,88%. На основе полученных данных можно сделать вывод, что предпосевная обработка семян микроудобрениями из линейки Изагри способствует улучшению качественных показателей маслосемян и может выступать в качестве приема повышения продуктивности сафлора.

Ключевые слова: сафлор красильный, микроудобрения, полевая всхожесть, урожайность, масличность, жирно-кислотный состав, качества семян

INFLUENCE OF MICROFERTILIZERS OF THE IZAGRI SERIES ON THE PRODUCTIVITY OF SAFFLOWER (*CARTHAMUS TINCTORIUS*)

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The results of the analysis of the influence of Izagri microelement fertilizers on safflower productivity in the forest-steppe conditions of the Middle Volga region are presented. The studies were conducted in 2020-2022 in the Penza region (experimental field of the Penza Research Institute of Agriculture). The object of the study was safflower of the Ershovsky 4 variety. The experiment consisted in pre-sowing seed treatment with Izagri series of microfertilizers. Izagri preparations were found to increase the growth force of seeds up to 1.21-1.57 cm, germination by 1.1-8.8%, safety of plants for harvesting by 0.5-6.2%. Against the background of fertilizer application, safflower productivity averaged 1.30-1.55 t/ha for 3 years, i.e. increased by 0.06-0.25 t/ha. The greatest effect was produced by Izagri Force and Izagri Vita, which helped to obtain a yield increase of 0.23-0.25 t/ha. The highest oil content of seeds was observed in the variants with Izagri Nitrogen (29.85%) and Izagri Boron

(30.04%): the increase was 2.7 and 3.0% respectively. Application of these preparations reduced seed huskiness to 37.7 and 37.9%, respectively. The largest seeds were formed in the variant with Izagri Vita - weight of 1 thousand seeds was 39.16 g. Treatment with Izagri Phosphorus and Izagri Vita gave a slight decrease in oleic acid content (to 9.94 and 9.62%). At the same time, the use of Izagri Vita maximized the amount of linoleic acid (up to 83.63%). After using Izagri Force, the concentration of this acid decreased to 81.88%. Based on the data obtained, it can be concluded that pre-sowing treatment of seeds with microfertilizers from Izagri line improves the quality indicators of oilseeds and can act as a method to increase the productivity of safflower.

Keywords: safflower, microfertilizers, field germination, productivity, oil content, fatty acid composition, seed quality

Для цитирования: *Прахова Т.Я., Дружинин В.Г.* Влияние микроудобрений серии Изагри на продуктивность сафлора (*Carthamus tinctorius*) // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 31–39. https://doi.org/10.26898/0370-8799-2023-5-4

For citation: Prakhova T.Ya., Druzhinin V.G. Influence of microfertilizers of the Izagri series on the productivity of safflower (*Carthamus tinctorius*). *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 31–39. https://doi.org/10.26898/0370-8799-2023-5-4

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Работа выполнена при поддержке Министерства науки и высшего образования Российской Федерации в рамках государственного задания ФГБНУ «Федеральный научный центр лубяных культур» (тема № FGSS-2022-0008).
Acknowledgements
The research was carried out under the support of the Ministry of Science and Higher Education of the Russian Federation within the state assignment of the Federal Scientific Center for Bast Fiber Crops (theme no. FGSS-2022-0008).

INTRODUCTION

Currently, the issue of climate change is gaining significant importance, and this is naturally reflected in agronomy [1]. In this context, the use of crops capable of withstanding abiotic and biotic stresses and ensuring high seed yields[1] becomes particularly relevant in agricultural production. One such crop is the safflower (*Carthamus tinctorius* L.) – a valuable oil crop that can be cultivated in various agroecological conditions due to its high adaptability to the external environment, resistance to drought, high temperatures, pathogens, and pests[2] [2].

According to various data, safflower seeds contain 25 to 45% oil, which finds numerous applications in the food, cosmetic, pharmaceutical, and technical industries [3, 4]. The oil consists mainly of two unsaturated fatty acids – oleic and linoleic acid (up to 90% combined) [5, 6]. The high content of linoleic acid allows the safflower oil to be used in the production of medicines for lowering cholesterol levels in atherosclerosis and heart diseases [7]. Additionally, this oil blends well with other vegetable oils, improving their nutritional properties and is used in the preparation of various mixtures [8].

Currently, high oleic oils are of great importance in the food industry [3]. Such oils possess high oxidative stability and are recommended for the production of biodiesel, cosmetics, lubricants, and other oleochemical products [9, 10].

According to many Russian [4, 6] and foreign [2, 11] studies, safflower is a heat-loving and highly drought-resistant plant. Its main biological feature is the presence of a root system that can reach depths of up to 2 meters and effec-

[1]*Kshnikatkina A.N., Kshnikatkin S.A., Alenin P.G., Shchanin A.A., Prakhova T.Ya., Prakhov V.A., Medvedev A.P., Voronova I.A.* Biological diversity of non-traditional oil crops // IOP Conference: International Conference on Engineering Studies and Cooperation in Global Agricultural Production. 2021. Vol. 659. p. 12091.

[2]*Eskova O.V., Eskov S.V.* Ecological aspects of cultivation of safflower dye depending on the norms and timing of its seeding in the foothill Crimea // Proceedings of the Kuban State Agrarian University. 2016. no. 60. pp. 87-92.

tively absorb various micro- and macroelements from the soil. As a result, safflower can obtain sufficient nutrients for biomass formation even in poor soils [12].

In the context of climate change, increased aridity, and frequent droughts, crops like safflower are becoming more and more in demand. However, a gap remains in the cultivation of safflower due to insufficient research on its cultivation technology, including the principles of applying microfertilizers containing a balanced set of macro- and microelements. The use of fertilizers can alter the growth and development rates of plants and promote not only higher crop productivity but also resistance to stressful situations[3] [13].

Nowadays, many authors are working on increasing the yield of safflower, including through the use of microfertilizers. However, all the studies described in the literature were conducted in different climatic conditions [11, 14, 15]. There are no works devoted to the use of Izagri products on safflower crops. Therefore, the purpose of our research was to analyze the impact of pre-sowing treatment of safflower seeds with Izagri microelement fertilizers on the productivity of safflower in the forest-steppe conditions of the Middle Volga region.

MATERIAL AND METHODS

The research was conducted from 2020 to 2022 in the fields of the Penza Scientific Research Institute of Agriculture, which is a branch of the Federal Research Center for Bast Fiber Crops. The experimental site's soils consisted of moderately alkaline chernozems with an average humus content of 5.75% and a soil pH_{salt} of 5.4. The readily hydrolyzable nitrogen content was 83.9 mg/kg (according to Tyurin and Kononova, GOST 26951–86), available phosphorus was 142.6 mg/kg (according to Chirikov, GOST 26204–91), and exchangeable potassium was 167.5 mg/kg (according to Chirikov, GOST 26204–91).

The experiment involved the pre-sowing treatment of safflower seeds of the Ershevsky 4 variety with Izagri microelement fertilizers. Izagri represented a range of liquid organomineral fertilizers with different proportions of mineral elements in a water-soluble form for seed treatment before sowing and foliar feeding of plants.

The field experiment included the following variants: 1) control (without treatment); 2) treatment with various types of Izagri microelement fertilizers at a concentration of 1 L/ton: a) Izagri Nitrogen; b) Izagri Boron; c) Izagri Vita; d) Izagri Phosphorus; e) Izagri Force.

Safflower was sown in the first ten-day period of May using the SN-16 seeder. The planting method was in rows, with a sowing rate of 0.3 million viable seeds per hectare. The experimental plot area was 10 m^2, and there were four replications. Harvesting was done by direct combining when the crop reached full maturity using the SAMPO-130 combine harvester.

The yield measurements, observations, and analyses were carried out following the recommended methods[4]. The leaf area was determined using the clippings method during the flowering stage, seed oil content was analyzed using the Soxhlet method, the fatty acid composition was analyzed using gas-liquid chromatography on a "Crystal 5000.1" chromatograph according to GOST R 51483–99, and protein content was determined using the Kjeldahl method in the agrotechnology laboratory of the Penza Scientific Research Institute of Agriculture. Seed variety and planting quality were determined according to GOST 9672–61, including the mass of 1,000 seeds according to GOST 10842–89, and impurity content according to GOST 10855–64.

The climate in the forest-steppe region of the Middle Volga, including the Penza region, is moderately continental. Its distinctive feature is the pronounced contrast and variability in heat and moisture resources. In 2020, the vegetation of safflower occurred under conditions of insufficient moisture, with a hydrothermal coefficient

[3]Alenin P.G., Prakhova T.Y., Safronkin A.E. Effect of microfertilizers and growth regulators on the productivity of winter winter redcurrants Penzyak // Volga Region Farmland. 2015. no. 3 (36). pp. 13-18.

[4]Methodology of field and agrotechnical experiments with oilseed crops. Krasnodar: VNIIMK Publishing House, 2010. 323 p.

(HTC) of 0.72 during this period. There was a sharp change in meteorological conditions during the stages of crop development. The phase from "sowing to stem elongation" had abundant moisture (HTC = 1.85), while from stem elongation to flowering, plant development occurred under drought conditions (HTC = 0.67). The "flowering to maturity" phase had more moderate conditions (HTC = 0.92).

In 2021, the vegetation period of the crop occurred against a slight deficit of precipitation, which was observed throughout all stages of plant development. The hydrothermal coefficient was consistent for all phenophases and the entire vegetation period, being 0.86, except for the time from sowing to the beginning of stem elongation, which experienced severe drought conditions (HTC = 0.07).

In 2022, safflower development from germination to flowering occurred under abundant moisture (HTC = 1.38), while further growth from flowering to maturity happened under severe drought conditions (HTC = 0.23), with only 7 mm of precipitation. The situation was exacerbated by high-temperature conditions, with the average daily air temperature reaching 25.6 °C, exceeding the climatic norm by 5.8 °C.

RESULTS AND DISCUSSION

It is necessary to form crops with optimal productive stalk density, which is determined primarily by field germination and plant safety for harvesting, in order to obtain high yields of any agricultural crop, including safflower. Initial changes occurring in seeds after their treatment with microelemental substances greatly affect the further development of plants and their productivity as a whole.

Laboratory studies revealed a high responsiveness of safflower seeds to pre-sowing treatment with Izagri microelement fertilizers. As a result of their application, the shoot growth force increased to 1.21–1.57 cm, which was 0.03–0.39 cm higher than in the control variant (see Table 1).

The most intense stimulation of initial growth was observed in the variants treated with Izagri Vita and Izagri Force, where the shoot growth force reached 1.57 and 1.48 cm, respectively, significantly exceeding the control. This indicates that the use of these preparations enhances seed vigor, growth, and development.

The use of the studied preparations tended to increase the percentage of field germination by 1.1–8.8% compared to the control. The highest germination rate was recorded in the variant with Izagri Vita – 78.1%, while the lowest values (70.4 and 70.6%) were obtained in the variants with Izagri Boron and Izagri Phosphorus, where the treatment did not significantly improve seed quality.

The average plant survival rate at harvest over 3 years was high (82.0–88.2%) and increased by 0.5–6.2% depending on the type of applied preparation relative to the control. High values of plant survival were observed in variants treated with Izagri Vita (88.2%) and Izagri Nitrogen (87.6%), which most effectively contributed to improving the production process.

Another indicator characterizing the state of the crop agrocoenosis is the photosynthetic ac-

Табл. 1. Влияние применения различных видов микроудобрения серии Изагри на посевные качества и формирование агроценоза сафлора (2020–2022 гг.)

Table 1. Effect of applying different types of Izagri series microfertilizer on the sowing qualities and formation of safflower agrocenosis (2020-2022)

Option	Growth force, cm	Field germination, %	Mortality before harvesting, %	Leaf area, thousand m^2/ha
Control	1,18	69,3	82,0	33,52
Izagri Boron	1,21	70,4	82,5	36,89
Izagri Vita	1,57	78,1	88,2	37,13
Izagri Phosphorus	1,32	70,6	84,0	35,67
Izagri Nitrogen	1,35	75,4	87,6	34,45
Izagri Force	1,48	76,5	86,9	39,65
LSD_{05}	0,19	1,47	1,57	1,12

tivity of plants, including the formation of an optimal leaf area. In the early period of safflower growth, the leaf area increases very slowly, reaching its maximum during the flowering phase. The most intensive increase in the leaf surface area was observed when the seeds were treated with Izagri Force: the maximum leaf area reached 39.65 thousand m^2/ha, which was 6.13 thousand m^2/ha higher than in the control and 2.52–6.13 thousand m^2/ha higher than in other treatment variants.

The average productivity of safflower over 3 years ranged from 1.30 to 1.55 t/ha, with a tendency of increased yield when using Izagri preparations. The most effective were the applications of Izagri Force and Izagri Vita, which led to yields of 1.53 and 1.55 t/ha, respectively. The increase in seed productivity due to treatment was 0.23 and 0.25 t/ha compared to the control (see Figure 1).

The use of Izagri Phosphorus also led to a slight but significant increase in yield by 0.16 t/ha, which falls within the least significant difference (LSD_{05} = 0.15 t/ha). Treatment with Izagri Boron and Izagri Nitrogen resulted in a statistically insignificant increase in the seed yield by 0.06 and 0.09 t/ha with LSD_{05} = 0.15 t/ha.

It is worth noting that fertilizers worked most effectively in 2021 (HTC = 0.86): in this year, plants had the highest yield of 1.63–1.78 t/ha compared to 1.48 t/ha in the control variant without fertilization.

As mentioned earlier, Izagri Vita and Izagri Force significantly increased the yield of safflower, but they had practically no effect on oil accumulation. The oil content in the seeds when using these preparations was 27.31 and 27.24%, respectively, which was slightly higher than the control variant by 0.17 and 0.10% with LSD_{05} = 1.04% (see Figure 2).

The highest oil content was observed in the variants treated with Izagri Nitrogen (29.85%) and Izagri Boron (30.04%), which were significantly (by 2.71 and 3.0% respectively) higher compared to the control. Presumably, these preparations were most actively involved in carbohydrate synthesis and fat formation. In the variant with Izagri Phosphorus, there was a decrease in the oil content to 26.86%, while the control had an oil content of 27.14%.

The highest protein content in the seeds was found in the variants treated with Izagri Vita and Izagri Boron – 23.55 and 23.18% respectively (see Table 2). The use of Izagri Force and Izagri Phosphorus had little effect on protein accumulation, with the content at the level of the control at 22.46%. Izagri Nitrogen reduced the protein content in seeds to 21.74% compared to 22.10% in the untreated variant.

The weight of 1,000 safflower seeds varied from 36.63 to 39.16 g. The largest seeds were formed as a result of the treatment with Izagri

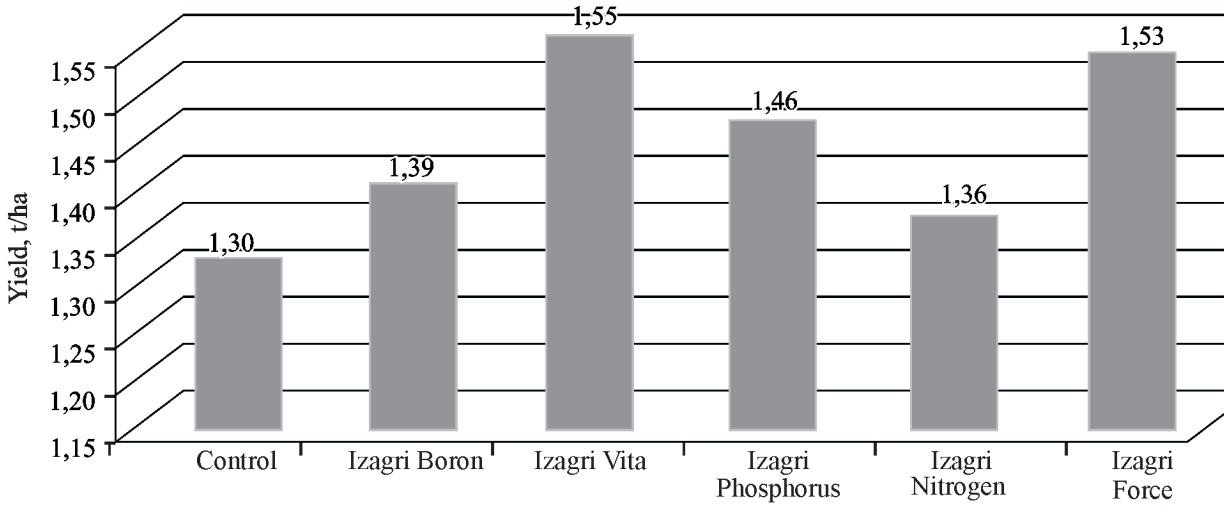

Рис. 1. Влияние применения различных видов микроудобрения серии Изагри на продуктивность сафлора (2020–2022 гг.)

Fig. 1. Effect of applying different types of Izagri series microfertilizer on safflower productivity (2020-2022)

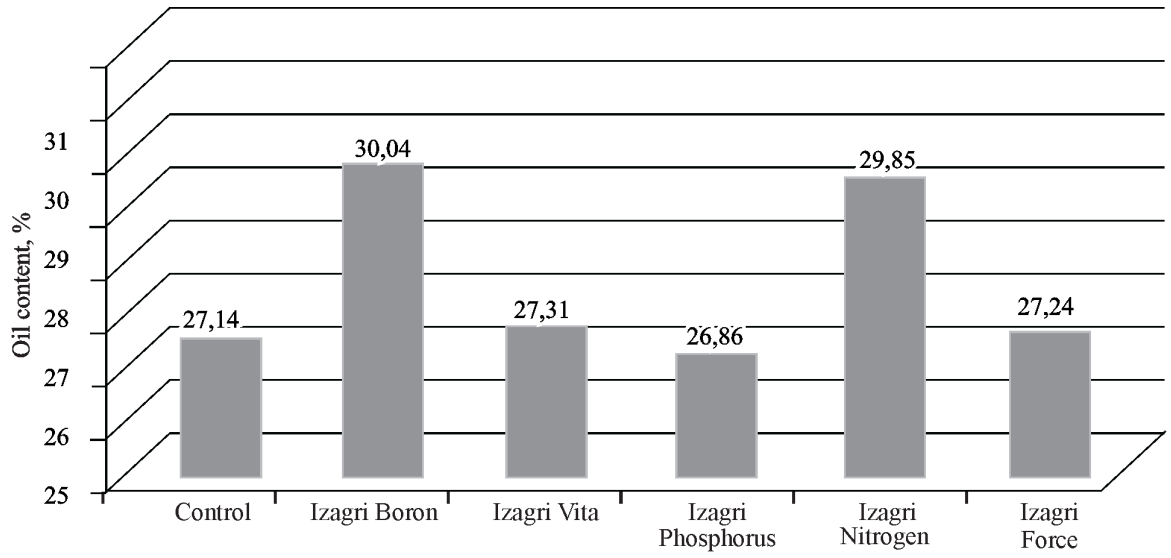

Рис. 2. Влияние применения различных видов микроудобрения серии Изагри на содержание масла в семенах сафлора (2020–2022 гг.)

Fig. 2. Effect of applying different types of Izagri series microfertilizer on the oil content of safflower seeds (2020-2022)

Vita, with a weight of 39.16 g per 1,000 seeds. In the variant with Izagri Force, the weight of 1,000 seeds was slightly lower at 38.19 g, which was marginally higher than in the other variants.

From an agronomic point of view, seeds with high test weight are more well-developed, having a well-developed endosperm and high specific gravity. Seeds with low test weight are more lightweight, underdeveloped, and characterized by the presence of a significant number of husks. In our experiment, the test weight of safflower seeds was sufficiently high and varied from 475.0 g/l in the control to 514.1 g/l in the variant with Izagri Boron. The highest test weight was observed in the variants using Izagri Boron (514.1 g/l) and Izagri Nitrogen (507.1 g/l). This indicates that the seeds in these variants are well-developed and have fewer fruit coats (hull).

The huskiness of the seeds in turn affects their oil content: the lower the huskiness, the higher the oil content. Increasing or decreasing huskiness can be achieved by changing nutritional conditions, e.g. by applying macro- or micro-fertilizers, etc. The application of microfertilizers in our studies reduced seed huskiness to 37.7-39.6% with 40.6% in the control variant. Low huskiness was recorded in the treatment with Izagri Boron and Izagri Nitrogen - 37.7 and 37.9%, respectively, as a consequence, these variants had the highest oil content of seeds.

The applied micro-fertilizers had no signifi-

Табл. 2. Влияние применения различных видов микроудобрения серии Изагри на показатели качества семян сафлора (2020–2022 гг.)

Table 2. Effect of applying different types of Izagri series microfertilizer on the quality indicators of safflower seeds (2020-2022)

Option	Protein content, %	Weight of 1 thousand seeds, g	Weight per bushel, g/l	Huskness, %
Control	22,10	36,63	475,0	40,6
Izagri Boron	23,18	37,82	514,1	37,7
Izagri Vita	23,55	39,16	502,2	38,1
Izagri Phosphorus	22,46	37,91	483,5	39,6
Izagri Nitrogen	21,74	36,86	507,1	37,9
Izagri Force	22,46	38,19	495,6	38,8
LSD_{05}	0,39	0,74	11,57	1,54

Табл. 3. Влияние применения различных видов микроудобрения серии Изагри на содержание основных жирных кислот в маслосеменах сафлора

Table 3. Effect of applying different types of Izagri series microfertilizer on the content of essential fatty acids in safflower oilseeds

Option	Saturated		Unsaturated		
	palmitic	stearic	oleic	linoleic	linolenic
Control	4,28	1,45	10,56	82,98	0,11
Izagri Boron	4,54	1,62	10,26	82,45	0,13
Izagri Vita	4,15	1,48	9,62	83,63	0,21
Izagri Phosphorus	4,61	1,63	9,94	82,71	0,18
Izagri Nitrogen	4,25	1,50	10,88	82,20	0,23
Izagri Force	4,68	1,63	10,71	81,88	0,14

cant effect on the fatty acid composition of the oilseeds. However, slight changes were observed in the content of monounsaturated oleic acid: on the background of Izagri Phosphorus and Izagri Vita, its concentration decreased to 9.94 and 9.62%, respectively. Meanwhile, treatment with Izagri Vita maximally (up to 83.63%) increased the amount of polyunsaturated linoleic acid. The use of Izagri Force reduced its concentration to 81.88% compared to other variants, where the level of linoleic acid was within 82.20–82.98% (see Table 3).

The content of saturated acids did not change significantly across the variants and was as follows: palmitic acid – 4.15–4.68%, stearic acid – 1.45–1.63%. The amount of linolenic acid varied from 0.13 to 0.23% depending on the applied preparations. Therefore, the use of micro-fertilizers allows for adjusting the fatty acid composition to some extent in the oilseeds of safflower.

CONCLUSION

Thus, pre-sowing treatment of safflower seeds with Izagri micro-fertilizers contributes to the improvement of the production process of crops, increases the productivity and quality indicators of oilseeds. Among the considered fertilizers, the most effective ones are Izagri Vita and Izagri Force, the application of which increased the intensity of seedling growth, improved field germination, and resulted in a yield increase of 0.23 and 0.25 t/ha, respectively, compared to the control variant. As a result of using these preparations, the largest seeds were obtained (1,000 seeds weight 39.16 and 38.19 g). Treatment with Izagri Nitrogen and Izagri Boron promoted an increase in seed oil content by 2.7 and 3.0% respectively, and reduced their shattering to 37.7 and 37.9%.

СПИСОК ЛИТЕРАТУРЫ

1. *Herger N., Angélil O., Abramowitz G., Donat M., Stone D., Lehmann K.* Calibrating Climate Model ensembles for assessing extremes in a Changing Climate // Journal of Geophysical Research: Atmospheres. 2018. Vol. 123. N 11. P. 5988–6004.
2. *Chehade L.A., Luciana G.A., Tavarini S.* Genotype and seasonal variation affect yield and oil quality of safflower (*Carthamus tinctorius* L.) under Mediterranean conditions // Agronomy. 2022. Vol. 12 (1). P. 122. DOI: 10.3390/agronomy12010122.
3. *Khalid N., Khan R.S., Hussain M.I., Farooq M., Ahmad A., Ahmed I.* A comprehensive characterisation of safflower oil for Its potential applications as a bioactive food ingredient – A Review // Trends in Food Science and Technology. 2017. Vol. 66. P. 176–186. DOI: 10.1016/j.tifs.2017.06.009.
4. *Турина Е.Л.* Значение сафлора красильного (*Carthamus tinctorius* L.) и обоснование актуальности исследований с ним в Центральной степи Крыма (обзор) // Таврический вестник аграрной науки. 2020. № 1 (21). С. 100–121. DOI: 10.33952/2542-0720-2020-1-21-100-121.
5. *Nasiyev B.N., Yessenguzhina A.N.* Formation of agricultural landscapes of saflor (*Cárthamus tinctórius*) in the system of biologized crop // Intellect, Idea, Innovation. 2021. N 1. P. 35–39. DOI: 10.12345/22266070_2021_1_35.

6. *Кшникаткина А.Н., Прахова Т.Я., Щанин А.А.* Продуктивность и качество сортообразцов сафлора красильного в условиях Среднего Поволжья // Нива Поволжья. 2019. № 1 (50). С. 2–7.
7. *Кароматов И.Д., Акрамова Н.Ш.* Перспективное лекарственное растение – сафлор красильный (обзор литературы) // Биология и интегративная медицина. 2018. № 6 (23). С. 68–95.
8. *Вольф Е.Ю., Козырева В.М., Симакова И.В., Вольф А.А.* Исследование жирно-кислотного состава некоторых растительных масел и их купажей // Ползуновский вестник. 2021. № 3. С. 131–140. DOI: 10.25712/ASTU.2072-8921.2021.03.018.
9. *Nogales-Delgado S., Encinar J.M., Cortés Á.G.* High oleic safflower oil as a feedstock for stable biodiesel and biolubricant production // Industrial Crops and Products. 2021. Vol. 170. P. 113701. DOI: 10.1016/j.indcrop.2021.113701.
10. *Турина Е.Л., Корнев А.Ю.* Сортоиспытание сафлора в Крыму и возможность получения биотоплива // Труды Кубанского государственного аграрного университета. 2022. № 98. С. 120–125. DOI: 10.21515/1999-1703-98-120-125.
11. *Ghassemi-Golezani K., Afkhami N.* Safflower productivity and oil yield affected by water limitation and nanofertilizers // Journal of Biodiversity and Environmental Sciences. 2018. Vol. 12. N 5. P. 425–431.
12. *Полякова А.И., Алиева О.Ю.* Продуктивность сафлора под влиянием минеральных удобрений и регуляторов роста // Вестник Белорусской государственной сельскохозяйственной академии. 2020. № 4. С. 51–55.
13. *Сафина Н.В., Кильянова Т.В.* Технология возделывания сафлора красильного в условиях Среднего Поволжья // Известия Самарского научного центра Российской академии наук. 2019. № 6 (92). С. 95–100.
14. *Милованов И.В., Кандалов Е.В., Нарушев В.Б., Кожагалиева Р.Ж.* Влияние стимуляторов роста и микроудобрения на продуктивность сафлора красильного в степной зоне Саратовского Правобережья // Аграрный научный журнал. 2021. № 4. С. 24–29. DOI: 10.28983/asj.y2021i4pp24-39.
15. *Насиев Б.Н., Гончаров С.В., Жылкыбай А.М.* Изучение биологизированной технологии возделывания сафлора в Западном Казахстане // Труды Кубанского государственного аграрного университета. 2022. № 94. С. 131–136. DOI: 10.21515/1999-1703-94-131-136.

REFERENCES

1. Herger N., Angélil O., Abramowitz G., Donat M., Stone D., Lehmann K. Calibrating Climate Model ensembles for assessing extremes in a Changing Climate. *Journal of Geophysical Research: Atmospheres*, 2018, vol. 123, no. 11, pp. 5988–6004.
2. Chehade L.A., Luciana G.A., Tavarini S. Genotype and seasonal variation affect yield and oil quality of safflower (*Carthamus tinctorius* L.) under Mediterranean conditions. *Agronomy*, 2022, vol. 12 (1), p. 122. DOI: 10.3390/agronomy12010122.
3. Khalid N., Khan R.S., Hussain M.I., Farooq M., Ahmad A., Ahmed I. A comprehensive characterisation of safflower oil for Its potential applications as a bioactive food ingredient – A Review. *Trends in Food Science and Technology*, 2017, vol. 66, pp. 176–186. DOI: 10.1016/j.tifs.2017.06.009.
4. Turina E.L. *Carthamus tinctorius* L. value and the relevance of the research with this crop in the Central Steppe of the Crimea (Review). *Tavricheskiy vestnik agrarnoy nauki = Tauride Bulletin of Agrarian Science*, 2020, no. 1 (21), pp. 100–121. (In Russian). DOI: 10.33952/2542-0720-2020-1-21-100-121.
5. Nasiyev B.N., Yessenguzhina A.N. Formation of agricultural landscapes of saflor (*Cárthamus tinctórius*) in the system of biologized crop. *Intellect, Idea, Innovation*, 2021, no. 1, pp. 35–39. DOI: 10.12345/22266070_2021_1_35.
6. Kshnikatkina A.N., Prakhova T.Ya., Shanin A.A. Productivity and quality of variety samples of safflower in the conditions of the Middle Volga region. *Niva Povolzh'ya = Volga Region Farmland*, 2019, no. 1 (50), pp. 2–7. (In Russian).
7. Karomatov I.D., Akramova N.Sh. Perspective herb – the Carthamus tinctorial (literature review). *Biologiya i integrativnaya meditsina = Biology and Integrative Medicine*, 2018, no. 6 (23), pp. 68–95. (In Russian).
8. Wolf E.Yu., Kozyreva V.M., Simakova I.V., Wolf A.A. Research of fat-acid composition of certain vegetable oils and their blends. *Polzunovskiy vestnik = Polzunovskiy vestnik*, 2021, no. 3, pp. 131–140. (In Russian). DOI: 10.25712/ASTU.2072-8921.2021.03.018.
9. Nogales-Delgado S., Encinar J.M., Cortés Á.G.

High oleic safflower oil as a feedstock for stable biodiesel and biolubricant production. *Industrial Crops and Products*, 2021, vol. 170, pp. 113701. DOI: 10.1016/j.indcrop.2021.113701.
10. Turina E.L., Kornev A.Yu. Variety testing of Carthamus tinctorius in Crimea and the possibility of obtaining biofuel. *Trudy Kubanskogo gosudarstvennogo agrarnogo universiteta = Proceedings of the Kuban State Agrarian University*, 2022, no. 98, pp. 120–125. (In Russian). DOI: 10.21515/1999-1703-98-120-125.
11. Ghassemi-Golezani K., Afkhami N. Safflower productivity and oil yield affected by water limitation and nanofertilizers. *Journal of Biodiversity and Environmental Sciences*, 2018, vol. 12, no. 5, pp. 425–431.
12. Polyakova A.I., Alieva O.Yu. Productivity of safflower under the influence of mineral fertilizers and growth regulators. *Vestnik Belorusskoy gosudarstvennoy sel'skokhozyaystvennoy akademii = Bulletin of the Belarusian State Agricultural Academy*, 2020, no. 4, pp. 51–55. (In Russian).
13. Safina N.V., Kilyanova T.V. Technology of cultivation of safflower in the Middle Volga region. *Izvestiya Samarskogo nauchnogo tsentra Rossiyskoy akademii nauk = Izvestia of Samara Scientific Center of the Russian Academy of Sciences*, 2019, no. 6 (92), pp. 95–100. (In Russian).
14. Milovanov I.V., Kandalov E.V., Narushev V.B., Kozhagalieva R.Zh. Influence of growth stimulants and microfertilizers on the productivity of Carthamus tinctorius in the steppe zone of the Saratov Right Bank. *Agrarnyy nauchnyy zhurnal = Agrarian Scientific Journal*, 2021, no. 4, pp. 24–29. (In Russian). DOI: 10.28983/asj.y2021i4pp24-39.
15. Nasiev B.N., Goncharov S.V., Zhylkybay A.M. Study of the biologized technology of safflower cultivation in Western Kazakhstan. *Trudy Kubanskogo gosudarstvennogo agrarnogo universiteta = Proceedings of the Kuban State Agrarian University*, 2022, no. 94, pp. 131–136. (In Russian). DOI: 10.21515/1999-1703-94-131-136.

ИНФОРМАЦИЯ ОБ АВТОРАХ

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Дата поступления статьи / Received by the editors 17.02.2023
Дата принятия к публикации / Accepted for publication 10.03.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-5
УДК: 633.13:631.527
Тип статьи: оригинальная
Type of article: original

ОЦЕНКА АДАПТИВНЫХ СВОЙСТВ СОРТОВ ОВСА ПО УРОЖАЙНОСТИ В ПРИОБСКОЙ ЛЕСОСТЕПИ

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Представлены результаты оценки адаптивных свойств районированных сортов овса сибирской селекции по урожайности в Приобской лесостепи Новосибирской области. Эксперимент проводили на опытном поле Сибирского научно-исследовательского института растениеводства и селекции в 2012–2021 гг. Объектом исследования являлись 37 сортов овса, включенных в Госреестр Российской Федерации и районированных по Западно-Сибирскому (№ 10) и Восточно-Сибирскому (№ 11) регионам. Оценку урожайности и фенологические наблюдения осуществляли согласно методике Всероссийского института генетических ресурсов растений им. Н.И. Вавилова. Для статистической обработки данных использовали методику Б.А. Доспехова. Потенциальную продуктивность и адаптивность сортов определяли по методике Л.А. Животкова с соавт., устойчивость сортов к стрессовым условиям – по А.А. Гончаренко, размах урожайности – по В.А. Зыкину. Анализ урожайности по группам спелости продемонстрировал закономерную тенденцию: по мере удлинения периода вегетации по группам спелости увеличивается и потенциал продуктивности. Высокими показателями потенциала продуктивности в благоприятные годы и адаптивности к неблагоприятным факторам внешней среды отличались следующие сорта: Краснообский, Мустанг, Метис, Овен, Отрада, Талисман, Иртыш 21, СИР 4, Орион. Высокую адаптивность и стабильность проявили сорта Овен, Новосибирский 5, СИР 4. Способностью давать не максимальную, но высокую стабильную урожайность в любых условиях характеризовались четыре сорта: Крупнозерный, Новосибирский 88, Белозерный, Корифей.

Ключевые слова: сорт, группа спелости, урожайность, стабильность

EVALUATION OF OAT VARIETIES ADAPTIVE PROPERTIES BY PRODUCTIVITY IN THE PRIOBSKAYA FOREST-STEPPE ZONE

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The results of evaluation of adaptive properties of released oat varieties of Siberian breeding by yield in the Priobskaya forest-steppe of Novosibirsk region are presented. The experiment was conducted on the experimental field of the Siberian Research Institute of Plant Production and Breeding in 2012-2021. The object of the study were 37 oat varieties included in the State Register of the Russian Federation and released in the West Siberian (№ 10) and East Siberian (№ 11) regions. Yield estimation and phenological observations were carried out according to the methodology of N.I. Vavilov All-Russian Institute of Plant Genetic Resources. For statistical data processing the method of B.A. Dospekhov was used. Potential productivity and adaptability of the varieties were determined by L.A. Zhivotkov et al. method, resistance of the varieties to stress conditions - by A.A. Goncharenko, the yield spread - by V.A. Zykin. Analysis of yields by groups of ripeness showed a natural tendency: as the growing season lengthens by groups of ripeness, the productivity potential also increases. The following varieties had high indicators of productivity potential in favorable years and adaptability to adverse environmental factors: Krasnoobsky, Mustang, Metis, Oven, Otrada, Talisman, Irtysh 21, SIR 4, Orion. The varieties Oven, Novosibirsk 5, CIR 4 showed high adaptability and stability. Four varieties were characterized by the ability to give not the maximum, but high stable yield under any conditions: Krupnozerny, Novosibirsk 88, Belozerny, and Korifey.

Keywords: variety, ripeness group, productivity, stability

Для цитирования: *Сотник А.Я.* Оценка адаптивных свойств сортов овса по урожайности в Приобской лесостепи // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 40–46. https://doi.org/10.26898/0370-8799-2023-5-5

For citation: Sotnik A.Ya. Evaluation of oat varieties adaptive properties by productivity in the Priobskaya forest-steppe zone. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 40–46. https://doi.org/10.26898/0370-8799-2023-5-5

Конфликт интересов
Автор заявляет об отсутствии конфликта интересов.
Conflict of interest
The author declares no conflict of interest.

Благодарность
Работа поддержана бюджетным проектом Федерального исследовательского центра «Институт цитологии и генетики СО РАН» № FWNR-2022-0018.
Acknowledgements
The work was supported by the budget project of the FRC IC&G SB RAS no. FWNR-2022-0018.

INTRODUCTION

Thanks to the balanced ratio of essential amino acids in the composition of plant-based protein, oats are considered a crop of versatile use [1, 2]. Consequently, the stable production of oat grains in various agroclimatic conditions is a crucial task[1] [3]. The solution to this problem is possible, in part, through the creation and use of new varieties[2,3] [4].

It is necessary to have a set of varieties with high potential productivity, ecological adaptability, and stability in different agroclimatic conditions for the selection of new varieties [5, 6]. Currently, there are 64 oat varieties included in the State Register of the Russian Federation and recommended for cultivation in the West Siberian (No. 10) and East Siberian (No. 11) regions, the vast majority of which have been developed by Siberian breeders. Many of these varieties exhibit a combination of challenging traits, such as high yield and grain quality, drought resistance, and lodging resistance. An important task is to enhance the adaptability of new varieties to stabilize yields under various stress conditions.

The purpose of this research is to evaluate the adaptive properties of regional oat varieties created by Siberian breeders in terms of yield in the Priobskaya forest-steppe of the Novosibirsk region.

The research object consists of 37 oat varieties included in the State Register of the Russian Federation and zoned for the West Siberian and East Siberian regions [4, 5].

MATERIAL AND METHODS

The experiment took place in the experimental field of the Siberian Scientific Research Institute, located 5 km from the Krasnoobsk settlement in the Novosibirsk region. The Siberian gene pool (demonstration nursery) was evaluated over 10 years (2012–2021). The agricultural practices for the experiment were generally accepted for the area. The plot area was 1 m², and the sowing period was mainly the second ten-day period of May. The seeding rate was 550 viable seeds per 1 m².

Yield assessment and phenological observations were conducted following the methodology of the N.I. Vavilov All-Russian Institute of Plant Genetic Resources[6]. Data processing was carried out using B.A. Dospeshov's methodology[7]. Potential productivity and adaptability of

[1] *Batalova G.A.* State and prospects of breeding and cultivation of grain-forage crops in Russia // Grain Economy of Russia. 2011. no. 3. pp. 14-22.

[2] *Chekmarev P.A.* Strategy of breeding and seed production development in Russia // Zemledelie. 2011. no. 6. pp. 3-5.

[3] *Komarova G.N.* Selection of oats in Western Siberia // Achievements of Science and Technology of AIC. 2010. no. 12. pp. 12-13.

[4] The State Register of Breeding Achievements Allowed for Use. URL: https://gossortrf.ru/gosreestr/(accessed on: 04.10.2022).

[5] Catalog of varieties of agricultural crops created by scientists of Siberia and included in the State Register of the Russian Federation (zoned) in 1929-2008. Novosibirsk, 2009. Issue. 4. vol. 1. 207 p.

[6] *Loskutov I.G., Kovaleva O.N., Blinova E.V.* Methodological guidelines for the study and conservation of the world collection of barley and oats. St. Petersburg, 2012. 63 p.

[7] *Dospekhov B.A.* Methodology of field experience. M.: Kolos, 1979. 416 p.

the varieties were determined using the methodology of L.A. Zivotkov's et al.[8], while the resistance of the varieties to stressful conditions was assessed based on A.A. Goncharenko's methodology[9], and the yield range was determined using V.A. Zykin's methodology[10].

According to the meteorological station data located in the Ogurtsovo village, the years of the research varied significantly in terms of temperature and precipitation amounts. The hydrotechnical coefficient (HTC), which indicates the ratio of precipitation volume to the sum of effective temperatures[11], varied from 0.59 to 3.17 during the period from May to August in different years. The moisture supply during the vegetative period was as follows: in 2012 – very low (HTC = 0.59), in 2014, 2016, 2019, and 2021 – insufficient (HTC = 1.06–1.36), in 2015, 2017, and 2020 – sufficient (HTC = 1.58–1.78), in 2018 – high (HTC = 1.94), and in 2013 – excessive (HTC = 3.17). The moisture supply classification follows the classification of E.K. Zoidze and T.V. Khomyakova[12]. The observed changes in meteorological conditions in different years reflect an important climatic feature of the region - absolute instability in terms of moisture and temperature factors.

RESULTS AND DISCUSSION

During the study, the examined oat varieties were classified into maturity groups based on the average duration of the "emergence - wax ripeness" period over ten years. Out of 37 varieties, three were early-maturing, 14 were medium-early, 19 were medium-maturing, and only one variety, "Irtysh 22," fell into the "Middle-late" group.

The yield analysis based on maturity groups revealed that as the duration of the vegetation period increased, the potential productivity of the varieties also increased (see the table). This biologically driven regularity is well-known and has been observed in several other studies [7–9].

The yield over the ten years varied from 264 (variety "Baikal" in 2012) to 1387 kg/m² (variety "Dogoy" in 2019). In the most favorable years in terms of agroclimatic conditions, the following varieties realized their potential productivity: for early-maturing varieties - Taeyzhnik, Krasnoobsky, for medium-early varieties - Mustang, Tarsky 2, Oven, "Metis, Tulunsky 19, Irtysh 13, and for medium-maturing varieties - SIR 4, Yegorych, Orion, Irtysh 21, Dogoy, Talisman, and Otrada.

The level of yield under different conditions serves as a criterion for their overall adaptive ability. The methodology of L.A. Zivotkov et al. is based on comparing the yield of varieties with the average group yield for the year. One of the most important regularities of morphogenesis is the dominance of species reactions of adaptation over specific morphogenetic traits among different varieties: all the varieties in the experiment simultaneously react as a single-species system, although individual varieties have different yields, they do not exceed the species norm (see footnote 8).

According to the mentioned methodology, a comparison of varieties with the mean group value was carried out for maturity groups. The numerical value of this indicator was expressed as the coefficient of adaptability (as a relative value). Based on the adaptability coefficient, the following varieties stood out: Krasnoobsky, Uran, Novosibirsky 5, Metis, Memory of Bogachkov, Oven, Mustang, Togurchanin, Sig, Otrada, Kreol, Talisman, Irtysh 21, SIR 4, and Orion. The high yield of these listed varieties, exceeding the average within the maturity group over ten years, indicates their highest adapta-

[8]*Zhivotkov L.A., Morozova Z.A., Sekatueva L.I.* Methodology for identifying the potential productivity and adaptability of varieties and breeding forms of winter wheat by the indicator "yield" // Breeding and Seed Production. 1994. no. 2. pp. 3-6.

[9]*Goncharenko A.A*. On adaptability and ecological stability of grain crop varieties // Bulletin of Rosselkhozakademy. 2005. no. 6. pp. 49-53.

[10]*Zykin V.A., Shamanin V.P., Belan I.A.* Ecology of wheat. Omsk, 2000. 124 p.

[11]Gringof I.G., Popova V.V., Strashny V.N. Agrometeorology. L.: Gidrometeoizdat, 1987. 310 p.

[12]*Zoidze E.K., Khomyakova T.V.* Modeling of moisture availability formation on the territory of European Russia in modern conditions and the basis for assessment of agroclimatic security // Meteorologiya i Gidrologiya. 2006. no. 2. pp. 98-105.

Адаптивность сортов овса по урожайности (2012–2021 гг.)
Adaptability of oat varieties by yield (2012-2021)

Variety, origin	Vegetation period, days	Yield, g/m²			Adaptability indicators			
		$X \pm S_x$	minimum	maximum	adaptivity coefficient	stress tolerance, g/m²	compensatory capacity, g/m²	*d*, %
1	2	3	4	5	6	7	8	9
Early								
Taezhnik, Tomsk region	68 ± 2	734 ± 78	330	1194	1,04	−864	762	72
Krasnobsky, Novosibirsk region	70 ± 2	744 ± 85	350	1179	1,05	−829	764	70
Sibiryak, Irkutsk region	70 ± 2	652 ± 66	280	977	0,92	−697	628	71
Average value within the group	69	707	320	1117	1,00			
Middle-early								
Uran, Omsk region	71 ± 4	811 ± 73	360	1130	1,05	−770	745	68
Baikal, Irkutsk region	71 ± 2	654 ± 64	264	992	0,84	−728	628	73
Anchar, Irkutsk region	71 ± 4	715 ± 66	400	1084	0,92	−784	742	63
Novosibirsky 5, Novosibirsk Region	72 ± 2	815 ± 83	390	1180	1,05	−790	787	67
Novosibirsky 88, Novosibirsk Region	72 ± 2	758 ± 61	425	1106	0,98	−681	765	62
Tarsky 2, Omsk region	72 ± 2	777 ± 87	365	1258	1,00	−893	811	71
Tulunsky 19, Irkutsk region	72 ± 4	753 ± 83	345	1210	0,97	−865	777	71
Metis, Tomsk region	72 ± 4	843 ± 91	375	1356	1,09	−981	865	72
Memory of Bogachkov, Omsk region	73 ± 2	814 ± 76	350	1120	1,05	−770	735	69
Oven, Irkutsk region	73 ± 2	826 ± 85	440	1254	1,07	−814	847	65
Mustang, Omsk region	73 ± 2	814 ± 92	320	1314	1,05	−996	817	76
Irtysh 13, Omsk region	73 ± 4	753 ± 86	325	1195	0,97	−870	760	73
Togurchanin, Tomsk region	73 ± 4	822 ± 74	360	1147	1,06	−787	753	69
Krupnozerny, Novosibirsk Region	73 ± 2	694 ± 62	380	984	0,89	−604	682	61
Average value within the group	72	775	364	1188	1,00			
Medium-maturing								
Rovesnik, Novosibirsk region	74 ± 4	798 ± 83	372	1207	1,00	−835	789	69
Belozerny, Novosibirsk region	74 ± 2	748 ± 64	410	1033	0,94	−623	721	61
Tubinsky, Krasnoyarsk territory	74 ± 4	742 ± 73	325	1108	0,93	−783	716	71
Sig, Krasnoyarsk territory	74 ± 2	822 ±85	382	1193	1,03	−811	787	68
Otrada, Tyumen region	74 ± 4	848 ± 85	345	1270	1,06	−925	807	73
Altaisky krupnozerny, Altai territory	74 ± 4	752 ± 76	375	1160	0,94	−785	767	68
Kreol, Kemerovo region	74 ± 2	844 ± 76	400	1202	1,05	−802	801	67
Talisman, Tyumen region	74 ± 4	854 ± 97	380	1354	1,07	−974	717	78
Dogoy, Republic of Buryatia	74 ± 4	813 ± 99	400	1387	1,02	−987	893	71
Irtysh 21, Omsk region	74 ± 2	842 ± 99	390	1240	1,05	−850	815	68

Окончание таблицы

1	2	3	4	5	6	7	8	9
Kemerovsky 90, Kemerovo region	74 ± 4	792 ± 83	320	1158	0,99	−838	739	72
Orion, Omsk region	75 ± 2	820 ± 83	362	1236	1,03	−874	799	71
Egorych, Irkutsk region	75 ± 4	795 ± 95	415	1310	1,00	−895	862	68
Narymsky 943, Tomsk region	75 ± 2	742 ± 30	350	1135	0,93	−785	742	69
Fobos, Omsk region	75 ± 4	801 ± 73	390	1204	1,00	−814	797	68
Korifei, Altai territory	75 ± 4	738 ± 73	375	1104	0,92	−729	739	66
SIR 4, Novosibirsk region	76 ± 4	837 ± 82	420	1246	1,05	−836	833	66
Pegasus, Altai territory	76 ± 4	783 ± 83	400	1196	0,98	−796	798	66
Barguzin, Republic of Buryatia	76 ± 4	793 ± 91	400	1202	0,99	−802	801	67
Average value within the group	75	798	379	1208	1,00			
Middle-late								
Irtysh 22, Omsk region	78 ± 4	803 ± 83	305	1154	1,00	−849	729	73

Note. X – average; S_x – error (for 10 years).

tion to growing conditions, surpassing the group norm (highest adaptability coefficient for maturity groups). The following varieties exhibited significant potential productivity in favorable years and adaptability to unfavorable external factors: Taeyzhnik, Krasnoobsky, Mustang, Metis, Oven, Otrada, Talisman, Dogoy, Yegorych, Irtysh 21, SIR 4, and Orion.

High potential yield is undoubtedly one of the primary tasks of the breeders. At the same time, creating varieties that provide average but stable yields with good quality agricultural products is a very important task[13] [10].

In different agroclimatic conditions, an important characteristic of oat varieties is their stress tolerance, which is determined by the difference between the minimum and maximum yields (Y_{min} - Y_{max}) [see footnote 9]. The smaller the gap between the maximum and minimum yields, the higher the stress resistance of the variety. The following varieties showed relative resistance to stressful environmental conditions (with minimal yield differences in contrasting conditions): Siberiak, Krupnozerny, Novosibirsky 88, Belozeri, and Korifey. On the other hand, the least stress tolerance was observed in the varieties Taeyzhnik, Mustang, Tarsky 2, Metis, Otrada, Talisman, Dogoy, and Yegorych.

To characterize stress tolerance, the indicator of compensatory capacity (genetic flexibility) of the variety is also used. The compensatory capacity, reflecting the average yield of the variety in favorable and unfavorable conditions, is calculated using the following formula:

(Ymin + Ymax)/2.

High values of the compensatory capacity indicate a strong correspondence between the genotype of the variety and the environmental factors. The higher this indicator, the more resistant the variety is to different environmental factors. Varieties with high compensatory capacity and high stress tolerance include Tarsky 2, Metis, Mustang, Otrada, Dogoy, Yegorych, and also Ovien, Kreol, Irtysh 21, SIR 4, and Barguzin, which, however, have a lower level of stress resistance.

Furthermore, the stability of productivity over the years based on increased resistance of varieties to the limiting factors of the external environment is of great importance. One of the indicators of variety stability is the magnitude of yield variation range. This parameter is calculated as the ratio of the difference between the maximum and minimum yield to its maximum value, expressed as a percentage [see footnote 10]. Genotypes may have the same difference

[13] *Dyakov A.B., Trunova M.V.* Relationship between the parameters of stability and adaptability of varieties // Oilseeds: Scientific and Technical Bulletin of the All-Russian Research Institute of Oilseed Crops. 2010. Issue 1. pp. 80-86.

between the maximum and minimum yields and, at the same time, differ in the magnitude of these values. The ratio of the difference between the maximum and minimum yields to its maximum value (d, %) allows ranking varieties by the degree of stability. The smaller the range of variation, the more stable the yield of a genotype under specific conditions. In our case, the yield variation range exceeded 50%, which is due to a large fluctuation in the indicator over the years.

The varieties with the smallest yield variation range in contrasting agroclimatic years were as follows: for medium-early varieties - Krupnozerny, Novosibirsky 88, Anchiar, Ovien, Novosibirsky 5, and for medium-maturing varieties - Belozerny, Korifey, SIR 4, Pegas, Kreol, and Barguzin. These varieties demonstrated the most stable yields in contrasting conditions.

Based on the evaluation of adaptive properties, the studied varieties can be divided into two groups:

a) combining high adaptability and stability: Krasnoobsky, Ovien, Novosibirsky 5, Uran, Togurchanin, Memory of Bogachkov, SIR 4, Sig, Kreol, and Irtysh 21;

b) possessing high stress tolerance, capable of providing not the maximum but high and stable yields in any conditions: Krupnozerny, Novosibirsky 88, Belozerny, and Korifey.

CONCLUSIONS

1. The following varieties exhibited high potential productivity in favorable years and adaptability to unfavorable environmental factors: Krasnoobsky, Mustang, Metis, Oven, Otrada, Talisman, Irtysh 21, SIR 4, and Orion.

2. The most stable yields in contrasting conditions were demonstrated by the varieties Krupnozerny, Novosibirsky 88, Anchiar, Oven, Novosibirsky 5, Belozerny, Korifey, SIR 4, Pegas, Kreol, and Barguzin.

3. The varieties Krasnoobsky, Oven, Novosibirsky 5, Uran, Togurchanin, Memory of Bogachkov, SIR 4, Sig, Kreol, and Irtysh 21 showed high adaptability and stability.

4. The varieties Krupnozerny, Novosibirsky 88, Belozerny, and Korifey demonstrated the ability to provide high and stable yields in any conditions, even if not the maximum yields.

СПИСОК ЛИТЕРАТУРЫ

1. *Thies F.*, *Masson L.F.*, *Boffetta P.*, *Kris-Etherton P.* Oats and CVD risk markers: a systematic literature review // British Journal of Nutrition. 2014. Vol. 112. Supl. 2. P. 19–30.
2. *Schuster J.*, *Beninca G.*, *Vitorazzi R.*, *Morelo Dal Bosco S.* Effects of oats on lipid profile, insulin resistance and weight loss // Nutrición Hospitalaria. 2015. Vol. 32. N 5. P. 2111–2116.
3. *Сурин Н.А.*, *Ляхова Н.Е.*, *Герасимов С.А.*, *Липшин А.Г.* Интегрированная оценка адаптивной способности образцов ячменя из коллекции ВИР в условиях Красноярской лесостепи // Достижения науки и техники АПК. 2016. Т. 30. № 6. С. 32–35.
4. *Анкудович Ю.Н.* Влияние климатических и агрохимических факторов на урожайность овса в условиях севера Томской области // Сибирский вестник сельскохозяйственной науки. 2015. № 5. С. 40–47.
5. *Сайнакова А.Б.*, *Литвинчук О.В.* Оценка экологической пластичности и стабильности коллекционных образцов овса по массе 1000 зерен // Вестник Кемеровского государственного университета. 2015. Т. 3. № 4 (64). С. 72–74.
6. *Кардашина В.Е.*, *Николаева Л.С.* Влияние метеорологических условий на продуктивность и хозяйственно ценные признаки овса // Пермский аграрный вестник. 2017. № 3 (19). С. 70–75.
7. *Липшин А.Г.*, *Герасимов С.А.* Источники генофонда овса коллекции ВИР для селекции в Восточной Сибири // Вестник Красноярского государственного аграрного университета. 2017. № 2. С. 16–21.
8. *Сотник А.Я.* Оценка сортов овса по урожайности и вегетационному периоду в условиях Приобской лесостепи // Сибирский вестник сельскохозяйственной науки. 2018. № 1 (48). С. 51–56.
9. *Русакова И.И.*, *Баталова Г.А.*, *Ведерников Ю.Е.*, *Тулякова М.В.* Источники хозяйственно ценных признаков для селекции овса пленчатого // Аграрная наука Евро-Северо-Востока. 2016. № 5 (54). С. 4–9.
10. *Баталова Г.А.* Селекция растений в условиях нестабильности агроклиматических ресурсов // Зернобобовые и крупяные культуры. 2012. № 3. С. 20–25.

REFERENCES

1. Thies F., Masson L.F., Boffetta P., Kris-Etherton P. Oats and CVD risk markers: a systematic literature review. *British Journal of Nutrition*, 2014, vol. 112, supl. 2, pp. 19–30. DOI: 10.1017/S0007114514002281.
2. Schuster J., Beninca G., Vitorazzi R., Morelo Dal Bosco S. Effects of oats on lipid profile, insulin resistance and weight loss. *Nutrición Hospitalaria*, 2015, vol. 32, no. 5, pp. 2111–2116. DOI: 10.3305/nh.2015.32.5.9590.
3. Surin N.A., Lyakhova N.E., Gerasimov S.A., Lipshin A.G. Integrated assessment of adaptive ability of barley samples from VIR collection under conditions of Krasnoyarsk forest-steppe. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2016, vol. 30, no. 6, pp. 32–35. (In Russian).
4. Ankudovich Yu.N. Effect of climatic and agrochemical factors on oats productivity under conditions of the north of Tomsk region. *Sibirskii vestnik sel'skhozaistvennoi nauki = Siberian Herald of Agricultural Science*, 2015, no. 5, pp. 40–47. (In Russian).
5. Sainakova A.B., Litvinchuk O.V. Assessment of ecological plasticity and stability of collection samples of oats by weight of 1000 grains. *Vestnik Kemerovskogo gosudarstvennogo universiteta = Bulletin of Kemerovo State University*, 2015, vol. 3, no. 4 (64), pp. 72–74. (In Russian).
6. Kardashina V.E., Nikolaeva L.S. Impact of meteorological conditions on productivity and economically valuable features of oats. *Permskiy agrarniy vestnik = Perm Agrarian Journal*, 2017, no. 3 (19), pp. 70–75. (In Russian).
7. Lipshin A.G., Gerasimov S.A. The sources of the gene pool of oats of VIR collection for selection in Eastern Siberia. *Vestnik Krasnoyarskogo agrarnogo universiteta = Bulletin of Kras GAU*, 2017, no. 2, pp. 16–21. (In Russian).
8. Sotnik A.Ya. Assessment of oat varieties by yield and vegetation period in the conditions of the Priobskaya forest-steppe. *Sibirskii vestnik sel'skhozaistvennoi nauki = Siberian Herald of Agricultural Science*, 2018, no. 1 (48), pp. 51–56. (In Russian).
9. Rusakova I.I., Batalova G.A., Vedernikov Yu.E., Tulyakova M.V. Sources of economically valuable traits for covered oat breeding. *Agrarnaya nauka Evro-Severo-Vostoka = Agricultural Science Euro-North-East*, 2016, no. 5 (54), pp. 4–9. (In Russian).
10. Batalova G.A. Selection of plants under conditions of instability of agro-climatic resources. *Zernoboboviye i krupyaniye kul'turi = Legumes and Groat Crops*, 2012, no. 3, pp. 20–25. (In Russian).

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Дата поступления статьи / Received by the editors 17.10.2022
Дата принятия к публикации / Accepted for publication 12.12.2022
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-6
УДК: 632.7(471.63)
Тип статьи: оригинальная
Type of article: original

ВИДОВОЙ СОСТАВ ВРЕДИТЕЛЕЙ ХВОЙНЫХ РАСТЕНИЙ УРБАНИСТИЧЕСКИХ ЛАНДШАФТОВ КРАСНОДАРСКОГО КРАЯ

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Представлены результаты исследований хвойных пород растений как материала для озеленения населенных мест, в ландшафтной архитектуре – в качестве акцента и доминанты в декоративных композициях или в монопосадках. Отмечено расширение сортимента хвойных растений для ландшафтного строительства юга России в 2000-е гг. за счет интродукции культур из других регионов с разными природно-климатическими условиями. Вновь посаженные насаждения испытывают стресс, который оказывает негативное влияние на иммунный статус интродуцированных растений. Представлены результаты изучения видового состава сосущих вредителей хвойных растений в урбанистических ландшафтах. Мировой опыт в исследованиях городских ландшафтов показывает расширение видового состава вредителей из отряда Равнокрылых (Homoptera). Проведен фитосанитарный мониторинг декоративных хвойных растений в городских насаждениях и парковых зонах в Прикубанской зоне центральной подзоны садоводства Краснодарского края в 2012–2022 гг. По результатам проведенных исследований выявлено видовое разнообразие сосущих вредителей хвойных растений в крае, проведено их ранжирование по типу питания, формируется база данных. Установлено, что в регионе доминирующими представителями надсемейства Coccidae являются щитовка европейская можжевельниковая (*Carulaspis juniperi* Bouché) и тисовая ложнощитовка (*Parthenolecanium pomeranicum* Kawecki), щитовка сосновая веретеновидная (*Anamaspis lowi Colvee*). Закономерности пищевой специализации щитовок имеют не только теоретическое, но и практическое значение. На основе исследований можно прогнозировать вероятный состав вредителей на вновь вводимой культуре. Полученные закономерности являются одной из теоретических основ защитных мероприятий по борьбе с вредителями.

Ключевые слова: хвойные растения, фитофаги, мониторинг, прогноз, сосущие вредители, фауна

SPECIES COMPOSITION OF CONIFEROUS PLANT PESTS IN THE URBAN LANDSCAPES OF THE KRASNODAR TERRITORY

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The results of the studies of conifers as a material for landscaping of settlements, and as an accent and dominant in decorative compositions or in mono-planting are presented. The expansion of coniferous plant assortment for landscape construction of southern Russia in the 2000s was noted due to the introduction of crops from other regions with different natural and climatic conditions. Newly planted crops are under stress, which has a negative effect on the immune status of the introduced plants. The results of the study of the species composition of sucking pests of coniferous plants in urban landscapes are presented. The world experience in the studies of urban landscapes shows the expansion of

the species composition of pests from the order of homopterous insects (Homoptera). Phytosanitary monitoring of ornamental conifers in urban plantations and park areas in the Kuban zone of the central horticultural subzone of the Krasnodar Territory in 2012-2022 was conducted. As a result of these studies, the species diversity of sucking pests of coniferous plants in the region has been identified, their ranking by the type of feeding has been carried out, and a database is being compiled. It has been found that the dominant representatives of the superfamily Coccidae in the region are: European juniper scale insect (*Carulaspis juniperi* Bouché) and yew pseudo scale insect (*Parthenolecanium pomeranicum* Kawecki), and pine spindle scale insect (*Anamaspis lowi Colvee*). The regularities of food specialization of scales are of not only theoretical but also practical importance. Based on the research, the probable composition of pests on a newly introduced crop can be predicted. The resulting patterns are one of the theoretical foundations of pest control measures.

Keywords: coniferous plants, phytophages, monitoring, forecast, sucking pests, fauna

Для цитирования: *Прах С.В., Васильченко А.В., Подгорная М.Е., Тыщенко Е.Л.* Видовой состав вредителей хвойных растений урбанистических ландшафтов Краснодарского края // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 47–53. https://doi.org/10.26898/0370-8799-2023-5-6

For citation: Prakh S.V., Vasilchenko A.V., Podgornaya M.E., Tyschenko E.L. Species composition of coniferous plant pests in urban landscapes of the Krasnodar Territory. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2023, vol. 53, no. 5, pp. 47–53. https://doi.org/10.26898/0370-8799-2023-5-6

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Coniferous plants are valuable materials for landscaping populated areas. Landscape architects often use coniferous species as striking accents in decorative compositions or single plantings. The valuable qualities of conifer cultivars, such as the diversity of crown habit, foliage color, and its changes throughout the year, as well as their potential for topiary, bordering, etc., allow for extensive use in landscaping. It is worth noting their economically valuable characteristic - phytocidal properties, which are particularly appreciated in greening recreational areas [1, 2].

During the 2000s, the assortment of coniferous plants used in landscaping in the southern regions of Russia significantly changed and expanded with new species, forms, and varieties. The expansion of the coniferous plant assortment in green construction occurs by 95% through the introduction of species and forms from other regions with different natural and climatic conditions. The main supply of coniferous planting material comes from countries such as the Netherlands, Poland, Germany, Italy, whose agricultural regions have a more moderate temperature and humidity regime for cultivating decorative plants. The Krasnodar region's territory is characterized by a wide variety of natural and climatic conditions. The primary abiotic stress factor in the region during the summer is the deficit of air and soil moisture against the backdrop of high temperatures, while in the winter period, there are periodically sharp drops in temperature to minus 15–17 °C and below. The intensification of the negative impact of low temperatures on agricultural crops is particularly relevant after periods of relatively moderate positive temperatures [3–5].

Therefore, in the Krasnodar region, planting materials of foreign origin experience stress when planted in landscaping objects, negatively affecting the introduced plant's immune status. Such cultivars are often affected by fungal diseases and damaged by numerous phytophagous pests of local origin.

Sap-sucking species are the most extensive and adaptable representatives among the pests of coniferous species. Damage caused by these phytophagous insects significantly reduces the decorative effect of created landscape compositions, worsens the ecological situation of agrolandscapes, and increases the costs of maintaining green plantings. The purpose of the re-

search is to identify the main composition of sap-sucking pests of coniferous plants in urban landscapes of the Krasnodar region.

MATERIAL AND METHODS

A phytosanitary monitoring of decorative coniferous plants in urban plantations and park areas in the Prikuban zone of the central horticultural subzone of the Krasnodar region was conducted from 2012 to 2022. The research focused on the representatives of the Pine family (Pinaceae), including two species from the genus *Pinus* and one from the genus *Abies*, the Yew family (Taxaceae) with one species from the genus *Taxus*, and the Cypress family (Cupressaceae) with one species from the genus *Thuja* and three from the genus *Juniperus.* The species affiliation of the identified coccids (together with a part of the fodder plant) was performed in the laboratory under a binocular microscope using the method by N.S. Borhsenius[1]. The identification of the species of phytophagous insects was carried out using a guidebook for damage on forest, ornamental, fruit trees, and shrubs [6].

RESULTS AND DISCUSSION

Decorative plantations are rich and diverse in terms of their species composition. Currently, over 3600 taxa of decorative woody plants are cultivated. This diversity of plants and favorable climatic conditions support the development of more than 500 species of harmful entomofauna from the orders Lepidoptera, Homoptera, Diptera, and Hymenoptera. Therefore, it is essential to identify the species composition of harmful organisms in urban ecosystems and improve methods for their control [6–9].

Based on our investigation of the state of coniferous plants in urban landscapes of the Krasnodar region, conducted for more than 10 years, it was established that the phytosanitary situation in coniferous plantations has deteriorated due to an increase in the population and harmfulness of sap-sucking pests [2]. Global research experience on urban landscapes indicates an expansion of the species composition of pests from the order Homoptera [10, 11]. In parks, gardens, and other green areas of the city environment in Belgrade, there has been a loss of decorative appearance and drying out of junipers (*Juniperus* spp.) due to an increase in the population of European juniper scale (*Carulaspis juniperi* Bouche). The use of *Juniperus* spp. in landscape design has become economically disadvantageous. Throughout the Republic of Belarus, urban coniferous plantations are widely affected by the spruce larch aphis (*Sacchiphantes viridis*), the fir-spruce aphid (*Aphrastasia pectinatae*), the yew soft scale (*Parthenolecanium pomeranicum*), and the cypress aphid (*Cinara cupressi*).

In Turkey and Spain, Coccidae represent a group of pests affecting decorative plants, and the most dangerous species is *Palaeococcus fuscipennis* Burmeister. In Crimea, on the territory of the Nikita Botanical Garden, 19 species of phytophagous insects have been identified, with the most numerous being from the families Diaspididae and Coccidae [12–16].

Phytosanitary monitoring of coniferous plants in urban landscapes of the Krasnodar region and the entomological assessment of the collected material revealed the following taxonomic composition of the order Homoptera:

Superorder proboscideans (Rhenchota)

Order homopterans (Homoptera)

Suborder Aphids (Aphididea)

Superfamily Aphids (Aphidoidea)

Family Aphids (Aphididae): cypress aphid (*Cinara cupressi* Buckton), mealy pine aphid (*Cinara costata* Zett.), juniper aphid (*Cinara juniperi* De Geer).

Superfamily Adelgoidae

Family Adelgidae: pine aphid (*Pineus pini* L. (Macq.), Aphrastasia pectinatae (*Adelges* (*Aphrastasia*) pectinatae Chol.).

Suborder coccids (Coccinea)

Superfamily Orthezioidea

Family giant coccids (Margarodidae): Brown Pine coccid (*Palaeococcus fuscipennis* Burm.).

Superfamily Coccidae

Family soft scale (Coccidae): European brown scale (*Parthenolecanium corni* Bouché),

[1]*Borchsenius N.S.* Practical determinator of coccids (Coccoidea) of cultivated plants and forest species of the USSR. Leningrad: Nauka, 1973. 311 p.

yew scale (*Parthenolecanium pomeranicum* Kawecki).

Family armoured scales (Diaspididae): European juniper scale (*Carulaspis juniperi* Bouche), pine spindle scale insect (*Anamaspis lowi Colvee*).

Among the Coccidae superfamily, the most damaging species to plants are European juniper scale (*Carulaspis juniperi* Bouche), yew scale (*Parthenolecanium pomeranicum* Kawecki), and pine spindle scale insect *(Anamaspis lowi Colvee*) (see Table 1).

The expansion of food specialization increases the distribution and harmfulness of many phytophagous species, which cause significant damage to urban landscapes. The ability to switch to different host species allows them to have a prolonged life cycle, less dependent on food availability. These factors enable them to have one or more generations per year and maintain a high population size. Based on the research, harmful organisms have been divided according to their food specialization. Monitoring shows that recently the most adapted pest species are Brown Pine coccid (*Palaeococcus fuscipennis* Burm.), European juniper scale (*Carulaspis juniperi* Bouche), and European brown scale (*Parthenolecanium corni* Bouché). Phytophages were distributed by feeding type according to the results of the study (see Table 2).

The patterns of food specialization in phytophagous insects have both theoretical and practical significance. Based on the obtained

Табл. 1. Видовое разнообразие сосущих вредителей на хвойных растениях в урбанистических ландшафтах Краснодарского края

Table 1. Species diversity of sucking pests on coniferous plants in the urban landscapes of the Krasnodar Territory

Crop	Family	Species
Scotch pine *(Pinus sylvestris* L.*)*	Adelgid plantlice *(*Adelgidae*)*	Pine aphid (*Pineus pini* L. (Macq.), Aphrastasia pectinatae (*Adelges (Aphrastasia*) pectinatae Chol.)
	Giant coccids (Margarodidae)	Brown Pine coccid (*Palaeococcus fuscipennis* Burm.)
	Scale insects (Diaspididae)	Pine spindle scale (*Anamaspis lowi Colvee*)
Crimean pine (*Pinus nigra* subsp. *pallasiana* (Lamb.))	Giant coccids (Margarodidae)	Brown Pine coccid (*Palaeococcus fuscipennis* Burm.)
	Scale insects (Diaspididae)	Pine spindle scale (*Anamaspis lowi Colvee*)
Yew tree (*Taxus* L.)	Soft scale (Coccidae)	Yew pseudo scale (*Parthenolecanium pomeranicum* Kawecki), European brown scale (*Parthenolecanium corni* Bouche)
Fir-tree (*Abies* spp.)	Adelgid plantlice (Adelgidae)	Aphrastasia pectinatae (*Adelges (Aphrastasia) pectinatae* Chol.)
Western red cedar *(Thuja* L.*)*	Aphids (Aphididae)	Cypress aphid (*Cinara cupressi* Buckton), European juniper scale (*Carulaspis juniperi* Bouche)
Common juniper *(Juniperus communis* Suecica*)*	Scale insects *(*Diaspididae*)*	European juniper scale (*Carulaspis juniperi* Bouche)
	Aphids (Aphididae)	Juniper aphid (*Cinara juniperi* De Geer)
Chinese juniper (*Juniperus chinensis* Stricta)	Aphids (Aphididae)	Juniper aphid (*Cinara juniperi* De Geer)
Scaly juniper (*Juniperus squamat*a Holger)	Scale insects (Diaspididae)	European juniper scale (*Carulaspis juniperi* Bouche)

Табл. 2. Пищевая специализация сосущих вредителей хвойных растений
Table 2. Food specialization of sucking pests of coniferous plants

Nutritional adaptation	Pest
Monophages	Leucaspis pusilla (*Leucaspis pusilla* Low), mealy Aphis pini (*Cinara costata* Zett.), pine adelges (*Pineus pini* L. (Macq.)), Aphrastasia pectinatae (*Aphrastasia* pectinatae Chol.), yew pseudo scale (*Parthenolecanium pomeranicum* Kawecki)
Oligophages	Cypress aphid (*Cinara cupressi* Buckton), juniper aphid (*Cinara juniperi* De Geer), pine spindle scale (*Anamaspis lowi Colvee*)
Polyphages	Brown Pine coccid (*Palaeococcus fuscipennis* Burm.), European juniper scale (*Carulaspis juniperi* Bouche), European brown scale (*Parthenolecanium corni* Bouche)

data, it is possible to predict the probable composition of pests on newly introduced crops. At the same time, these patterns serve as a theoretical basis for protective measures against pests.

CONCLUSION

In the southern regions of Russia, planting material of imported coniferous plants experiences stress, which negatively affects the immune status of the introduced plants. According to the research, such cultivars are affected by fungal diseases and damaged by indigenous phytophagous insects as well as newly introduced ones. It has been identified that the most adapted pest species on coniferous plants in the Krasnodar region are Brown Pine coccid (*Palaeococcus fuscipennis* Burm.), European juniper scale (*Carulaspis juniperi* Bouche), and European brown scale (*Parthenolecanium corni* Bouché). The feeding specialization of sap-sucking pests on coniferous plants has been determined, and six monophagous, three oligophagous, and three polyphagous species have been identified.

СПИСОК ЛИТЕРАТУРЫ

1. *Прах С.В., Подгорная М.Е., Тыщенко Е.Л.* Инвазивные виды кокцид (*HOMOPTERE*, *COCCOIDAE*) юга России, их вредоносность и распространение // Плодоводство и виноградарство юга России. 2021. № 71 (5). С. 234–246.
2. *Ülgentürk S., Evren N., Ayhan B., Dostabil Ö., Dursun O. ve Civelek H.* Türkiye'nin çam ağaçlarında pul böcek (Hemiptera: Coccoidea) türleri // Turkish Journal of Zoology. 2012. N 36 (5). P. 623–636.
3. *Pachauri R.K.*, *Mejer L.A.* Climate Change, 2014: Summary report. ZHeneva: MGEIK, 2014. 163 p.
4. *Egorov E.A., Shadrina Zh.A., Kochyan G.A.* Increasing the technological and economic efficiency of nursery production based on processes biologization // International Scientific Online-Conference "Bioengineering in the Organization of Processes Concerning Breeding and and Viticulture". 2020. P. 01001.
5. *Габрид Н.В.* Насекомые, повреждающие хвойные породы, их экологические особенности в зеленых насаждениях города Бишкек // Исследование живой природы Кыргызстана. 2019. № 2. С. 59–70.
6. *Попов Г.В.* Основные вредители декоративных насаждений Донецкой области (2000–2009 гг.) и борьба с ними // Промышленная ботаника. 2009. № 9. С. 213–219.
7. *Gertsson C.* The Hungarian Spruce Scale, *Physokermes inopinatus* Danzig & Kozar (Hemiptera: Coccoidea: Coccidae) in Sweden // Acta Zoologica Bulgarica suppl. 2014. № 6. P. 83–86.
8. *Gertsson C., Winde I.* A significant record of the Hungarian Spruce Scale *Physokermes inopinatus* Danzig & Kozar in Scania, southern Sweden (Hem. Coccoidea) // ResearchGate. 2014. P. 32–34.
9. *Papanastasiou I., Kavallieratos N.G, Saitanis C.J, Chatzaki M., Papadoulis G., Emmanouel N.G.* Parasitoids and Predators of *Physokermes hellenicus* (Hemiptera: Coccomorpha: Coccidae) in Greece // Journal of Economic Entomology. 2018. N 111 (3). P. 1121–1130.
10. *Мустафаева Г.А.* Видовой состав щитовок (*Hemiptera: Diaspididae*) Азербайджана, их вредоносность и распространенность //

Бюллетень науки и практики. 2017. № 3. С. 86–98.
11. *Baders E., Jansons A., Matisons R., Elferts D., Desaine I.* Landscape Diversity for Reduced Risk of Insect Damage: A Case Study of Spruce Bud Scale in Latvia // Forests. 2018. № 9 (9). P. 545.
12. *Suh S., Evans G.* A new record of the armored scale genus *Carulaspis* MacGillivray (Hemiptera: Diaspididae) from Korea and its aphelinid parasitoids (Hymenoptera: Aphelinidae) // Insecta Mundi. 2016. N 0466. P. 1–6.
13. *Косовская М.А., Хренова Т.К., Лямина Н.В.* Оценка функционального состояния дендроформ г. Севастополя в условиях интенсивной антропогенной нагрузки // Энергетические установки и технологии. 2021. Т. 7. № 1. С. 97–104.
14. *Куниченко О.В., Антюхова Н.И., Шульман В.В., Власов В.В., Соколова Л.Н., Кудина Т.Н.* Мониторинг фитосанитарного состояния декоративных урболандшафтов ПМР // Вестник приднестровского университета. Серия: медико-биологические и химические науки. 2015. № 2 (50). С. 78–86.
15. *Miezite O., Okmanis M., Indriksons A., Ruba J., Polmanis K., Freimane L.* Assessment of sanitary conditions in stands of Norway spruce (*Picea abies* Karst.) damaged by spruce bud scale (*Physokermes piceae* Schrnk.) // Biogeosciences and Forestry. 2013. N 6 (2). P. 73–78.
16. *Trikoz N.N.* Actual phytosanitary state of park cenoses of the Southern Coast of the Crimea // Plant Biology and Horticulture theory innovation. 2021. N 1 (157). P. 56–66.

REFERENCES

1. Prakh S.V., Podgornaya M.E., Tyshchenko E.L. Invasive species of coccids (*HOMOPTERE*, *COCCOIDAE*) of the South of Russia, their harmfulness and distribution. *Plodovodstvo i vinogradarstvo Yuga Rossii = Fruit growing and viticulture of South* Russia, 2021, no. 71 (5), pp. 234–246. (In Russian).
2. Ülgentürk S., Evren N., Ayhan B., Dostabil Ö., Dursun O. ve Civelek H. Türkiye'nin çam ağaçlarında pul böcek (Hemiptera: Coccoidea) türleri. *Turkish Journal of Zoology*, 2012, no. 36 (5), pp. 623–636.
3. Pachauri R.K., Mejer L.A. *Climate Change, 2014: Summary report*. ZHeneva, MGEIK, 2014. 163 p.
4. Egorov E.A., Shadrina Zh.A., Kochyan G.A. Increasing the technological and economic efficiency of nursery production based on processes biologization/ *International Scientific Online-Conference "Bioengineering in the Organization of Processes Concerning Breeding and and Viticulture"*. 2020, pp. 01001.
5. Gabrid N.V. Insects harmful coniferous breeds, their ecological features in the green plants of the city of Bishkek. *Issledovanie zhivoi prirody Kyrgyzstana = Kyrgyzstan live nature research*, 2019, no. 2, pp. 59–70. (In Russian).
6. Popov G.V. The principal pests of decorative plantations in Donetsk region (2000–2009) and their control. *Promyshlennaya botanika = Industrial Botany,* 2009, no. 9, pp. 213–219. (In Russian).
7. Gertsson C. The Hungarian Spruce Scale, Physokermes inopinatus Danzig & Kozar (Hemiptera: Coccoidea: Coccidae) in Sweden // *Acta Zoologica Bulgarica suppl.* 2014, no. 6, pp. 83–86.
8. Gertsson C., Winde I. A significant record of the Hungarian Spruce Scale *Physokermes inopinatus* Danzig & Kozar in Scania, southern Sweden (Hem. Coccoidea). *ResearchGate*, 2014, pp. 32–34.
9. Papanastasiou I., Kavallieratos N.G, Saitanis C.J, Chatzaki M., Papadoulis G., Emmanouel N.G. Parasitoids and Predators of Physokermes hellenicus (Hemiptera: Coccomorpha: Coccidae) in Greece. *Journal of Economic Entomology*, 2018, no. 111 (3), pp. 1121–1130.
10. Mustafaeva G.A. Species composition scale insects (*Hemiptera: Diaspididae*) of Azerbaijan, their injuriousness and distribution. *Byulleten' nauki i praktiki = Bulletin of Science and Practice,* 2017, no. 3, pp. 86–98. (In Russian).
11. Baders E., Jansons A., Matisons R., Elferts D., Desaine I. Landscape Diversity for Reduced Risk of Insect Damage: A Case Study of Spruce Bud Scale in Latvia. *Forests*, 2018, no. 9(9), pp. 545.
12. Suh S., Evans G. A new record of the armored scale genus Carulaspis MacGillivray (Hemiptera: Diaspididae) from Korea and its aphelinid parasitoids (Hymenoptera: Aphelinidae). *Insecta Mundi*, 2016, no. 0466, pp. 1–6.
13. Kosovskaya M.A., Khrenova T.K., Lyamina N.V. Assessment of the functional state of

dendroforms in Sevastopol under conditions of intense anthropogenic load. *Energeticheskie ustanovki i tekhnologii = Power plants and technologies,* 2021, vol. 7, no. 1, pp. 97–104. (In Russian).
14. Kunichenko O.V., Antyukhova N.I. Shul'man V.V. Vlasov V.V., Sokolova L.N., Kudina T.N. Monitoring the phytosanitary condition of ornamental urban landscapes in the PMR. *Vestnik pridnestrovskogo universiteta. Seriya: mediko-biologicheskie i khimicheskie nauki = Vestnik of the Transnistrian university. Series: Medical-Biological and Chemical Sciences,* 2015, no. 2 (50), pp. 78–86. (In Russian).
15. Miezite O., Okmanis M., Indriksons A., Ruba J., Polmanis K., Freimane L. Assessment of sanitary conditions in stands of Norway spruce (Picea abies Karst.) damaged by spruce bud scale (Physokermes piceae Schrnk.). *Biogeosciences and Forestry,* 2013, no. 6 (2), pp. 73–78.
16. Trikoz N.N. Actual phytosanitary state of park cenoses of the Southern Coast of the Crimea. *Plant Biology and Horticulture theory innovation*, 2021, no. 1 (157), pp. 56–66.

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Дата поступления статьи / Received by the editors 05.09.2022
Дата принятия к публикации / Accepted for publication 20.12.2022
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-7
УДК: 636.085:577.17
Тип статьи: оригинальная
Type of article: original

ВОЗДЕЙСТВИЕ КАВИТИРОВАННОЙ ПОДСОЛНЕЧНОЙ ЛУЗГИ И МОЛОЧНОЙ КИСЛОТЫ НА ИЗМЕНЕНИЕ ТАКСОНОМИЧЕСКОГО ПРОФИЛЯ МИКРОБИОМА РУБЦА ЖВАЧНЫХ *IN VITRO*

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Проведена оценка воздействия кавитированной подсолнечной лузги и молочной кислоты на изменение таксономического профиля микробиома рубца жвачных *in vitro.* Определено изменение бактериального состава рубцовой жидкости путем применения метода секвенирования на приборе MiSeq во временной экспозиции 6–24 ч. Объекты исследований – подсолнечная лузга измельченная (0,01 см) – контроль; кавитированная: лузга и вода в соотношении 1 : 3, обработанные ультразвуком; лузга и молочная кислота в соотношении 1 : 3 – лузга кавитированная + молочная кислота. Полученные образцы после высушивания при 105 ºС использовали в исследованиях *in vitro* с рубцовой жидкостью на инкубаторе (аналог искусственного рубца). Отбор рубцовой жидкости у крупного рогатого скота осуществляли через хроническую фистулу. Возраст животных – 12 мес, порода – казахская белоголовая. Введение кавитированной лузги подсолнечника как отдельно, так и совместно с молочной кислотой, после 6 ч увеличивало количество бактерий, относящихся к классам *Flavobacteriia,* на 5,43 и 3,93%, *Elusimicrobia* – 3,77 и 3,98%, *Gammaproteobacteria* –11,75 и 10,07%, и снижало численность бактерий класса *Bacteroidia* на 5,72 и 2,63%, *Clostridia* на 3,26 и 2,20% относительно контроля. Во временной экспозиции 12–24 ч, напротив, происходило увеличение бактерий класса *Bacteroidia* на 3,30–4,90 и на 8,29–11,28%, *Clostridia* – на 1,66–1,50 и на 2,74–3,27% по отношению к контролю.

Ключевые слова: кавитированная лузга подсолнечника, таксономический профиль, микробиом, молочная кислота

THE EFFECT OF CAVITATED SUNFLOWER HUSK AND LACTIC ACID ON THE CHANGES IN THE TAXONOMIC PROFILE OF THE RUMEN MICROBIOME OF RUMINANTS *IN VITRO*

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The effect of cavitated sunflower husk and lactic acid on the changes in the taxonomic profile of the rumen microbiome of ruminants *in vitro* was evaluated. Changes in the bacterial composition of the cicatricial fluid were determined by using the MiSeq sequencing method in a time exposure of 6-24 h. The objects of research were sunflower husk milled (0.01 cm) - control; cavitated: husk and water in a ratio of 1 : 3, treated with ultrasound; husk and lactic acid in a ratio of 1 : 3 - cavitated husk + lactic acid. The obtained samples after drying at 105 ºC were used in *in vitro* studies with rumen fluid on an incubator (analog of artificial rumen). Selection of the rumen fluid in cattle was carried out through a chronic fistula. The age of animals - 12 months, the breed - Kazakh white-headed. Administration of cavitated sunflower husks alone or together with lactic acid after 6 h increased the number of bacteria belonging to the *Flavobacteriia* class by 5.43 and 3.93%, *Elusimicrobia* by 3.77 and 3.98%, *Gam-*

maproteobacteria by 11.75 and 10.07% and decreased the number of *Bacteroidia* by 5.72 and 2.63%, *Clostridia* by 3.26 and 2.20% relative to the control. In contrast, in the 12-24 h exposure time, there was an increase in *Bacteroidia* class bacteria by 3.30-4.90 and 8.29-11.28%, *Clostridia* by 1.66-1.50 and 2.74-3.27% relative to the control.

Keywords: cavitated sunflower husk, taxonomic profile, microbiome, lactic acid

Для цитирования: *Мирошников С.А., Дускаев Г.К., Атландерова К.Н., Матющенко Н.С.* Воздействие кавитированной подсолнечной лузги и молочной кислоты на изменение таксономического профиля микробиома рубца жвачных *in vitro* // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 54–61. https://doi.org/10.26898/0370-8799-2023-5-7

For citation: Miroshnikov S.A., Duskaev G.K., Atlanderova K.N., Matyushchenko N.S. The effect of cavitated sunflower husk and lactic acid on the changes in the taxonomic profile of the rumen microbiome of ruminants *in vitro*. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 54–61. https://doi.org/10.26898/0370-8799-2023-5-7

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Исследование выполнено при финансовой поддержке Российского научного фонда (проект 20-16-00088).
Acknowledgements
The study was financially supported by the Russian Science Foundation (project 20-16-00088).

INTRODUCTION

The use of food production waste in animal feed has been known for a long time [1]. High demand for sunflower oil and other related industries in oil extraction has led to the generation of a large amount of sunflower husk waste [2]. It is commonly used as a source of protein, fiber, and fatty acids in animal feeding, aiming for a closed-loop economy model [3–5].

Liquid media activated by various methods in combination with ultrasonic treatment are usually employed to unlock the potential of solid fraction degradation from waste for feed production while preserving nutrients, [6]. Ultrasonic technology is considered environmentally friendly, beneficial in reducing chemical load and reaction time with efficient conversion. This technology is applied to various food materials for processing, preservation, and product quality enhancement [7]. Cavitation increases the mass fraction of raw protein and reduces the mass fraction of raw fiber [8]. This protein-to-fiber ratio positively affects the energy potential of the waste when considered as a feed additive [9]. However, sunflower husk proteins are largely degraded in the rumen, which may disrupt nitrogen metabolism [10]. Scientists have found that the use of acids reduces protein degradation in the rumen and increases its digestibility in the intestines [11].

Acids improve the consumption of feed additives by ruminant animals due to their taste and aromatic properties [12]. Additionally, the influence of ultrasound and acids alters the structure of the sunflower husk's solid fraction, promoting better adhesion to the surface of the feed by bacteria [13, 14].

The purpose of this research is to investigate the efficiency of using sunflower husk waste as an alternative animal feed and as a feed additive that encourages a shift in bovine rumen microbial zymolysis towards more efficient microbial pathways.

MATERIAL AND METHODS

The research was conducted at the Federal Research Centre of Biological Systems and Agrotechnologies of the Russian Academy of Sciences.

Research Objects:

– control group: finely ground sunflower husk (0.01 cm);

– 1st experimental group: cavitated husk treated with ultrasound and water in a 1:3 ratio (husk:water);

– 2nd experimental group: cavitated husk + lactic acid in a 1:3 ratio.

The chemical composition of sunflower husk before and after ultrasonic treatment, as well as

in combination with lactic acid, had the following composition (see the table).

The obtained samples after drying (105 °C) were used in *in vitro* studies with rumen fluid in a Daisy D200I incubator (an artificial rumen analog) from Ankom Technology (USA).

Rumen fluid from cattle was collected through a chronic fistula. The age of the animals was 12 months, and the breed was Kazakh white-headed. Measures were taken during the research to minimize animal suffering and reduce the number of the samples used.

The taxonomic composition of the rumen contents was determined using NGS sequencing on a MiSeq instrument from Illumina (USA). Genomic DNA was extracted using a chemical extraction method, and its concentration was determined using the Qubit 2.0 fluorometer with high sensitivity dsDNA analysis (Life Technologies). DNA 16S libraries were prepared according to the Illumina workflow with primers targeting the V3 and V4 regions of the SSU rRNA gene, such as the forward primer SD-Bact-0341-bS-17 and reverse primer SD-Bact-0785-aA-21.

The results obtained from the research were processed using the Microsoft Office suite, particularly Excel, and data analysis was performed using Statistica 10.0.

RESULTS AND DISCUSSION

During the incubation of cavitated sunflower husk and cavitated sunflower husk combined with lactic acid in the "artificial rumen" model,

Химический состав подсолнечной лузги, %
Chemical composition of sunflower husk, %

Mass fraction	Husk		
	ground sunflower (control)	cavitated	cavitated + lactic acid
Crude fat	4,12	1,55	2,50
Dry matter	93,2	71,2	87,4
Crude protein	5,38	10,7	5,25
Crude fiber	50,9	45,1	50,2
Crude ash	2,40	2,00	3,20
Calcium	0,24	0,30	0,30
Phosphorus	0,10	0,10	0,10
Sugar	1,90	1,40	0,70
Starch	3,80	2,20	1,10

an increase in the representatives of the class *Flavobacteriia* by 5.43% and 3.93%, *Elusimicrobia* by 3.77% and 3.98%, and *Gammaproteobacteria* by 11.75% and 10.07%, respectively, was observed after 6 hours. Meanwhile, there was a decrease in the abundance of bacteria in the class *Bacteroidia* by 5.72% and 2.63%, and *Clostridia* by 3.26% and 2.20%, respectively, relative to the control (see Figure 1). On the contrary, in the time exposure of 12-24 hours, an increase in bacteria in the class *Bacteroidia* by 3.30-4.90% and 8.29-11.28%, and *Clostridia* by 1.66-1.50% and 2.74-3.27%, respectively, was observed relative to the control.

At the class level, bacteria belonging to the phylum *Bacteroidetes* predominated in the groups.

The taxonomic diversity of the rumen microbiome at the order level determines the temporal aspect at 6, 12, and 24 hours (see Figure 2).

After 6 hours of incubation in the experimental groups (cavitated husk and cavitated husk with lactic acid), an increase in the representatives of the order *Flavobacteriales* by 5.43% and 3.93%, and *Elusimicrobiales* by 3.77% and 3.98%, respectively, was observed relative to the control. These groups also showed a numerical decrease in *Bacillales* by 0.11% and 0.21%, and *Clostridiales* by 3.26% and 2.20%, respectively, compared to the control.

After 12 hours of incubation, the highest numerical values were recorded for the orders *Bacteroidales* at 3.30% and 4.90%, and *Clostridiales* at 1.66% and 1.50%, respectively, relative to the control group. A decrease in the orders *Bacillales* by 0.37% and 0.40%, and *Pseudomonadales* by 8.30% and 10.0% compared to the control was also observed.

After 24 hours of incubation, an increase in the numerical values of the order *Bacteroidales* by 8.29% and 11.3%, and *Bacillales* by 3.79% and 5.34%, respectively, was found in the experimental groups compared to the control sample.

The species diversity of the rumen fluid microbiota throughout the experiment showed a similar trend in the percentage ratio of bacteria in the experimental groups compared to the control (see Figure 3).

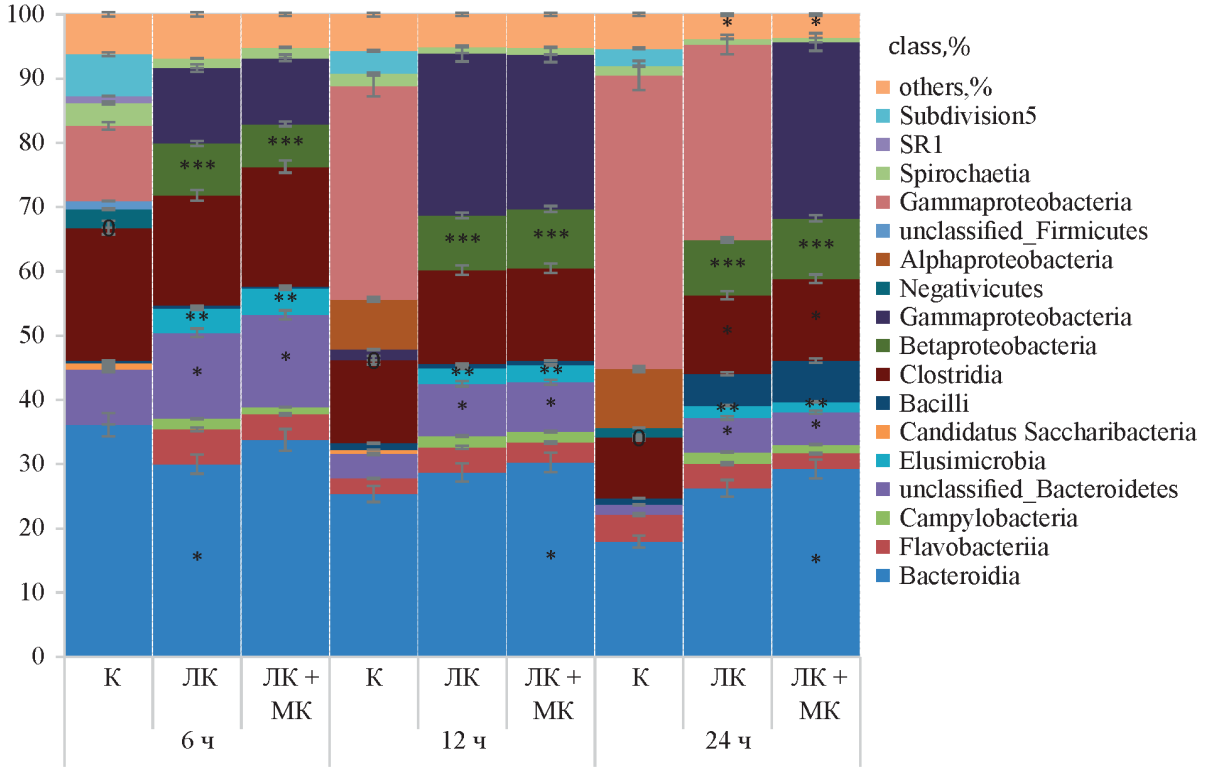

Рис. 1. Профиль бактериальной численности класса (6–24 ч) в рубцовой жидкости при включении в рацион кавитированной лузги подсолнечника отдельно и совместно с молочной кислотой, %

Fig. 1. The profile of the bacterial population of the class (in the time aspect of 6 - 24 hours) in the rumen fluid when cavitated sunflower husks are included in the diet, both separately and together with lactic acid, %

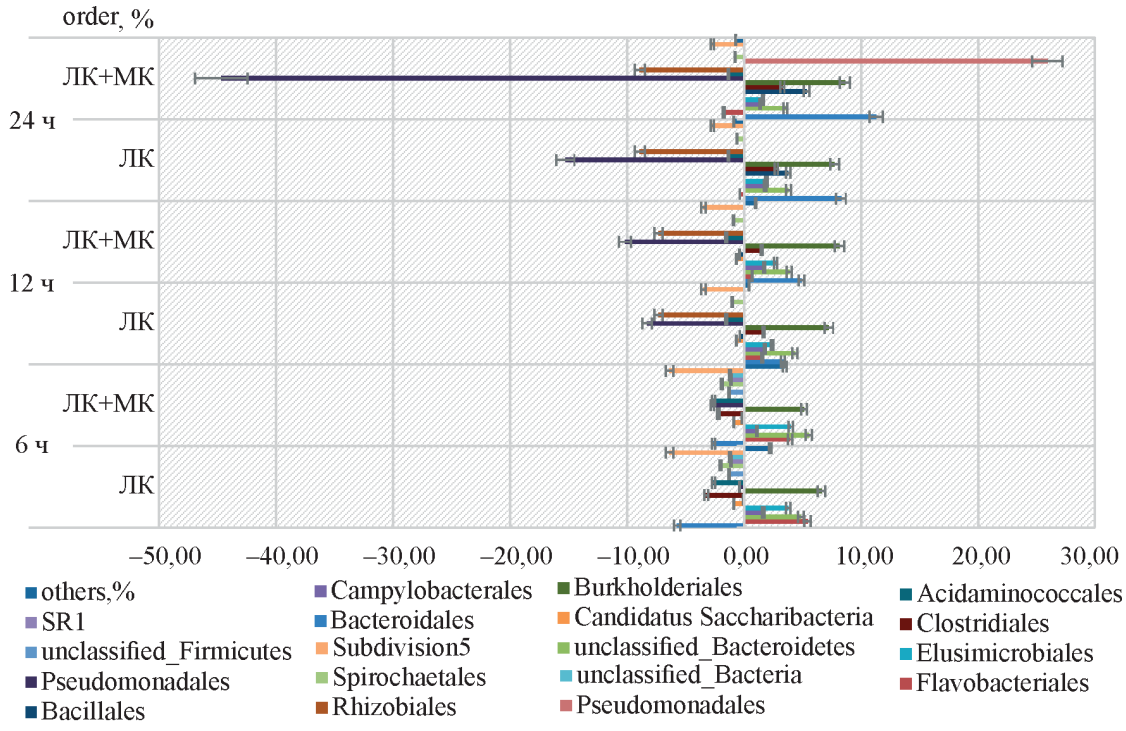

Рис. 2. Различие таксономического состава рубцовой жидкости при включении в рацион кавитированной лузги подсолнечника отдельно и совместно с молочной кислотой относительно контроля, %

Fig. 2. The difference in the taxonomic composition of the ruminal fluid when cavitated sunflower husks are included in the diet, both separately and together with lactic acid, relative to the control, %

In the time interval of 6 h of *in vitro* incubation, *Prevotella* species prevailed in all groups, but in the experimental groups it was more abundant: by 2.65% (cavitated husk) and by 3.33% (cavitated husk + lactic acid), in the interval of 12 h - by 3.07 and 2.66%, 24 h - 3.14 and 3.0%, respectively, relative to the control. This may be due to the fact that the experimental additives after exposure to ultrasound and lactic acid reconstruct the bacterial ecosystem of the rumen, especially the decomposition of fiber and starch [15].

The introduction of experimental additives led to a reduction in the population of *Acinetobacter* species in the 1st experimental group by 1.28 (6 hours) to 18.06% (24 hours) and in the 2nd experimental group by 3.37 (6 hours) to 19.67% (24 hours). Similarly, the population of *Butyrivibrio* species decreased in the 1st experimental group by 0.17 (6 hours) to 1.15% (24 hours) and in the 2nd experimental group by 0.16 (6 hours) to 1.01% (24 hours) relative to the control.

In the 6–12 hour time interval, the species *Bacillus* was absent in all groups, and after 24 hours, the experimental groups showed this species ranging from 0.5 to 1.5% of the total bacterial count in the sample.

It was observed that during the 6-hour exposure, the quantitative content of *Clostridia* bacteria decreased in the 2nd experimental group compared to the control, while after the 12–24 hour exposure, there was an increase in *Clostridia* bacteria by 2.74–3.27% relative to the control. This increase might be due to the treatment of cavitated husk with lactic acid, which leads to an increase in the number of lactate-utilizing families in the *Clostridia* class after 12–24 hours of exposure [16]. The introduction of cavitated sunflower husk and cavitated husk with lactic acid contributes to an increase in the diversity of bacterial classes belonging to the phylum *Bacteroidetes*. Scientists have found that the *Bacteroidetes* phylum is one of the major bacteria involved in the production of short-chain fatty

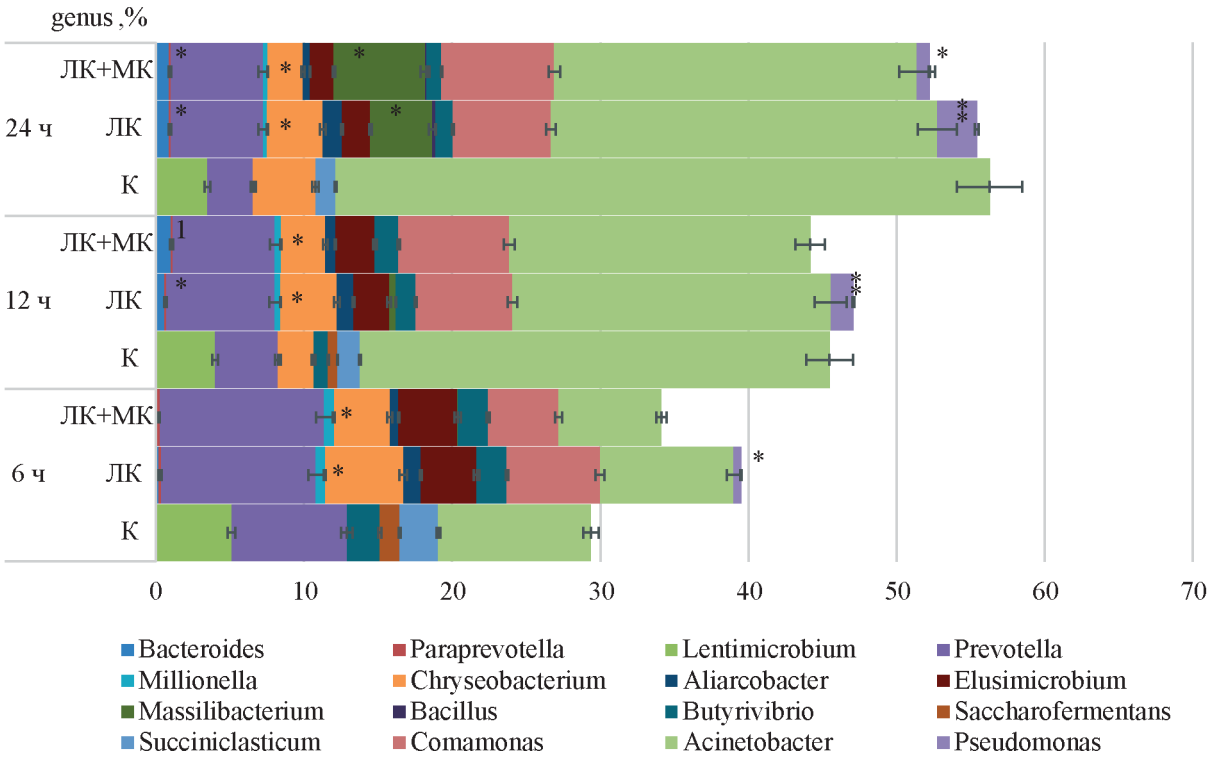

Рис. 3. Изменение бактериальной численности вида (6–24 ч) в рубцовой жидкости при включении в рацион кавитированной лузги подсолнечника отдельно и совместно с молочной кислотой, %

Fig. 3. Change in the bacterial abundance of the species (in the temporal aspect of 6 - 24 hours) in the rumen fluid when cavitated sunflower husks are included in the diet, both separately and together with lactic acid, %

acids [17], and it is more numerous in communities associated with the rumen epithelium or adhered to the surfaces of feed particles [18].

The determining factor for the better productive effect of feed additives based on oil extraction waste, activated by various methods, in combination with ultrasonic treatment on the digestive process is the lower bacterial saturation of the rumen, resulting in a simpler metabolic pathway. This leads to an increase in the concentrations of certain enzymatic substances responsible for the digestibility of nutrients [19].

CONCLUSION

In the 6-hour *in vitro* incubation, the species *Prevotella* predominated in the experimental groups with an increase of 2.65% (cavitated husk) and 3.33% (cavitated husk + lactic acid) compared to the control. This increase is likely due to the reconstruction of the rumen bacterial ecosystem, especially the degradation of cellulose and starch, after the application of ultrasound and lactic acid. The incubation of cavitated sunflower husk, either separately or combined with lactic acid, in the rumen fluid of cattle affects the taxonomic diversity of bacteria with a predominance of those belonging to the phylum *Bacteroidetes*, particularly an increase in the number of representatives of the class *Flavobacteriia*.

СПИСОК ЛИТЕРАТУРЫ

1. *Lima J., Auffret M.D., Stewart R.D., Dewhurst R.J., Duthie C.A., Snelling T.J., Walker A.W., Freeman T.C., Watson M., Roehe R.* Identification of rumen microbial genes involved in pathways linked to appetite, growth, and feed conversion efficiency in cattle // Frontiers in Genetics. 2019. Vol. 8. N 10. P. 701. DOI: 10.3389/fgene.2019.00701.
2. *Zubiria I., Garcia-Rodriguez A., Atxaerandio R., Ruiz R., Benhissi H., Mandaluniz N., Lavín J.L., Abecia L., Goiri I.* Effect of feeding cold-pressed sunflower cake on ruminal fermentation, lipid metabolism and bacterial community in dairy cows // Animals (Basel). 2019. Vol. 9. N 10. P. 755. DOI: 10.3390/ani9100755.
3. *Osman N.S., Sapawe N., Sapuan M.A.U., Fozi M.F.M., Azman M.H.I.F., Fazry A.H.Z., Zainudin M.Z.H., Hanafi M.F.* Sunflower shell waste as an alternative animal feed // Materials Today: Proceedings. 2018. Vol. 5. N 10. P. 21905–21910. DOI: 10.1016/j.matpr.2018.07.049.
4. *Haro A., Gonzalez J., de Evan T., de la Fuente J., Carro M.D.* Effects of feeding rumen-protected sunflower seed and meal protein on feed intake, diet digestibility, ruminal, cecal fermentation, and growth performance of lambs // Animals (Basel). 2019. Vol. 9 (7). P. 415. DOI: 10.3390/ani9070415.
5. *Javourez U., O'Donohue M., Hamelin L.* Waste-to-nutrition: a review of current and emerging conversion pathways // Biotechnology Advances. 2021. Vol. 53. P. 107857. DOI: 10.1016/j.biotechadv.2021.107857.
6. *Saha S., Roy A.* Whole grain rice fortification as a solution to micronutrient deficiency: Technologies and need for more viable alternatives // Food Chemistry. 2020. N 326. P. 127049. DOI: 10.1016/j.foodchem.2020.127049.
7. *Muslyumova D.M., Kurilkina M.Ya., Duskaev G.K., Zavyalov O.A.* A method for increasing the productivity of meat gobies thanks to the use of cavitated sunflower oil sludge in the diet // IOP Conference Series: Earth and Environmental Science. 2021. P. 22055. DOI: 10.1088/1755-1315/839/2/022055.
8. *Kamal H., Ali A., Manickam S., Le C.F.* Impact of cavitation on the structure and functional quality of extracted protein from food sources – An overview // Food Chemistry. 2023. Vol. 1. N 407. P. 135071. DOI: 10.1016/j.foodchem.2022.135071.
9. *Zubiria I., Garcia-Rodriguez A., Atxaerandio R., Ruiz R., Benhissi H., Mandaluniz N., Lavín J.L., Abecia L., Goiri I.* Effect of feeding cold-pressed sunflower cake on ruminal fermentation, lipid metabolism and bacterial community in dairy cows // Animals (Basel). 2019. Vol. 9. N 10. P. 755. DOI: 10.3390/ani9100755.
10. *Alharthi A.S., Al-Baadani H.H., Al-Badwi M.A., Abdelrahman M.M., Alhidary I.A., Khan R.U.* Effects of sunflower hulls on productive performance, digestibility indices and rumen morphology of growing Awassi lambs fed with total mixed rations // Journal of Veterinary Science. 2021. Vol. 8. N 9. P. 174. DOI: 10.3390/vetsci8090174.
11. *Haro A., Carro M., Evan T., González J.* Influence of feeding sunflower seed and meal protected against ruminal fermentation on ruminal fermentation, bacterial composition and in situ degradability in sheep // Archives of Animal Nutrition. 2020. Vol. 1. N 17. P. 74. DOI: 10.1080/1745039X.2020.1756679.
12. *Gerlach K., Daniel J.L.P., Jobim C.C., Nussio L.G.* A data analysis on the effect of acetic acid on dry matter intake in dairy cattle // Animal Feed Science and Technology. 2021. Vol. 272. P. 114782. DOI:

10.1016/j.anifeedsci.2020.114782.

13. *Zardo I., de Espíndola Sobczyk A., Marczak L.D.F.* Optimization of ultrasound assisted extraction of phenolic compounds from sunflower seed cake using response surface methodology // Waste and Biomass Valorization. 2019. N 10. P. 33–44. DOI: 10.1007/s12649-017-0038-3.
14. Cangiano *L.R., Yohe T.T., Steele M.A., Renaud D.L.* Invited Review: Strategic use of microbial-based probiotics and prebiotics in dairy calf rearing // Applied Animal Science. 2020. Vol. 36. Is. 5. P. 630–651. DOI: 10.15232/aas.2020-02049.
15. *Duskaev G.K., Karimov I.F., Levakhin G.I., Nurzhanov B.S., Rysaev A.F., Dusaeva K.B.* Ecology of ruminal microorganisms under the influence of Quercus cortex extract // International Journal of GEOMATE. 2019. Vol. 16. N 55. P. 59–66.
16. *Yang Y., Dong G., Wang Z.* Treatment of corn with lactic acid or hydrochloric acid modulates the rumen and plasma metabolic profiles as well as inflammatory responses in beef steers // BMC Veterinary Research. 2018. N 14. P. 408. DOI: 10.1186/s12917-018-1734-3.
17. *Nogal A., Valdes A.M., Menni C.* The role of short-chain fatty acids in the interplay between gut microbiota and diet in cardio-metabolic health // Journal of Gut Microbes. 2021. Vol. 13. N 1. P. 1–24. DOI: 10.1080/19490976.2021.1897212.
18. *Pinnel L.J., Reyes A.A., Wolfe C.A., Weinroth M.D., Metcalf J.L., Delmore R.J., Belk K.E., Morley P.S., Engle T.E.* Bacteroidetes and Firmicutes drive differing microbial diversity and community composition among micro-environments in the bovine rumen // Frontiers in Veterinary Science, Animal Nutrition and Metabolism. 2022. Vol. 9. DOI: 10.3389/fvets.2022.897996.
19. *Atlanderova K.N., Duskaev G.K., Bykov A.V.* Optimization of sunflower husk utilization methods using various ultrasonic treatment methods // IOP Conference Series: Earth and Environmental Science. 2022. Vol. 1076. P. 12041. DOI: 10.1088/1755-1315/1076/1/012041.

REFERENCES

1. Lima J., Auffret M.D., Stewart R.D., Dewhurst R.J., Duthie C.A., Snelling T.J., Walker A.W., Freeman T.C., Watson M., Roehe R. Identification of rumen microbial genes involved in pathways linked to appetite, growth, and feed conversion efficiency in cattle. *Frontiers in Genetics*, 2019, vol. 8, no. 10, p. 701. DOI: 10.3389/fgene.2019.00701.
2. Zubiria I., Garcia-Rodriguez A., Atxaerandio R., Ruiz R., Benhissi H., Mandaluniz N., Lavín J.L., Abecia L., Goiri I. Effect of feeding cold-pressed sunflower cake on ruminal fermentation, lipid metabolism and bacterial community in dairy cows. *Animals (Basel),* 2019, vol. 9, no. 10, p. 755. DOI: 10.3390/ani9100755.
3. Osman N.S., Sapawe N., Sapuan M.A.U., Fozi M.F.M., Azman M.H.I.F., Fazry A.H.Z., Zainudin M.Z.H., Hanafi M.F. Sunflower shell waste as an alternative animal feed. *Materials Today: Proceedings*, 2018, vol. 5, no. 10. pp. 21905–21910. DOI: 10.1016/j.matpr.2018.07.049.
4. Haro A., Gonzalez J., de Evan T., de la Fuente J., Carro M.D. Effects of feeding rumen-protected sunflower seed and meal protein on feed intake, diet digestibility, ruminal, cecal fermentation, and growth performance of lambs. *Animals (Basel),* 2019, vol. 9 (7), p. 415. DOI: 10.3390/ani9070415.
5. Javourez U., O'Donohue M., Hamelin L. Waste-to-nutrition: a review of current and emerging conversion pathways. *Biotechnology Advances*, 2021, vol. 53, p. 107857. DOI: 10.1016/j.biotechadv.2021.107857.
6. Saha S., Roy A. Whole grain rice fortification as a solution to micronutrient deficiency: Technologies and need for more viable alternatives. *Food Chemistry*, 2020, no. 326, p. 127049. DOI: 10.1016/j.foodchem.2020.127049.
7. Muslyumova D.M., Kurilkina M.Ya., Duskaev G.K., Zavyalov O.A. A method for increasing the productivity of meat gobies thanks to the use of cavitated sunflower oil sludge in the diet. *IOP Conference Series: Earth and Environmental Science*, 2021, p. 22055. DOI: 10.1088/1755-1315/839/2/022055.
8. Kamal H., Ali A., Manickam S., Le C.F. Impact of cavitation on the structure and functional quality of extracted protein from food sources – An overview. *Food Chemistry*, 2023, vol. 1, no. 407, p. 135071. DOI: 10.1016/j.foodchem.2022.135071.
9. Zubiria I., Garcia-Rodriguez A., Atxaerandio R., Ruiz R., Benhissi H., Mandaluniz N., Lavín J.L., Abecia L., Goiri I. Effect of feeding cold-pressed sunflower cake on ruminal fermentation, lipid metabolism and bacterial community in dairy cows. *Animals (Basel),* 2019, vol. 9, no. 10, p. 755. DOI: 10.3390/ani9100755.
10. Alharthi A.S., Al-Baadani H.H., Al-Badwi M.A., Abdelrahman M.M., Alhidary I.A., Khan R.U. Effects of sunflower hulls on productive performance, digestibility indices and rumen morphology of growing Awassi lambs fed with total mixed rations. *Journal of Veterinary Science*, 2021,

vol. 8, no. 9, p. 174. DOI: 10.3390/vetsci8090174.

11. Haro A., Carro M., Evan T., González J. Influence of feeding sunflower seed and meal protected against ruminal fermentation on ruminal fermentation, bacterial composition and in situ degradability in sheep. *Archives of Animal Nutrition*, 2020, vol. 1, no. 17, p. 74. DOI: 10.1080/1745039X.2020.1756679.
12. Gerlach K., Daniel J.L.P., Jobim C.C., Nussio L.G. A data analysis on the effect of acetic acid on dry matter intake in dairy cattle. *Animal Feed Science and Technology*, 2021, vol. 272, p. 114782. DOI: 10.1016/j.anifeedsci.2020.114782.
13. Zardo I., de Espíndola Sobczyk A., Marczak L.D.F. Optimization of ultrasound assisted extraction of phenolic compounds from sunflower seed cake using response surface methodology. *Waste and Biomass Valorization*, 2019, no. 10, p. 33–44. DOI: 10.1007/s12649-017-0038-3.
14. Cangiano L.R., Yohe T.T., Steele M.A., Renaud D.L. Invited Review: Strategic use of microbial-based probiotics and prebiotics in dairy calf rearing. *Applied Animal Science*, 2020, vol. 36, is. 5, pp. 630–651. DOI: 10.15232/aas.2020-02049.
15. Duskaev G.K., Karimov I.F., Levakhin G.I., Nurzhanov B.S., Rysaev A.F., Dusaeva K.B. Ecology of ruminal microorganisms under the influence of Quercus cortex extract. *International Journal of GEOMATE*, 2019, vol. 16, no. 55, pp. 59–66.
16. Yang Y., Dong G., Wang Z. Treatment of corn with lactic acid or hydrochloric acid modulates the rumen and plasma metabolic profiles as well as inflammatory responses in beef steers. *BMC Veterinary Research*, 2018, no. 14, p. 408. DOI: 10.1186/s12917-018-1734-3.
17. Nogal A., Valdes A.M., Menni C. The role of short-chain fatty acids in the interplay between gut microbiota and diet in cardio-metabolic health. *Journal of Gut Microbes*, 2021, vol. 13, no. 1, pp. 1–24. DOI: 10.1080/19490976.2021.1897212.
18. Pinnel L.J., Reyes A.A., Wolfe C.A., Weinroth M.D., Metcalf J.L., Delmore R.J., Belk K.E., Morley P.S., Engle T.E. Bacteroidetes and Firmicutes drive differing microbial diversity and community composition among micro-environments in the bovine rumen. *Frontiers in Veterinary Science, Animal Nutrition and Metabolism*, 2022, vol. 9. DOI: 10.3389/fvets.2022.897996.
19. Atlanderova K.N., Duskaev G.K., Bykov A.V. Optimization of sunflower husk utilization methods using various ultrasonic treatment methods. *IOP Conference Series: Earth and Environmental Science*, 2022, vol. 1076, p. 12041. DOI: 10.1088/1755-1315/1076/1/012041.

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Дата поступления статьи / Received by the editors 14.09.2022
Дата принятия к публикации / Accepted for publication 07.12.2022
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-8
УДК: 636.03:636.5.033
Тип статьи: оригинальная
Type of article: original

ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ КОРМОВОЙ МУКИ ЖИВОТНОГО ПРОИСХОЖДЕНИЯ ПРИ ВЫРАЩИВАНИИ ЦЫПЛЯТ-БРОЙЛЕРОВ КРОССА РОСС-308

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Представлены исследования по эффективности применения кормовой муки собственного производства, приготовленной из отходов птицеводства, в качестве ингредиента рационов для кормления цыплят-бройлеров. Научно-хозяйственный и физиологический опыты проведены в производственных условиях Новосибирской области в 2021, 2022 гг. Объектом исследования были цыплята-бройлеры кросса Росс-308 в возрасте от 5 до 40 сут. В рационе кормления контрольной группы использовали мясо-костную муку в количестве 5% от структуры рациона, которую в двух опытных группах заменяли на кормовую муку животного происхождения собственного производства, стерилизованную при различных температурных режимах. В 1-й опытной группе молодняк потреблял кормовую муку, стерилизованную при температуре 135 °С, во 2-й опытной – при 150 °С. Стерилизацию осуществляли в котле ВС 10 000. Полученные данные свидетельствуют, что живая масса цыплят-бройлеров была высокой во всех группах, при этом молодняк контрольной и 1-й опытной групп по живой массе достоверно превышал птицу 2-й опытной на 3,1 и 2,6% ($p < 0,05$). Энергия роста, сохранность поголовья и затраты кормов были близкими во всех группах и находились на уровне 71,1–73,4 г, 97,0–98,0% и 1,49–1,56 кг на 1 кг прироста соответственно. Переваримость сырого протеина и жира была высокой, различия между группами незначительны. Переваримость сырой клетчатки отмечена практически одинаковой в контрольной и 1-й опытной группах, во 2-й опытной она уменьшилась на 1% по отношению к контрольной ($p < 0,05$). Максимальный убойный выход мяса (75,8%) отмечен в 1-й опытной группе, в контрольной этот показатель оказался немного меньше (на 2,3%). Во 2-й опытной он был ниже по сравнению с контрольной и опытной группами на 3,0 ($p < 0,05$) и 4,3% ($p < 0,01$) соответственно. Во 2-й опытной группе индекс продуктивности оказался ниже по сравнению с другими группами. Экономическая эффективность была высокой во всех группах, однако при скармливании молодняку кормовой муки, стерилизованной при 135 °С, эффективность производства увеличилась на 16%.

Ключевые слова: цыплята-бройлеры, прирост живой массы, кормовая мука животного происхождения, убойный выход, рентабельность производства, индекс продуктивности, конверсия корма

EFFICIENCY OF USING FODDER MEAL OF ANIMAL ORIGIN IN THE REARING OF BROILER CHICKENS OF THE ROSS-308 CROSS

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Studies on the effectiveness of the use of fodder meal of own production prepared from poultry waste as an ingredient of diets for feeding broiler chickens are presented. Scientific-economic and physiological experiments were carried out under production conditions in the Novosibirsk region in 2021, 2022. The object of the study were broiler chickens of the Ross-308 cross from 5 to 40 days of age. In the diet of the control group meat and bone meal in the amount of 5% of the diet structure was used, which in the two experimental groups was replaced by animal fodder meal of own production sterilized at different temperature regimes. In the 1st experimental group young animals consumed fodder meal sterilized at 135 °C, in the 2nd experimental group - at 150 ◦C. Sterilization was carried out in the boiler BC 10,000. The data obtained indicate that the live weight of broiler chickens was high in all groups, with the young birds of the control and 1st experimental groups significantly exceeded the 2nd experimental group by 3.1 and 2.6% ($p < 0.05$) in terms of live weight. Energy of

growth, keeping stock and feed expenses were close in all groups and were at the level of 71.1-73.4 g, 97.0-98.0% and 1.49-1.56 kg per 1 kg of growth respectively. Digestibility of crude protein and fat was high, differences between groups were insignificant. Digestibility of crude fiber was almost the same in the control and 1st experimental groups, in the 2nd experimental group it decreased by 1% relative to the control ($p < 0.05$). The maximum slaughter yield of meat (75.8%) was observed in the 1st experimental group, while in the control group this indicator was slightly lower (by 2.3%). In the 2nd experimental group, it was lower compared to the control and 1st experimental groups by 3.0 ($p < 0.05$) and 4.3% ($p < 0.01$), respectively. In the 2nd experimental group, the productivity index was lower compared to the other groups. Economic efficiency was high in all groups, but production efficiency increased by 16% when feed flour sterilized at 135 0C was fed to young animals.

Keywords: broiler chickens, live weight gain, fodder meal of animal origin, slaughter yield, profitability of production, productivity index, feed conversion

Для цитирования: *Реймер В.А., Князев С.П., Ковалев Г.В.* Эффективность использования кормовой муки животного происхождения при выращивании цыплят-бройлеров кросса Росс-308 // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 62–69. https://doi.org/10.26898/0370-8799-2023-5-8

For citation: Reymer V.A., Knyazev S.P., Kovalev G.A. Efficiency of using fodder meal of animal origin in the rearing of broiler chickens of the Ross-308 cross. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 62–69. https://doi.org/10.26898/0370-8799-2023-5-8

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Poultry farming in Russia is one of the most dynamically developing branches of animal husbandry with economically positive production outcomes [1]. The efficiency of production largely depends on the proper and balanced feeding of birds, as feed constitutes 65-75% of the cost structure. In order to increase productivity, product quality, and reduce its cost, various production techniques are employed. This includes the use of feed additives and biologically active substances that enhance nutrient digestibility and normalize the physiological state of the organisms [2-6]. Utilizing byproducts from different production processes to improve the completeness of diets contributes to increased poultry productivity[1] and reduced production costs [7-9].

The relevance of this study lies in investigating the possibility of replacing meat and bone meal in the feed ration with feed meal of its own production. This feed meal is prepared from non-infectious waste of poultry farming, such as slaughter, incubation, and non-infectious bird mortality. The study compared the meal sterilized under various temperature regimes.

The purpose of this study is to examine the impact of animal-origin feed meal on the economic efficiency of raising broiler chickens for meat production. The research tasks included determining the live weight of broiler chickens receiving a ration with the addition of feed meal, average daily growth, digestibility, feed costs for produced goods, meat quality, and the economic efficiency of its production.

MATERIAL AND METHODS

Scientific, economic, and physiological experiments were conducted at the poultry farm of the "Novosibirsk Poultry Factory" in the Novosibirsk region in 2021 and 2022. The subject of the research was Ross-308 crossbred broiler chicks. The chicks were raised in battery cages from 5 to 40 days of age (see Table 1).

The groups of chicks were formed using the method of age, weight, and origin analogs. The microclimate, lighting regime, and stocking density were consistent across all groups and

[1] *Alekseeva Z.N., Reimer V.A., Sivilgaev A.V., Klemeshova I.Y., Chupina L.V.* Activated fodder from grain production wastes. Novosibirsk: NSAU, 2009. 134 p.

complied with the standards for this crossbreed's chicks[2]. The animal-origin feed meal was produced according to the Haarslev company's technology.

Presented diet density on crude protein (22-20% for the most part of the growing period) corresponded to the norms, in which it is recommended to provide its content in the diet of broilers at the age of 21-27 days at the level of 19,94%[3] .

Sterilization of the obtained meal was carried out in the VS 10,000 boiler under two different temperature regimes. The quality and nutritional value of the feed meal and poultry meat were determined in the chemical laboratory of NSAU. The nutritional value of the diet was the same for all groups but varied with the age of the broilers during the rearing process (see Table 2).

The live weight of Ross-308 crossbred broiler chicks was determined by weighing them at various growth stages. Feed conversion was calculated by daily recording of the feed provided and leftovers. Nutrient digestibility was assessed through balance experiments using 5 chicks from each group at 28 days of age. The viability of the chicks was monitored daily by recording mortality. Slaughter yield and meat quality were determined based on the results of controlled slaughter in the farm's slaughterhouse.

Absolute average daily weight gain, productivity index, and economic efficiency were determined using a computational method. The digital data obtained during the research were processed using the method of variation statistics with the Microsoft Excel software.

Табл. 1. Схема опыта (n = 100)

Table 1. Experiment scheme (n = 100)

Group	Poultry feeding
Control	BD (basic diet used on farms, including 5% of industrially produced meat and bone meal)
1st experimental	BD + 5% feed meal sterilized at 135 ^{0}C (instead of meat and bone meal)
2nd experimental	BD + 5% feed meal sterilized at 150 ^{0}C (instead of meat and bone meal)

Табл. 2. Структура и питательность основного рациона цыплят-бройлеров

Table 2. Structure and nutritional content of the basic diet of broiler chickens

Component, %	Rearing period, days		
	5–20	21–27	28–40
Forage wheat	47,0	47,0	47,0
Barley	7,0	15,0	11,0
Wheat bran	–	2,5	–
Full-fat toasted soybeans	10,0	10,0	5,9
Sunflower oil cake	15,0	5,0	15,0
Meat and bone flour	5,0	5,0	5,0
Fish flour	4,5	8,0	–
Bakery yeast	5,0	–	5,0
Sunflower oil	4,4	4,5	7,0
Monocalcium phosphate	0,4	0,4	0,6
Limestone flour	0,2	1,2	2,1
Table salt	0,3	0,2	0,2
Premix PK-1 (farm order)	1,0	1,0	1,0
Gravel	0,2	0,2	0,2
Feed mixture content in 100 g, g			
Exchangeable energy, MJ	1,243	1,265	1,283
Crude protein	22,17	20,0	18,1
Crude fiber	5,07	4,7	5,1
Linoleic acid	2,61	1,63	2,02
Calcium	1,09	1,1	1,2
Total phosphorus	0,78	0,7	0,71
Digestible phosphorus	0,52	0,6	0,6
Sodium	0,24	0,21	0,20
Lysine	1,1	0,75	0,85
Methionine + cystine	0,75	0,72	0,72
Tryptophan	0,27	0,16	0,19

RESULTS AND DISCUSSION

Animal-origin feed meal obtained under various sterilization conditions is characterized by high quality: in terms of appearance, it is a granulated product, free from dense, non-dispersing lumps upon pressure, with a specific smell; the meal is non-toxic, with a total bacterial count not

[2]Material and methodology of experiments (scientific research) // Methods of scientific and production research on poultry feeding / edited by V.I. Fisinin. Sergiev Posad, 2013. pp. 5-31.

[3]Guidelines for raising and maintaining broiler stock. http: ru.aviagen/com/assets/TechCenter/BB_Foreign_Language_Docs/RUS_TechDocs/08a-Ross-308-Broiler-PO/pdf

exceeding 3.4 × 105 CFU per 1 g. Thus, it complies with the requirements of the GOST[4].

The nutritional content of meat and bone meal and animal-origin feed meal included in the diets for the three broiler groups is presented in Table 3.

The raw protein content in the animal-origin feed meal used in feeding the broiler chicks of the 1st experimental group was 48.5%, and in the 2nd experimental group, the content of this nutrient slightly decreased.

Crude fiber in the diets of the experimental groups was 0.6% and 0.61%, respectively, while the control group's diet lacked it. The crude fat content in the experimental groups was nearly the same (about 9%). In the control group's diet, which used industrial meat and bone meal, it was higher by 1.2–1.3%. The content of amino acids and minerals in all groups was virtually the same.

The data obtained in our experiment regarding the quality of animal-origin feed meal align with similar parameters reported in studies by other authors [10, 11]. The experiment established that feeding animal-origin feed meal allows obtaining broiler chicks with live weights ranging from 2633 to 2703 g at 40 days of age. Table 4 presents data on the dynamics of live weight for the control and experimental chicks.

The live weight of the chicks differed at the end of the rearing period in all three groups. The highest weight (2715 g) was observed in the control group of broiler chicks that were fed 5% industrial meat and bone meal as part of their compound feed. In the 1st experimental group (with locally prepared feed meal added to the diet, sterilized at 130°C), this indicator was slightly and insignificantly lower (by 12 g), amounting to 2703 g. When using animal-origin feed meal sterilized at 150°C, the live weight of broiler chicks at the end of the feeding period was significantly ($p < 0.05$) lower than in the control and 1st experimental groups, by 3.0% and 2.6%, respectively. This difference may be attributed to the higher sterilization temperature of the meal [9].

The growth energy of the chicks was maintained at a high level when using meat and bone meal and animal-origin feed meal. Table 5 presents data on the average daily growth of the broilers. This indicator varied over growth periods both in terms of age and between groups. In the first 5 days of chick growth, this measure was higher in the control group compared to the 1st experimental group by 3.4%, and compared to the 2nd experimental group by 6.1%.

As the chicks' age increased, their growth energy changed. Until the 30th day of rearing, the broilers in the control group outperformed the young birds in the experimental groups in terms of average daily gain. However, during the 31–40-day period, the energy for growth was slightly higher (by 1.7%) in the 1st experimental group (with feed meal sterilized at 130°C) compared to the control group, and significantly higher (by 8%) and significantly more pronounced ($p <$

Табл. 3. Питательность мясо-костной и кормовой муки животного происхождения, %

Table 3. Nutritional value of meat and bone and fodder meal of animal origin, %

Indicator	Group		
	control	1st experimental	2nd experimental
Crude protein	48,0	48,5	48,0
Crude fiber	–	0,60	0,61
Crude fat	10,5	9,3	9,2
Lysine	2,37	2,41	2,22
Methionine + cystine	1,05	1,02	1,01
Calcium	6,51	6,81	6,43
Phosphorus	3,28	3,33	3,12
Finished product output	–	36,0	34,6

Табл. 4. Живая масса цыплят-бройлеров кросса Росс-308, г

Table 4. Live weight of broiler chickens of the Ross-308 cross, g

Poultry's age, days	Group		
	control	1st experimental	2nd experimental
5	144,5 ± 6,1	145 ± 5,4	144 ± 6,7
10	310,0 ± 8,6	305 ± 8,7	300 ± 9,3
20	915,1 ± 16,9	905 ± 17,5	883 ± 18,6
30	1845,0 ± 22,1	1800 ± 20,1	1794 ± 21,3
40	2715,0 ± 25,1*	2703 ± 22,2*	2633 ± 26,5

*$p < 0,05$.

[4]GOST 17536-82 Animal feed flour. Technical conditions. Moscow: Standards Publishing House, 2002.

Табл. 5. Среднесуточный прирост живой массы цыплят-бройлеров, г
Table 5. Average daily live weight gain of broiler chickens, g

Group	Rearing period, days				
	6–10	11–20	21–30	31–40	6–40
Control	33,1 ± 0,68	60,5 ± 1,64	93,0 ± 1,45	87,0 ± 1,65	73,4 ± 1,53
1st experimental	32,0 ± 0,75	60,0 ± 1,1	89,5 ± 1,2	90,3 ± 1,75^{xx}	73,1 ± 1,61
2nd experimental	31,2 ± 0,9	58,3 ± 2,1	91,1 ± 1,7	83,1 ± 2,11	71,1 ± 1,11

0.05) than in the 2nd experimental group. Over the entire rearing period (from 6 to 40 days), the values of absolute average daily gain were similar between the control and 1st experimental groups, differing by only 0.3 g (0.4%) in favor of the control. A trend of lower growth energy was observed in the 2nd experimental group compared to both the control and 1st experimental groups, by 3.1% and 2.8%, respectively.

An important indicator determining the efficiency of poultry meat production is feed consumption per 1 kg of live weight gain (see Table 6). The obtained data indicate an increase in feed consumption per unit of production with the age of the birds in all groups. Variations in this indicator among the groups over the rearing periods of the chicks and overall for the entire rearing cycle were insignificant. A substantial increase in feed consumption for production was observed in the 2nd experimental group from day 28 to 40. Throughout the rearing period, the trend of decreasing feed conversion ratio for production was maintained in the 2nd experimental group. While the control and 1st experimental groups had a feed consumption of 1.49 and 1.50 kg per 1 kg gain, respectively, the 2nd group's consumption was higher by 4.7% and 4.0%, respectively.

The trend of increasing feed consumption for production is also supported by the results of the analysis of nutrient digestibility in the three studied broiler groups (see Table 7). The digestibility of raw protein and raw fat in all groups remained at a high level, ranging from 78.8% to 82.3% for protein and 70.7% to 74.2% for fat. The reduction in digestibility of crude fiber in the experimental groups compared to the control group was due to the presence of a small amount of crude fiber in the animal-origin feed meal. This fiber hindered more complete hydrolysis[5] compared to industrial meat and bone meal, which was completely devoid of fiber.

This circumstance is not a limiting factor when assessing the prospects of using substitutes for industrial meat and bone meal based on the in-house processing of by-products by poultry enterprises, which reduces the expenses for purchasing additives and contributes to the increased efficiency of the industry[6].

Our research has shown that feeding animal-origin feed meal did not have a negative impact on the viability of broiler chicks. The survival rate of the chicks during the rearing period was high and remained at a level of 97.0–98.0% across all groups. The use of feed meal with a sterilization temperature of 135°C increased the survival rate by 0.5% and 1.0% compared to the control and 2nd experimental groups.

The quality of the obtained products when us-

Табл. 6. Затраты кормов на прирост живой массы цыплят-бройлеров, кг
Table 6. Feed costs for live weight gain in broiler chickens, kg

Group	Poultry rearing period, days			
	6–20	21–27	28–40	6–40
Feed conversion				
Control	1,25	1,5	1,65	1,49
1st experimental	1,26	1,42	1,69	1,50
2nd experimental	1,24	1,58	1,78	1,56

[5]Testar R.F., Karkalas J., Kee C. Starch structure and digestibility. Enzyme-substrate relationship // World's Poultry Science Journal. 2004. vol. 60. no. 2. pp. 257–258.

[6]Volik V., Zinoviev S., Ismailova D., Erokhina O. Meat and bone meal - by new technology. Animal Husbandry of Russia. April 2016. pp. 9-10.

Табл. 7. Переваримость питательных веществ, %
Table 7. Digestibility of nutrients, %

Indicator	Group		
	control	1st experimental	2nd experimental
Crude protein	82,3 ± 3,2	81,2 ± 2,7	78,8 ± 2,3
Crude fat	73,5 ± 2,8	74,2 ± 3,2	70,7 ± 2,6
Crude fiber	8,7 ± 0,3*	7,9 ± 0,6	7,7 ± 0,4

*$p < 0,05$.

ing animal-origin feed meal at different sterilization temperatures varied (see Table 8).

At the same time, different diets did not have a significant effect on the meat yield, with fluctuations being minor, ranging from 72.7% to 75.8%. However, the quality of the broiler meat was highest in the 1st experimental group, among which the percentage of first-grade carcasses reached 87.1%. In the 2nd experimental group, this percentage was significantly lower, by 3.0% and 4.3% compared to the control ($p < 0.05$) and 1st experimental group ($p < 0.001$), respectively.

At the end of the experiment, an economic analysis of broiler rearing was conducted based on the productivity index and the economic efficiency of production.

The highest productivity index was observed in the 1st experimental group, where broilers consumed compound feed with feed meal sterilized at 135°C, and in the control group, where industrial meat and bone meal was fed to the birds. In the 2nd experimental group, which was fed animal-origin feed meal sterilized at 150°C, the productivity index decreased by 7.5% and 7.3%, respectively.

Feeding broiler chicks with different types of feed meal led to changes in the economic efficiency of production. The cost of producing 1 kg of feed meal on the farm during the experiment was 137 rubles, while the cost of industrial meat and bone meal purchased by the farm during the same period was 293 rubles per 1 kg. Calculations based on commonly accepted methodology showed that the level of profitability when feeding a diet with animal-origin feed meal sterilized at 135°C (1st experimental group) was 16.6% higher than the profitability in the control group (using industrial meat and bone meal), and 16.4% higher than the profitability in the 2nd experimental group, which used animal-origin feed meal with a sterilization temperature of 150°C. The decrease in profitability in the 2nd experimental group occurred due to the reduction in the live weight of the chicks and the decrease in the quality of the products, while in the control group it was due to the high cost of industrial meat and bone meal compared to the less expensive self-prepared feed meal.

CONCLUSION

Incorporating 5% animal-origin feed meal from poultry farming waste into the diet of broiler chicks with a sterilization temperature of 135°C instead of industrial meat and bone meal

Табл. 8. Качество продукции при скармливании цыплятам-бройлерам мясо-костной муки и кормовой муки животного происхождения
Table 8. Product quality when feeding broiler chickens with meat and bone and fodder meal of animal origin

Indicator	Group		
	control	1st experimental	2nd experimental
Average live weight of 1 head, g	2697 ± 24,1	2691 ± 22,2	2643 ± 26,5
Weight of gutted carcass, g	1982 ± 23,1	2040 ± 21,8	1914,2 ± 22,3
Slaughter yield, %	73,5 ± 0,96	75,8 ± 1,08	72,7 ± 1,25
Meat quality, %:			
first category	85,8 ± 1,04*	87,1 ± 1,11**	82,8 ± 1,08
second category	14,2 ± 0,64	12,9 ± 0,78	17,2 ± 0,57**

*$p < 0,05$.
**$p < 0,01$.

allows for a 2.3% increase in slaughter yield, a 1.3% improvement in meat quality, and a 16.6% increase in profitability compared to using a standard diet with meat and bone meal. This method of preparing feed meal appears to be the most optimal, while higher-temperature sterilization of feed meal results in a decrease in nearly all considered indicators of broiler poultry production efficiency using the Ross-308 crossbreed as an example. The obtained results confirm recent conclusions by Academician V.I. Fisinin [12] on the importance of applying resource-saving technologies when organizing poultry feeding based on their genetic background (original lines, parents, hybrids).

СПИСОК ЛИТЕРАТУРЫ

1. *Фисинин В.И.* Мировое и российское птицеводство: реалии и вызовы будущего: монография. М.: Хлебпродинформ, 2019. 470 с.
2. *Карапетян А.К.* Использование нетрадиционных кормов, различных рецептур премиксов и БВМК при производстве мяса бройлеров // Кормление сельскохозяйственных животных и кормопроизводство. 2022. № 10. С. 37–54. DOI: 10.33920/sel-05-2210-04.
3. *Фисинин В.И., Егоров И.А., Лаптев Г.Ю., Ленкова Т.Н., Никонов И.Н., Ильина Л.А., Манукян В.А., Грозина А.А., Егорова Т.А., Новикова Н.И., Йылдырым Е.А.* Получение продукции птицеводства без антибиотиков с использованием перспективных программ кормления на основе пробиотических препаратов // Вопросы кормления. 2017. Т. 86 (6). С. 114–124. DOI: 10.24411/0042-8833-2017-00013.
4. *Скрябин В.А., Сабоиев И.А., Табанюхов К.А.* Побочные продукты мукомольно-крупяного производства как источник белка повышенной биологической ценности // Инновации и продовольственная безопасность. 2019. № 3 (25). С. 105–111. DOI: 10.31677/2311-0651-2019-25-3-105-111.
5. *Цой З.В., Адушинов Д.С.* Кормовая добавка из отходов рыбного промысла в комбикормах для кур-несушек в условиях Приморского края // Кормление сельскохозяйственных животных и кормопроизводство. 2022. № 12. С. 20–32. DOI: 10.33920/sel-05-2212-03.
6. *Цой З.В., Васильева Н.В.* Влияние нетрадиционных кормовых добавок на яичную продуктивность кур-несушек в условиях Приморского края // Вестник ИрГСХА. 2020. Вып. 98. С. 145–153. DOI: 10.51215/1999-3765-2020-98-145-153.
7. *Цой З.В., Васильева Н.В.* Влияние нетрадиционных кормовых добавок растительного и морского происхождения на яичную продуктивность кур-несушек // Вестник ИрГСХА. 2020. Вып. 101. С. 135–143. DOI: 10.51215/1999-3765-2020-101-135-143.
8. *Рогачев В.А., Мерзлякова О.Г., Лукьянчикова Н.Л., Магер С.Н.* Белково-витаминная мука из пшеничных отрубей, обогащенная фитазой в рационе перепелов // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 46–54. DOI: 10.26898/0370-8799-2022-2-6.
9. *Фисинин В.И., Исмайлова Д.Ю., Волик В.Г.* Глубокая переработка вторичных продуктов птицеводства для разных направлений использования // Сельскохозяйственная биология. 2017. Т. 52. № 6. С. 1105–1115. DOI: 10.15389/agrobiology.2017.6.1105rus.
10. *Цой З.В., Васильева Н.В.* Влияние нетрадиционных кормовых добавок на яичную продуктивность кур-несушек // Вестник КрасГАУ. 2021. № 2. С. 118–122. DOI: 10.36718/1819-4036-2021-2-118-122.
11. *Пономаренко Ю.А., Фисинин В.И., Егоров И.А.* Комбикорма, корма, кормовые добавки, биологически активные вещества, рационы, качество, безопасность: монография. Минск; Москва, 2020. 468 с.
12. *Фисинин В.* Мировые и российские тренды развития птицеводства // Животноводство России. Тематический выпуск. 2018. № 4. С. 1–4.

REFERENCES

1. Fisinin V.I. *World and Russian Poultry Production: Realities and Challenges of the Future*. Moscow, Khlebprodinform Publ., 2019. 470 p. (In Russian).
2. Karapetyan A.K. The use of non-traditional feeds, different formulations of premixes and BVMC in the production of broiler meat. *Kormlenie sel'skokhozyaistvennykh zhivotnykh i kormoproizvodstvo = Feeding of Agricultural Animals and Feed Production*, 2022, no. 10, pp. 37–54. (In Russian). DOI: 10.33920/sel-05-2210-04.
3. Fisinin V.I., Egorov I.A., Laptev G.Yu., Lenkova T.N., Nikonov I.N., Il'ina L.A., Manukyan V.A., Grozina A.A., Egorova T.A., Novikova N.I., Iyldyrym E.A. Antibiotic-free poultry production based on innovative nutritional pro-

grams with the involvement of probiotics. *Voprosy kormleniya = Problems of Nutrition*, 2017, vol. 86 (6), pp. 114–124. (In Russian). DOI: 10.24411/0042-8833-2017-00013.

4. Scriabin V.A., Saboiev I.A., Tabanyukhov K.A. By-products of milling and corn production as a source of protein of increased biological value. *Innovatsii i prodovol'stvennaya bezopasnost' = Innovations and Food Safety*, 2019, no. 3 (25), pp. 105–111. (In Russian). DOI: 10.31677/2311-0651-2019-25-3-105-111.
5. Tsoi Z.V., Adushinov D.S. Feed additive from marine fishing waste in compound feed for laying hens under the conditions of the Primorsky Territory. *Kormlenie sel'skokhozyaistvennykh zhivotnykh i kormoproizvodstvo = Feeding of Agricultural Animals and Feed Production*, 2022, no. 12, pp. 20–32. (In Russian). DOI: 10.33920/sel-05-2212-03.
6. Tsoi Z.V., Vasilyeva N.V. Influence of non-traditional feed additives on egg productivity of laying hens in the conditions of Primorsky Krai. *Vestnik IrGSKhA = Vestnik IrGSHA*, 2020, is. 98, pp. 145–153. (In Russian). DOI: 10.51215/1999-3765-2020-98-145-153.
7. Tsoi Z.V., Vasilyeva N.V. Influence of non-conventional fodder additives of plant and marine origin on egg productivity of laying hens. *Vestnik IrGSHA = Vestnik IrGSHA*, 2020, is. 101, pp. 135–143. (In Russian). DOI: 10.51215/1999-3765-2020-101-135-143.
8. Rogachev V.A., Merzlyakova O.G., Lukyanchikova N.L., Mager S.N. Protein-vitamin flour from wheat bran enriched with phytase in the diet of quails. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 2, pp. 46–54. (In Russian). DOI: 10.26898/0370-8799-2022-2-6.
9. Fisinin V.I., Ismailova D.Yu., Volik V.G. Deep processing of collagen-rich poultry products for different use. *Sel'skokhozyaistvennaya biologiya = Agricultural Biology*, 2017, vol. 52, no. 6, pp. 1105–1115. (In Russian). DOI: 10.15389/agrobiology.2017.6.1105rus.
10. Tsoi Z.V., Vasilyeva N.V. Effects of non-conventional feed additives on egg efficiency of laying hens. *Vestnik KrasGAU = Bulletin of KrasGAU*, 2021, no. 2, pp. 118–122. (In Russian). DOI: 10.36718/1819-4036-2021-2-118-122.
11. Ponomarenko Yu.A., Fisinin V.I. Egorov I.A. *Feed, fodder, feed additives, biologically active substances, rations, quality, safety.* Minsk; Moscow, 2020, 468 p. (In Russian).
12. *Fisinin V.* Global and Russian trends in poultry farming development. *Zhivotnovodstvo Rossii = Livestock in Russia*, 2018, no. 4, pp. 1–4. (In Russian).

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Дата поступления статьи / Received by the editors 13.01.2023
Дата принятия к публикации / Accepted for publication 31.03.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-9
УДК: 619:619.9-036.2
Тип статьи: оригинальная
Type of article: original

НОЗОЛОГИЧЕСКИЙ ПРОФИЛЬ И КЛАССИФИКАЦИЯ ИНФЕКЦИОННЫХ БОЛЕЗНЕЙ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ЖИВОТНЫХ НА ТЕРРИТОРИИ РЕСПУБЛИКИ САХА (ЯКУТИЯ)

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Представлены результаты классификации инфекционных болезней сельскохозяйственных животных, распространенных на территории Республики Саха (Якутия) за период 2001–2021 гг. Установлено, что на территории Якутии в эпизоотическом процессе участвовало 42 нозологические единицы болезней животных. Инфекции крупного рогатого скота вызывают 18 видов возбудителей, лошадей – 12, северных домашних оленей – 4, свиней – 10, птиц – 11, мелкого рогатого скота – 3, пушных зверей – 7, прочих видов животных – 9. По классификации МЭБ, в Якутии распространено 10 нозоформ болезней – бешенство, бруцеллез, вирусная геморрагическая септицемия, инфекционная анемия лошадей, инфекционный бронхит кур, инфекционный ринотрахеит крупного рогатого скота, паратуберкулез, пастереллез и туберкулез. Зарегистрированы болезни, не отраженные в списке МЭБ, в том числе болезнь Марека, дизентерия свиней, колибактериоз, парвовирусный энтерит, сальмонеллез, рожа свиней, эмфизематозный карбункул. Ряд нозоформ, распространенных в Якутии, относится к особо опасным болезням, по которым могут устанавливаться ограничительные мероприятия (карантин). К ним относятся актиномикоз, бешенство, бруцеллез, инфекционная анемия лошадей, инфекционный бронхит кур, инфекционный ринотрахеит крупного рогатого скота, лейкоз крупного рогатого скота, лептоспироз, паратуберкулез, рожа свиней, туберкулез и чума плотоядных. Ряду болезней (болезнь Марека, инфекционный гепатит плотоядных, лейкоз крупного рогатого скота, мыт лошадей, орнитоз птиц, синдром снижения яйценоскости, рожа свиней и эмфизематозный карбункул) свойствен только один вид животных. Многим инфекциям присуща персистенция возбудителя в организме разных видов сельскохозяйственных и мелких домашних животных, птиц и представителей дикой фауны, что определяет межвидовую степень эпизоотической опасности этих инфекций. В Якутии превалируют инфекции бактериальной этиологии (бактериозы) – 21 нозоформа. Вирусные болезни (вирозы) представлены 15 нозоформами, микоплазмозы и хламидиозы – по одной. Наиболее многочисленны инфекции с основным алиментарным, или фекально-оральным, способом (22 болезни). С передачей возбудителя воздушно-капельным или респираторным путем (основной) отнесены 10 инфекций, в том числе инфекционный атрофический ринит, инфекционный ринотрахеит крупного рогатого скота, чума плотоядных. Трансмиссивную передачу возбудителя (с помощью переносчиков) характеризуют актиномикоз и инфекционная анемия лошадей; через наружные покровы (без участия переносчиков) – 5 болезней, в том числе баланопостит и бешенство. Для большинства всех инфекций, наряду с основным механизмом передачи возбудителя, характерны один и более дополнительных (бешенство, болезнь Марека, лейкоз крупного рогатого скота, рожа свиней и др.). По источнику возбудителя для всех болезней (ктенонозы) ими являются домашние животные, однако при таких инфекциях, как бешенство, болезнь Марека, вирусная геморрагическая септицемия, лептоспироз и другие, наряду с домашними дополнительным источником являются дикие животные (ктенотерионозы). По восприимчивости большинство инфекций (30) относятся к зоонозам, свойственным только животным, остальные 12 – к более опасным зооантропонозам, общим для животных и человека.

Ключевые слова: сельскохозяйственные животные**,** нозологическая форма болезни, классификация

NOSOLOGICAL PROFILE AND CLASSIFICATION OF INFECTIOUS DISEASES OF FARM ANIMALS IN THE TERRITORY OF THE REPUBLIC OF SAKHA (YAKUTIA)

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The results of the classification of infectious diseases of farm animals spread on the territory of the Republic of Sakha (Yakutia) for the period 2001-2021 are presented. It was found that there were 42 nosological units of animal diseases involved in the epizootic process on the territory of Yakutia. Infections in cattle are caused by 18 types of pathogens, horses - 12, reindeer - 4, pigs - 10, birds - 11, small ruminants - 3, fur-bearing animals - 7, other types of animals - 9. According to the OIE classification, 10 nosoforms of diseases are common in Yakutia: rabies, brucellosis, viral hemorrhagic septicemia, equine infectious anemia, avian infectious bronchitis, infectious bovine rhinotracheitis, paratuberculosis, pasteurellosis and tuberculosis. Diseases not on the OIE list, including Marek's disease, swine dysentery, colibacillosis, parvoviral enteritis, salmonellosis, diamond-skin disease, blackleg were registered. A number of nosoforms common in Yakutia belong to particularly dangerous diseases for which restrictive measures (quarantine) may be imposed. These include actinomycosis, rabies, brucellosis, infectious equine anemia, avian infectious bronchitis, infectious bovine rhinotracheitis, bovine leukosis, leptospirosis, paratuberculosis, diamond-skin disease, tuberculosis and canine distemper virus. A number of diseases (Marek's disease, carnivorous infectious hepatitis, bovine leukosis, horse strangles, avian ornithosis, egg drop syndrome, diamond-skin disease, and blackleg) are peculiar to only one species of animals. Many infections are characterized by the persistence of the pathogen in different species of farm and small domestic animals, birds and wildlife, which determines the interspecies degree of epizootic danger of these infections. Infections of bacterial etiology (bacterioses) prevail in Yakutia with 21 nosoforms. Viral diseases (viroses) are represented by 15 nosoforms, mycoplasmosis and chlamydia - one each. The most numerous infections are those with the main alimentary, or fecal-oral, route (22 diseases). Ten infections, including infectious atrophic rhinitis, infectious bovine rhinotracheitis, distemper, are classified as airborne or respiratory (major) pathogen transmission. Transmissive carry-over (by vectors) is characterized by actinomycosis and infectious equine anemia; through the outer covers (without the participation of vectors) - 5 diseases, including balanoposthitis and rabies. The majority of the infections are characterized by one or more additional mechanisms of transmission (rabies, Marek's disease, bovine leukemia, diamond-skin disease, etc.) in addition to the main mechanism of transmission of the pathogen. According to the source of the causative agent for all diseases (ktenonoses) they are domestic animals, but for such infections as rabies, Marek's disease, viral hemorrhagic septicemia, leptospirosis and others, along with domestic animals, wild animals are an additional source (ktenotherionoses). In terms of susceptibility, most infections (30) belong to zoonoses peculiar only to animals; the remaining 12 belong to the more dangerous zooanthroponoses common to animals and humans.

Keywords: farm animals, nosological form of the disease, classification

Для цитирования: *Петров П.Л., Смолянинов Ю.И., Протодьяконова Г.П., Юшкова Л.Я.* Нозологический профиль и классификация инфекционных болезней сельскохозяйственных животных на территории Республики Саха (Якутия) // Сибирский вестник сельскохозяйственной науки, 2023. Т. 53. № 5. С. 70–89. https://doi.org/10.26898/0370-8799-2023-5-9

For citation: Petrov P.L., Smolyaninov Yu.I., Protodyakonova G.P., Yushkova L.Ya. Nosological profile and classification of infectious diseases of farm animals in the territory of the Republic of Sakha (Yakutia). *Sibirskii vestnik sel'skokhozyaistvennoi nauki=Siberian Herald of Agricultural Science,* 2023, vol. 53, no. 5, pp. 70–89. https://doi.org/10.26898/0370-8799-2023-5-9

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Исследования проведены в соответствии с реализацией проекта «Стратегия развития государственной ветеринарной службы в Республике Саха (Якутия) до 2030 года» (Утверждены центром стратегических исследований при главе Республики Саха (Якутия), приказ от 15 февраля 2021 г. № 20/1-ОД).
Acknowledgements
The research was conducted in accordance with the project "Strategy for the Development of the State Veterinary Service in the Republic of Sakha (Yakutia) until 2030" (Approved by the Center for Strategic Studies under the Head of the Sakha (Yakutia), order of February 15, 2021 № 20/1-OD).

INTRODUCTION

The most important condition for achieving sustainable development of the agro-industrial complex of the Republic of Sakha (Yakutia) is the implementation of the measures on prevention and elimination of infectious diseases of farm animals, increasing the economic efficiency of anti-epizootic measures, ensuring the epizootic well-being of the republic and food security.

The classification of infectious animal diseases with the aim of grouping them based on some common significant feature is relevant in epizootiology. This is necessary to identify common epizootiological characteristics within these groups that have uniform characteristics, which contribute to the optimization of diagnostics, prevention, understanding the causes of the emergence and spread of infections, and based on this, develop the main directions of anti-epizootic measures [1].

Such research becomes particularly relevant when studying regional epizootiology, taking into account the climatic and geographical characteristics of the region, the composition of livestock industries, and the nosological profile of infectious diseases.

Across the territory of Yakutia with its extreme natural and climatic conditions for livestock management, the epizootic characteristic of the peculiarities of epizootic processes has been studied for certain infectious diseases of farm animals, including Rangiferine brucellosis [2–5], diseases of cattle [6], Siberian plague [7], and strangles in horses[1] [8].

Research has also been conducted in several regions of Russia on the classification of infectious diseases, including the republics of Tuva[2], Buryatia[3], Altai Territory[4], and Omsk Region[5]. Important regional and population-specific features of epizootic processes have been identified, based on which recommendations for optimizing anti-epizootic measures have been made.

The purpose of this research is to study the nosological profile and provide classification of prevalent infectious diseases of farm animals on the territory of the Republic of Sakha (Yakutia).

MATERIAL AND METHODS

The research was conducted using official veterinary statistics from the Department of Veterinary Medicine of the Republic of Sakha (Yakutia). Summary data for the years 2001–2021 were compiled using Form 1-Vet "Information on Infectious Diseases" and Form 1-Vet A "Information on Anti-Epizootic Measures."

The nosological profile was determined based on the registration of the cases of occurrence of

[1]*Neustroev M.P., Petrova S.G., Elbyadova E.I., Tarabukina N.P.* Laboratory tests of vaccine against mite // Prospects for the development of agrarian sciences: Proceedings of the Intern. scientific-practical conf. (April 10, 2020). Cheboksary, 2020. pp. 129-130.

[2]*Lopsan Ch.O.* Analysis of diseases of infectious pathology of farm animals in the Republic of Tyva // Methodology of the measures for the prevention and elimination of diseases of farm animals. Novosibirsk, 1995. pp. 289-291.

[3]*Murueva G.B.* Analysis of the epizootic situation of the Republic of Buryatia. Modern problems of epizootology. Novosibirsk, 2004. pp. 161-165.

[4]*Guslavsky I.I., Apalkin V.A., Gustokashin K.A.* Regional epizootology of infectious diseases, the basis of forecasting, prevention and control. Barnaul: AltSAU Publishing House. 2004. 148 p.

[5]Vasina N.I. Epizootological classification of infectious diseases on the territory of the Omsk region // Young scientists to the agriculture of Siberia: materials of conf. Barnaul, 2010. pp. 162-170.

infectious diseases in all types of farm animals in the structure of the agricultural sector of the region (cattle, horses, northern domestic deer, pigs, poultry, small ruminants, fur-bearing animals, other species).

The nomenclature and classification of infectious animal diseases registered in the region were established in accordance with the list of the International Epizootic Bureau (IEB)[6]. The classification of infectious animal diseases as particularly dangerous, for which restrictive measures (quarantine) can be established, was determined based on the list approved by the Ministry of Agriculture of the Russian Federation[7].

The epizootiological classification of diseases was conducted according to the scheme developed by I.A. Bakulov et al.[8] which is based on three main principles:

– correspondence between the localization of the infectious agent and the mechanism of its transmission;

– division of diseases based on the source of the infectious agent: ktenonoses (the source of the agent is exclusively domestic farm animals), therionoses (the source of the agent is only wild animals), and ktenotherionoses (the source of the agent can be both domestic and wild animals);

– distribution of diseases into categories of infectious agents (bacterioses, viroses, mycoplasmoses, rickettsioses, chlamydioses, mycoses, mycotoxicoses).

This classification has a clearly defined epizootiological orientation, which allows for its practical use in the system of anti-epizootic measures – in the development of effective measures for diagnosis, prevention, and elimination of infectious diseases of farm animals.

RESULTS AND DISCUSSION

It has been found that during the analyzed period (2001–2021) within the territory of the Republic of Sakha (Yakutia), 42 nosological units of diseases of various animal species were involved in the epizootic process (see the table).

The distribution of diseases among animal species showed that within the cattle population, 18 species of agents of different etiology were involved in the epizootic processes, while in horses there were 12, in northern domesticated reindeer 4, in pigs 10, in poultry 11, in small ruminants 3, in fur-bearing animals 7, and in other animal species (dogs, cats, etc.) 9.

Taking into account the nomenclature and classification of the IEB, over the analyzed period in Yakutia, 10 nosological forms of animal diseases have been identified. These include rabies, brucellosis, viral hemorrhagic septicemia, infectious anemia of horses, infectious bronchitis in chickens, infectious bovine rhinotracheitis, paratuberculosis, pasteurellosis, and tuberculosis. However, numerous other infectious diseases have been registered in the region that are not listed by the IEB, including Marek's disease, swine dysentery, diplococcal infection, colibacillosis, parvovirus enteritis, salmonellosis, swine erysipelas, emphysematous carbuncle, and others.

No transboundary infectious animal diseases of exceptional economic, trade, health, and food security significance, as indicated in the IEB list, have been registered within the territory of the Republic of Sakha (Yakutia) during the analyzed period.

According to the order of the Ministry of Agriculture of the Russian Federation, several nosological forms that are prevalent in Yakutia are categorized as animal diseases for which restrictive measures (quarantine) can be established. These include actinomycosis, rabies, brucellosis, infectious anemia of horses, infectious bronchitis in chickens, infectious bovine rhinotracheitis, leukemia in cattle, leptospirosis, paratuberculosis, swine erysipelas, tuberculosis, and carnivore plague.

Naturally focal infectious diseases transmitted from animals to humans, with their main

[6]OIE list and transboundary animal infections / V.V. Makarov, V.A. Rude, K.N. Gruzdev, O.I. Sukharev. Makarov, V.A. Rude, K.N. Gruzdev, O.I. Sukharev. Vladimir: VNIIZZh, 2012. 162 p.

[7]The list of contagious, including especially dangerous animal diseases, for which restrictive measures (quarantine) may be established. Appendix to the Order of the Ministry of Agriculture of the Russian Federation dated December 19, 2011 No. 476.

[8]Bakulov I.A., Yurkov G.G., Vedernikov V.A., Orlov F.M. Epizootic dictionary-reference book. Moscow: Rosselhozizizdat, 1987. 188 p.

Нозологический профиль и классификация инфекционных болезней животных, регистрируемых на территории Республики Саха (Якутия)
Nosological profile and classification of infectious diseases of farm animals in the territory of the Republic of Sakha (Yakutia)

Infectious disease	Large cattle	Horses	Deer	Pigs	Poultry	Small cattle	Fur-bearing animals	Other species	Classification OIE	Particularly dangerous (quarantine)	Epizootological classification			
											Nature of the stimulus agent	Primary (additional) transmission method	Nature (animals)	Sensitivity
Adenovirus infection	–	–	–	–	+	–	+	–	–	–	V	P	D	Z
Actinomycosis	+	–	–	–	–	–	–			+	M	T	D	Z
Balanoposthitis	+	–	–	–	–	–	–	–	–	–	B	H	D	Z
Rabies	–	+	+	–	–	–	–	+	+	+	V	H(P)	DW	ZA
Marek's disease	–	–	–	–	+	–	–	–	n	–	V	P(O)	DW	Z
Brucellosis (*br. melitensis*)	–	–	+	–	–	–	–	–	+	+	B	A(H)	D	ZA
Brucellosis (*br. canis*)	–	–	–	–	–	–	–	+	+	+	B	A(H)	D	Z
Virus diarrhoea	–	–	+	–	–	–	–	–	–	–	V	A	D	ZA
Viral haemorrhagic septicaemia	–	–	–	–	–	–	–	+	+	–	V	P(A)	DW	Z
Viral enteritis	–	–	–	–	–	–	+	–	–	–	V	A	D	Z
Swine dysentery	–	–	–	+	–	–	–	–	n	–	B	A	D	Z
Diplococcus infection	+	–	–	–	–	–	–	–	n	–	B	A(P)	D	Z
Equine infectious anemia	–	+	–	–	–	–	–	–	+	+	V	T(A)	D	Z
Infectious atrophic rhinitis	–	–	–	+	–	–	–	–	–	–	B	P	D	Z
Avian infectious bronchitis	–	–	–	–	+	–	–	–	+	+	V	A(P)	D	Z
Carnivore infectious hepatitis	–	–	–	–	–	–	+	–	–	–	V	H(A,У)	DW	Z
Infectious bovine rhinotracheitis	+	–	–	–	–	–	–	–	+	+	V	P	D	Z
Colibacteriosis	+	–	–	+	+	+	+	+	n	–	B	A	D	Z
Cattle leucosis	+	–	–	–	–	–	–	–	–	+	V	A (PTH)	D	Z
Leptospirosis	+	+	–	+	–	+	+	+	n	+	B	A(H)	DW	ZA

Listeriosis	–	–	–	–	+	–	–	–	–	–	B	A(T)	DW	ZA
Microsporia	–	+	–	–	–	–	–	–	n	–	M	H	DW	Z
Horse strangles	–	+	–	–	–	–	–	–	n	–	B	A(PH)	D	Z
Necrobacillosis	+	–	+	–	–	–	–	+	–	–	B	A(H)	DW	ZA
Ornithosis (parrot fever)	–	–	–	–	+	–	–	–	–	–	Ch	A(PH)	DW	ZA
Paratuberculosis	+	–	–	–	–	–	–	–	+	+	B	A(H)	DW	Z
Pasteurelllosis	+	+	–	+	+	–	+	–	+	–	B	P(A)	D	Z
Panleukopenia	–	–	–	–	–	–	–	+	n	–	V	A(PTO)	DW	Z
Parvoviral enteritis	–	–	–	–	–	–	–	+	–	–	V	A(PH)	D	Z
Pneumococcosis	+	–	–	–	–	–	–	–	n	–	B	P(T)	D	Z
Pseudomonosis	+	+	–	+	+	+	–	+	–	–	B	A	D	Z
Equine rhinopneumonitis	–	+	–	–	–	–	–	–	–	–	V	P(A)	D	Z
Swine eruption	–	–	–	+	–	–	–	–	–	+	B	A(PH)	DW	ZA
Paratyphoid fever	+	+	–	+	+	–	+	–	n	–	B	A	DW	ZA
Salmonella abortion of mares	–	+	–	–	–	–	–	–	n	–	B	A	D	Z
Egg drop syndrome	–	–	–	–	+	–	–	–	n	–	B	H	D	Z
Staphylococcosis	+	+	–	+	+	–	–	+	n	–	V	O(H)	D	Z
Tetanus	+	–	–	–	–	–	–	–	–	–	B	H	DW	Z
Streptococcosis	+	+	–	+	+	–	–	+	n	–	B	A(P)	D	Z
Tuberculosis	+	–	–	–	–	–	–	–	+	+	B	P(A)	DW	ZA
Canine distemper virus	–	–	–	–	–	–	–	+	–	–	V	A	DW	ZA
Quarter evil	+	–	–	–	–	–	–	–	–	+	B	A	D	Z

Note: n - not defined in the OIE classification list. Nature of the pathogen: B - bacteriosis, V - virosis, M - mycosis, Ch - chlamydia; main (additional) mode of pathogen transmission: A - alimentary, R - respiratory, T - transmissible, N - through the outer skin without the participation of vectors, O - transovarial, U - intrauterine; source of the pathogen: D - domestic animals (ktenonoses), DW - domestic and wild animals (ktenotherionoses); susceptibility to the pathogen: Z - zoonosis, ZA - zooanthroponosis

sources being wild, farm, and domestic animals, as well as rodents, are represented in Yakutia by nine nosological forms, including rabies, leptospirosis, listeriosis, and others.

Certain diseases are characteristic of only a specific animal species, and only that species is involved in the epizootic process. Among the diseases listed in the analyzed nomenclature that are prevalent in Yakutia, such diseases include Marek's disease, infectious carnivore hepatitis, cattle leukemia, strangles in horses, ornithosis (psittacosis) in birds, egg drop syndrome, swine erysipelas, and emphysematous carbuncle.

Many diseases are characterized by the persistence of the pathogen in the bodies of various farm animals, birds, small domestic animals, and wild fauna, determining the inter-species degree of epizootic danger posed by these infections.

The analysis showed that several animal species are involved in the epizootic process of certain diseases in the region:

– adenovirus infection (birds, fur-bearing animals);

– rabies (horses, northern reindeer, other species) and necrobacillosis (cattle, northern reindeer, other species). In the case of rabies, the rabies virus was found in the biomaterial from wild animals such as red foxes, wolves, Siberian weasels, ermines and Russian sables.

– pasteurellosis (cattle, horses, pigs, poultry, fur-bearing animals) and salmonellosis (cattle, horses, pigs, poultry, fur-bearing animals);

– colibacillosis (cattle, pigs, poultry, small ruminants, fur-bearing animals, other species) and leptospirosis (cattle, horses, pigs, small ruminants, fur-bearing animals, other species). A unique case of isolating the causative agent of leptospirosis was recorded from the biomaterial of wild bison in the Khangalassky District of Yakutia.

According to the epizootological classification it was established that according to the nature of the pathogens persisting in animals and the external environment, infections caused by pathogens of bacterial etiology - bacterioses - prevail in Yakutia. There are 21 nosological forms of bacterial origin, constituting 50% of all infectious diseases. Viral diseases (viroses) are represented by 15 nosological forms (35.7%), one mycoplasmosis-related (mycoplasmoses), and one chlamydial (chlamydioses) – both at 2.4%.

When analyzing diseases based on the mechanism of transmission of the causative agent, the most numerous group of infections is characterized by the primary alimentary, or fecal-oral, mode of transmission. This characteristic applies to more than half of all diseases (22, or 52.4%), with seven infections (viral diarrhea in cattle, swine dysentery, colibacillosis, pseudomoniasis, salmonellosis, salmonellosis-related abortion in mares, emphysematous carbuncle) exhibiting only this mode.

A group of diseases transmitted through the airborne-droplet, or respiratory, route (primary) comprises 10 cases, or 23.8%, including infectious atrophic rhinitis, infectious rhinotracheitis in cattle, carnivore plague, and others.

Two diseases (4.8%) - actinomycosis and infectious anemia of horses - were associated with transmission of the infectious agent transmissibly (by vectors).

Five diseases (11.9%) fall into the category of transmission through external coverings (without vector involvement), including balanoposthitis, rabies, and others.

Analyzing infectious diseases based on the mechanism of transmission of the causative agent, it should be noted that the majority of diseases (22 nosological units, or 52.4%) are characterized by one or more additional mechanisms of transmission along with the main mechanism of pathogen transmission. These include rabies, Marek's disease, cattle leukemia, swine erysipelas, and others.

In terms of the source of the causative agent, all infectious diseases originate exclusively from domestic animals and are classified as ktenonoses. However, for several infections, such as rabies, Marek's disease, viral hemorrhagic septicemia, leptospirosis, and others, wild animals also serve as additional sources (ktenotherionoses).

According to the classification sign of susceptibility, the majority of infections (30) nosologic forms, or 71.4%, belong to zoonoses - infectious diseases peculiar only to animals, the remaining 12 - to the more dangerous zooanthroponoses, common diseases for animals and humans.

CONCLUSIONS

1. From 2001 to 2021, 42 nosological units of infectious diseases affecting various animal species have been registered within the territory of the Republic of Sakha (Yakutia). In this process, 18 types of pathogens are involved in the epizootic events in cattle, 12 in horses, 4 in northern domestic reindeer, 10 in pigs, 11 in birds, 3 in small cattle, 7 in fur-bearing animals, and 9 in other species.

2. According to the IEB classification, 10 nosoforms of animal diseases are prevalent in Yakutia. No transboundary infections have been reported. 12 infections fall under the diseases for which restrictive measures (quarantine) could be established.

3. Based on the epizootiological classification, bacterioses are prevalent in the territory of Yakutia, comprising 21 diseases. Viroses are represented by 15 infections, with one case each of mycoplasmosis and chlamydiosis.

4. The diseases transmitted through the alimentary route are the most numerous (22 nosoforms). Ten diseases are transmitted through the respiratory route, two through transmission, and five through external coverings. In terms of the source of the causative agent, all diseases originate from domestic animals (ktenonoses), and 13 diseases are classified as ktenotherionoses, with wild animals serving as additional sources. In terms of susceptibility, 30 infections are categorized as zoonoses (affecting only animals), while 12 belong to zoonanthroponoses, common to both animals and humans.

СПИСОК ЛИТЕРАТУРЫ

1. *Макаров, В.В., Петров А.К., Васильев Д.А.* Основы учения об инфекции: монография. М.: Ульяновск, 2018. 160 с.
2. *Слепцов Е.С., Винокуров Н.В., Федоров В.И., Григорьев И.И., Захарова О.И.* Эпизоотическое состояние по бруцеллезу северных оленей в Республике Саха (Якутия) // Аграрный вестник Урала. 2018. № 8 (175). С. 57–61.
3. *Забродин В.А., Лайшев К.А., Гулюкин М.И., Гулюкин А.М., Искандаров М.И., Слепцов Е.С., Винокуров Н.В., Федоров В.И., Бочкарев И.И., Захарова О.И.* Бруцеллез оленей и некоторых диких животных на Енисейском Севере: монография. Новосибирск: СибАК, 2018. 290 с.
4. *Слепцов Е.С., Искандаров М.И., Винокуров Н.В., Племяшов К.В., Павлова А.И.* Анализ материалов эффективности применения вакцинных штаммов и систем профилактики и ликвидации бруцеллеза животных на территории РФ // Ветеринария и кормление. 2020. № 5. С. 45–48. DOI: 10.30917/ATT-VK-1814-9588-2020-5-14.
5. *Петров П.Л., Протодьяконова Г.П.* Влияние агроклиматических условий на заболеваемость бруцеллезом северных оленей в арктических районах Якутии // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 6. С. 94–102. DOI: 10.26898/0370-8799-2022-6-11.
6. *Обоева Н.А., Тарабукина Н.П., Неустроев М.П., Былгаева А.А., Протодьяконова Г.П.* Эпизоотическая ситуация по инфекционным болезням крупного рогатого скота в Якутии // Ветеринария и кормление. 2019. № 2. С. 17–19. DOI: 10.30917/ATT-VK-1814-9588-2019-2-6
7. *Дягилев Г.Т., Неустроев М.П.* Кадастр неблагополучных пунктов по сибирской язве животных в Республике Саха (Якутия) // Сибирский вестник сельскохозяйственной науки. 2019. Т. 49. № 5. С. 80–87. DOI: 10.26898/0370-8799-2019-5-11.
8. *Neustroev M.P., Petrova S.G., Elbyadova E.I., Tarabukina N.P., Alekseev V.A., Popov A.A.* Identification of Causative Agent of Horse Strangles in Northern Siberia // Annals of the Romanian Society for Cell Biology. 2021. Vol. 25. Is. 3. P. 516–527.

REFERENCES

1. Makarov V.V., Petrov A.K., Vasiliev D.A. *Fundamentals of the doctrine of infection (textbook).* Moscow: Ulyanovsk, 2018, 160 p. (In Russian).
2. Sleptsov E.S., Vinokurov N.V., Fedorov V.I., Grigoriev I.I. Zakharova O.I. Epiizootic condition of brucellosis of northern reindeer in the Republic of Sakha (Yakutia). *Agrarnyi vestnik Urala = Agrarian Bulletin of the Urals,* 2018, no. 8 (175), pp. 57–61. (In Russian).
3. Zabrodin V.A., Laishev K.A., Gulyukin M.I., Gulyukin A.M., Iskandarov M.I., Sleptsov E.S., Vinokurov N.V., Fedorov V.I., Bochkarev I.I., Zakharova O.I. *Brucellosis of deer and some wild animals in the Yenisei North*. Novosibirsk, SibAK Publ., 2018, 290 p. (In Russian).

4. Sleptsov E.S., Iskandarov M.I., Vinokurov N.V., Plemyashov K.V., Pavlova A.I. Analysis of materials on the effectiveness of vaccine strains and systems for the prevention and elimination of animal brucellosis in the Russian Federation. *Veterinariya i kormlenie = Veterinaria i Kormlenie*, 2020, no. 5, pp. 45–48. (In Russian). DOI: 10.30917/ATT-VK-1814-9588-2020-5-14.
5. Petrov P.L., Protodyakonova G.P. Effect of agro-climatic conditions on the incidence of brucellosis of reindeer in the arctic regions of Yakutia. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 6, pp. 94–102. (In Russian). DOI: 10.26898/0370-8799-2022-6-11.
6. Oboeva N.A., Tarabukina N.P., Neustroev M.P., Bylgaeva A.A., Protodyakonova G.P. Epizootic situation on infectious diseases of cattle in Yakutia. *Veterinariya i kormlenie = Veterinaria i Kormlenie*, 2019, no. 2, pp. 17–19. (In Russian). DOI: 10.30917/ATT-VK-1814-9588-2019-2-6.
7. Diaghilev G.T., Neustroev M.P. Cadastre of unfavorable locations for anthrax in animals in the Republic of Sakha (Yakutia). *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2019, vol. 49, no. 5, pp. 80–87. (In Russian). DOI: 10.26898/0370-8799-2019-5-11.
8. Neustroev M.P., Petrova S.G., Elbyadova E.I., Tarabukina N.P., Alekseev V.A., Popov A.A. Identification of Causative Agent of Horse Strangles in Northern Siberia. *Annals of the Romanian Society for Cell Biology*, 2021, vol. 25, is. 3, pp. 516–527.

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Дата поступления статьи/Received by the editors 13.02.2023
Дата принятия к публикации/ Accepted for publication 27.04.2023
Дата публикации/Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-10
УДК: 636.32/38
Тип статьи: оригинальная
Type of article: original

БИОХИМИЧЕСКИЕ ПОКАЗАТЕЛИ И БАКТЕРИЦИДНОСТЬ КРОВИ МОЛОДНЯКА ОВЕЦ ЦИГАЙСКОЙ ПОРОДЫ

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Представлены результаты изучения показателей биохимии и бактерицидной активности сыворотки крови (БАСК) ремонтного молодняка овец цигайской породы, выращиваемого в условиях Присивашской низменности Крымского полуострова. Образцы крови обработаны в сертифицированных лабораториях организаций Республики Крым в 2020–2022 гг. Параметры сыворотки крови определены на основе 12 проб баранов и 12 проб ярок. Для обработки биохимических показателей использован фотометрический анализатор Vitalab Flexor E, бактерицидной активности сыворотки крови – термостатируемый прибор Multiskan. По результатам исследования у животных зафиксирован нормальный уровень креатинина и мочевины: у баранов 87,5 ± 0,7 и 6,6 ± 0,2 ммоль/л соответственно, у ярок – 85,5 ± 1,2 и 6,4 ± 0,4 ммоль/л. Пониженный уровень глюкозы (1,6 ± 0,1…1,7 ± 0,1 ммоль/л) в сыворотке крови молодняка, вероятно, связан с активным моционом на фоне жаркой погоды. Отмеченное количество ферментов переаминирования обусловило повышение коэффициента Ритиса у баранов до 2,5 ед., у ярок – до 3,8 ед., что свидетельствует о нагрузке на сердечную мышцу животных на фоне длительных прогулок на жаре. Содержание калия у нижних нормальных границ (4,3 ± 0,01…4,7 ± 0,1 ммоль/л) и несколько пониженный уровень фосфора (1,3 ± 0,01…1,2 ± 0,01 ммоль/л) указывают на необходимость дополнительной подкормки растущего молодняка минеральными премиксами в летний период. Средние значения БАСК увеличивались у ярок, достоверно превышая этот показатель в сравнении с баранами на 45,8–26,6 абс.% ($p \leq 0{,}001$). У баранов наибольшие значения БАСК отмечены в отношении *S. aureus* на 10-й час экспозиции (36,82 ± 2,19%), в то время как рост *E. coli* подавлялся до уровня 7,23 ± 1,34%, что в том числе является фактором, провоцирующим проблемы с пищеварением. У ярок зафиксировано удовлетворительное состояние кожных покровов, что обусловлено высоким уровнем БАСК в отношении *S. aureus* (до 35,30 ± 2,64% на 10-й час экспозиции).

Ключевые слова: цигайская порода, бараны, ярки, биохимические показатели, бактерицидная активность сыворотки крови

BIOCHEMICAL PARAMETERS AND BLOOD BACTERICIDAL ACTIVITY OF YOUNG TSIGAI SHEEP

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The results of the study of blood serum biochemistry and bactericidal activity of the herd replacements sheep of the Tsigai breed, grown in the Prisivash lowland of the Crimean Peninsula are presented. Blood samples were processed in certified laboratories of the organizations of the Republic of Crimea in 2020-2022. Blood serum parameters were determined on the basis of 12 samples of rams

and 12 samples of gimmers. A Vitalab Flexor E photometric analyzer was used to process biochemical parameters, a Multiskan thermostatically controlled device was used to process bactericidal activity of blood serum. The animals showed normal creatinine and urea levels: 87.5 ± 0.7 and 6.6 ± 0.2 mmol/l in rams, respectively, and 85.5 ± 1.2 and 6.4 ± 0.4 mmol/l in gimmers. The reduced glucose level (1.6 ± 0.1...1.7 ± 0.1 mmol/l) in the blood serum of young animals is probably related to active exercise in hot weather. The observed amount of transamination enzymes caused an increase in the Ritis coefficient in rams up to 2.5 units, in gimmers up to 3.8 units, which indicates the load on the heart muscle of the animals during long walks in the heat. Potassium content near the lower normal limits (4.3 ± 0.01...4.7 ± 0.1 mmol/l) and slightly reduced phosphorus level (1.3 ± 0.01...1.2 ± 0.01 mmol/l) indicate the need for additional supplementation of growing young animals with mineral premixes in summer period. Average BSBA values increased in gimmers, significantly exceeding this index in comparison with rams by 45.8-26.6 abs.% ($p \leq 0.001$). In rams, the highest BSBA values were observed for *S. aureus* at 10 hours of exposure (36.82 ± 2.19%), while the growth of *E. coli* was suppressed to 7.23 ± 1.34%, which is, among other things, the factor provoking digestive problems. In the gimmers, a satisfactory skin condition was recorded due to the high level of BSBA against *S. aureus* (up to 35.30 ± 2.64% at 10 hours of exposure).

Keywords: Tsigai breed, rams, gimmers, biochemical parameters, blood serum bactericidal activity

Для цитирования: *Остапчук П.С., Постникова О.Н., Зубоченко Д.В., Усманова Е.Н., Куевда Т.А., Пихтерева А.В.* Биохимические показатели и бактерицидность крови молодняка овец цигайской породы // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 79–89. https://doi.org/10.26898/0370-8799-2023-5-10

For citation: Ostapchuk P.S., Postnikova O.N., Zubochenko D.V., Usmanova E.N., Kuevda T.A., Pikhtereva A.V. Biochemical parameters and blood bactericidal activity of young Tsigai sheep. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 79–89. https://doi.org/10.26898/0370-8799-2023-5-10

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Исследование проведено в рамках НИР (номера государственной регистрации: AAAA-A16-116022610122-2 и FNZW-2022-0011).
Acknowledgements
The study was conducted as part of the R&D program (state registration numbers: AAAA-A16-116022610122-2 and FNZW-2022-0011).

INTRODUCTION

The effectiveness of selection processes in sheep breeding depends on identifying the best variants and their subsequent intensive use in breeding [1]. In this regard, significant attention is given to animal health. It has been established that environmental conditions directly influence the formation of productive traits in sheep[1] [2, 3]. However, the impact of reference values of blood biochemical indicators on the sheep's organism state remains insufficiently studied[2].

Biochemical indicators provide insights into the health status of animals [4], reflecting distinct characteristics of their productivity [5], and natural resistance constitutes a factor of internal organism stability[3].

The complex of natural resistance factors possesses antimicrobial properties[4], including

[1]*Kosilov V.I., Nikonova E.A., Shkilev P.N.* Features of development of young Tsigai sheep breed in the sharply continental climate of the Southern Urals // Collection of scientific papers of the Stavropol Research Institute of Animal Husbandry and Fodder Production. 2013. vol. 1. no. 6. pp. 48–53.

[2]Novgorodova I.P., Iolchiev B.S., Klenovitsky P.M., Prytkov S.A. Biochemical status of blood of lambs // Improving the competitiveness of livestock and the challenges of staffing: Proceedings of the XXVI International Scientific and Practical Conf. Moscow, 2020. pp. 253-256.

[3]Nikitenko E.V., Shumaenko S.N., Skorykh L.N., Kovalenko D.V. Influence of laser-puncture on the natural resistance of young sheep in postnatal ontogenesis // Modern trends in science and technology. 2016. no. 7-1. pp. 42-44.

[4]Chysyma R.B., Fedorov Yu.N., Makarova E.Yu., Kuular G.D. Humoral and cell factors of natural resistance in the animals of local breeds in specific environmental conditions of the Tyva Republic // Agricultural Biology. 2015. vol. 50. no. 6. pp. 847–852.

impeding the formation of biofilms[5], which serve as starting mechanisms for the development of most bacterial infections caused by opportunistic pathogens like *Staphylococcus aureus* and *Escherichia coli*[6].

Blood has the ability to inhibit the growth or cause the demise of numerous microorganisms[7]: blood serum disrupts the matrix of bacterial biofilms, which is one of the factors of humoral innate immunity. Thus, blood serum bactericidal activity (BSBA) serves as an integral indicator of the level of nonspecific organism resistance [6], and the susceptibility of young sheep to infections becomes an objective indicator in assessing and predicting animal productivity [7]. It has been established that unidirectional selection for productivity in ruminants leads to a reduction in resistance [8].

The research objective is to uncover the correlation between the blood's biochemical and immunological characteristics and the live weight of replacement lambs of the Tsigai sheep breed.

The objectives:

1) determining the peculiarities of the blood serum's biochemical composition in replacement lambs of the Tsigai sheep breed;

2) investigating the serum bactericidal activity of rams and gimmers towards *S. aureus* and *E. coli* cultures.

MATERIAL AND METHODS

The research object was the blood serum of replacement lambs of the Tsigai sheep breed (rams and gimmers) aged 14 months, collected two weeks after shearing. The blood collection time and location were in the first ten-day period of June 2020 at the "Southern Crimean Sheep Farm," Nizhnegorsky District, Republic of Crimea. The young sheep were raised under a pasture-stall system, and their feeding followed physiological norms with available feed sources. The parameters under investigation included live weight, blood serum biochemical indicators, and Blood Serum Bactericidal Activity (BSBA).

Live weight was measured with a precision of 0.5 kg using platform mechanical scales during the scoring period. Blood was drawn from the jugular vein into a vacuum tube with coagulation activator in the morning hours before releasing the animals to the pasture. Biochemical indicators were determined using a Vitalab Flexor E analyzer in the clinical-diagnostic laboratory of the Crop Production Department of the Scientific Research Institute of Agriculture of Crimea. The measured parameters included total protein (g/l), glucose (mmol/l), alanine aminotransferase (AlAT, U/l), aspartate aminotransferase (AsAT, U/l), creatinine (μmol/l), urea (mmol/l), potassium (mmol/l), and phosphorus (mmol/l)[8].

Blood serum bactericidal activity was determined in the laboratory of the Microbiology Department at the Medical Academy named after S. I. Georgievsky using a temperature-controlled Multiskan device. Reference strains *S. aureus* ATCC 25923 and *E. coli* ATCC 25922 served as test cultures. Bacterial suspensions with a turbidity of 0.5 McFarland standard were prepared from 24-hour agar cultures. 0.02 ml of serum was added to 0.180 ml of meat-peptone broth (MPB). Control samples containing 0.180 ml of MPB received 0.02 ml of isotonic sodium chloride solution. Hence, sheep serum was diluted in a 1:10 ratio. Experimental and control samples were supplemented with 0.02 ml suspension of the respective reference cultures each.

Optical density measurements for all the samples were performed in a 96-well plastic plate at a wavelength of 540 nm every hour for a duration of 24 hours. The change in the growth rate (optical density) of bacterial cultures was determined for the samples with added serum and controls at 2, 4, 6, 8, and 10 hours. Blood serum bactericidal activity was calculated as the ratio

[5]Hall-Stoodley L., Stoodley P. Evolving concepts in biofilm infections // Cell Microbiology. 2009. vol. 11 (7). pp. 1034–1043.

[6]Römling U., Balsalobre C. Biofilm infections, their resilience to therapy and innovative treatment strategies // Journal of Internal Medicine. 2012. vol. 272 (6). pp. 541–561.

[7]Slivinska L.G., Fedorovych N.M. Application chelates microelements in young animal sheep // Scientific messenger of Lviv National University of Veterinary Medicine and Biotechnologies. 2012. vol. 14. no. 3-1 (53). pp. 252–257.

[8]Kotomtsev V.V. Clinical and biochemical indicators of animal blood: method. manual. Ekaterinburg, 2006. 102 p.

of the reference cultures growth rates in the experimental group to the growth rates of the same cultures over the same time in the control group. The results were expressed in percentages, and the mean values were calculated based on eight repetitions. BSBA in each experimental variant was determined using the formula

$$BSBA = 100 - E_{OP}3 - E_{OP}0\ E_C3 - E_C0 \times 100,$$

where $E_{OP}0$ is the optical density of the sample before incubation; $E_{OP}3$ is the optical density of the sample after 3 hours of incubation; E_C0 is the optical density of the control sample before incubation; and E_C3 is the optical density of the control sample after 3 hours of incubation.

Statistical analysis of the results was performed according to the assessment and utilization of selection-genetic parameters in sheep breeding [9].

RESULTS AND DISCUSSION

According to the weather archives for the Nizhnegorsky District[9], the following environmental conditions were present at the time of blood collection. The average temperature in the first ten-day period of June was 19.3°C, accompanied by a persistent lack of precipitation. During the period when the animals were on pasture, daytime temperatures gradually increased from 23.1°C to 33.3°C. The precipitation deficit in May (1st ten-day period – 2.4 mm, 2nd ten-day period – none, 3rd ten-day period – 12.8 mm), as well as in the first ten-day period of June (see Figure 1), did not favor the formation of stable vegetation cover on the pasture (see Figure 2).

Blood biochemical indicators are essential components in assessing the animals' condition and are influenced by natural-climatic conditions in the region, management practices, dietary regimen, and breed composition [10–12]. Table 1 presents the indicators of the biochemical profile of Tsigai sheep lambs reared in the conditions of the Prisivashskaya Lowland of the Crimean Peninsula. Among the examined subjects, the total protein levels were within the normal range, indicating adequate protein metabolism. Normal

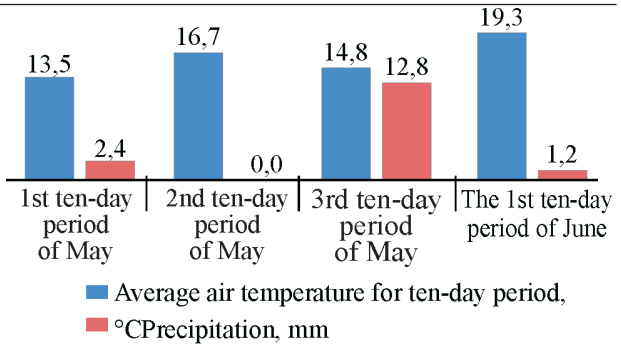


Рис. 1. Климатические условия в мае и I декаде июня 2020 г. в районе расположения хозяйства

Fig. 1. Climatic conditions in May and the first ten days of June 2020 in the area of the farm location

Рис. 2. Растительность, характерная для пастбищ Присивашской низменности

Fig. 2. Vegetation characteristics of the Prisivash lowland pastures

levels of creatinine and urea reflect good kidney function, established due to the animals' optimal adaptation to the external environment.

Hypoglycemia is likely associated with increased physical exertion on the sheep, which typically spend the entire day grazing in June, coupled with the hot weather prevalent during this period (though the difference between the studied groups of lambs is not statistically significant). The elevated level of the enzyme AsAT by 14.1% ($p \leq 0.001$) in gimmers further suggests a connection between aspartate and nervous tissue, which is enriched in glucose. In contrast, the state of the liver is likely normal, given the normal level of AlAT, which is significantly higher by 24.2% ($p \leq 0.001$) in rams. The

[9]Weather archive in the Nizhnegorsk district.URL: https://rp5.ru/Архив_погоды_в_Нижнегорском.

Табл. 1. Биохимический профиль и показатели БАСК молодняка овец цигайской породы
Table 1. Biochemical profile and BSBA values of the young Tsigai sheep

Indicator		Unit of measurement	Rams (n = 12)		Gimmers (n = 12)		Norm [14]
			$X \pm m_X$	C_v, %	$X \pm m_X$	C_v, %	
Total protein		g/l	50,2 ± 0,5	3,4	49,8 ± 0,5	3,8	42–97
Glucose		mmol/l	1,6 ± 0,1	11,5	1,7 ± 0,1	26,7	2,5–3,3
ALT		ед./л	55,5 ± 2,1*	12,8	42,1 ± 2,8	22,9	до 44
AST		ед./л	139,6 ± 3,0	7,4	159,2 ± 5,9*	12,8	до 124
Creatinine		μmol/l	87,5 ± 0,7	2,6	85,5 ± 1,2	4,7	53–120
Urea		mmol/l	6,6 ± 0,2	12,4	6,4 ± 0,4	19,3	3,3–9,0
Potassium		mmol/l	4,3 ± 0,0	2,0	4,7 ± 0,1*	4,3	4,3–6,3
Phosphorus		mmol/l	1,3 ± 0,0	6,4	1,2 ± 0,0	10,7	1,45–1,66
Live weight		kg	56,9 ± 1,1*	6,5	44,2 ± 0,9	6,9	–
Group average BSBA value for test cultures	*S. aureus* ATCC 25923	%	25,9 ± 1,7	22,5	37,7 ± 1,8*	16,1	–
	E. coli ATCC 25922	%	20,1 ± 1,6	27,6	25,5 ± 0,4*	5,3	–

*$p \leq 0{,}001$.

high level of the Ritis coefficient in the Tsigai replacement lambs overall (2.5 in rams and 3.8 in gimmers) indicates a substantial workload on the animals' heart muscles due to extended movement during grazing under elevated temperature conditions.

In the early summer of 2020, the pastures exhibited sparse vegetation cover, which likely contributed to a deficiency in the intake of mineral elements by the animals. Consequently, supplementary feeding with concentrates was provided in the evenings to ensure a relatively well-balanced diet in terms of essential nutrients. This is evidenced by the animals' normal enzymatic profile.

The average value of the BSBA against *S. aureus* in rams was lower than in gimmers by 45.8 absolute percentage points ($p \leq 0.001$). A similar pattern persisted in the average BSBA values concerning the *E. coli* test culture, with a difference of 26.6 absolute percentage points ($p \leq 0.001$).

Thus, based on the higher values of this indicator in gimmers, it can be concluded that the gender of the animals influences the bactericidal activity of blood serum against both *Staphylococcus aureus* and *Escherichia coli*.

The associations between the serum blood biochemistry indicators and body weight, as reflected in Table 2, generally exhibit an insignificant correlation. However, the correlation between body weight and the levels of potassium and phosphorus in the serum shows a moderate negative correlation. This indicates the need for additional mineral supplementation of growing lambs with mineral premixes during the summer period. Meeting the required standards for mineral intake is a critical factor for the proper functioning of the organism [13]. According to the data from Table 2, a significant correlation is observed between body weight and phosphorus levels in rams, and between body weight and potassium levels in gimmers. The potassium content, responsible for water and salt balance, was found to be at the lower limit in the animals' blood, and the phosphorus levels in the serum of all individuals were lowered. Therefore, considering the negative correlation between these elements' levels and the body weight, it is advisable to enhance the mineral supplementation of the lambs' diet.

The deficiency of mineral substances can be partly attributed to the established natural-climatic conditions. During the summer period, the

Табл. 2. Сопряженность биохимических показателей с живой массой

Table 2. Correlation of biochemical indicators with live weight

Indicator	Rams	Gimmers
Total protein	−0,25 ± 0,31	0,20 ± 0,31
Glucose	0,01 ± 0,32	−0,22 ± 0,31
ALT	−0,28 ± 0,30	−0,11 ± 0,31
AST	−0,48 ± 0,28	0,37 ± 0,29
Creatinine	0,48 ± 0,28	−0,08 ± 0,32
Urea	−0,18 ± 0,31	0,05 ± 0,32
Potassium	0,14 ± 0,31	−0,67 ± 0,23*
Phosphorus	−0,56 ± 0,26*	−0,21 ± 0,31

*$p \leq 0,05$.

animals are kept in conditions of active movement, spending a significant part of the day on natural pastures, as the territory of the Prisivashskaya Lowland is predominantly suitable for such pasture organization [14].

Figure 3a presents the results of the blood serum bactericidal activity measurement against *S. aureus* in rams. During the first two hours of exposure, the BSBA ranged from 15.52% to negative values (-0.09...-8.00%) in half of the individuals. On average, this indicator reached 3.86 ± 2.03%. Subsequently, there was a gradual increase in the BSBA level: during the 4-hour incubation, the average value was 24.38 ± 2.28%, and after 6 hours of incubation, it increased to 28.19 ± 1.33%. The indicator then stabilized at later time points (after 8 hours of growth - 36.08 ± 1.84%, after 10 hours - 36.82 ± 2.19%).

The average BSBA value against the *E. coli* culture in rams during the first two hours of incubation was 20.11 ± 1.69% (see Figure 3 б). The highest bactericidal activity was observed after 4 hours of growth, reaching 41.21 ± 3.25%. Subsequently, there was a gradual decrease in the indicator: to 22.88 ± 2.51% after 6 hours and to 9.53 ± 1.10% after 8 hours. Growth suppression was noted after 10 hours, at which point the indicator value reached an average of 7.23 ± 1.34%, with only one sample showing a negative value (-8.77%).

The blood serum of the Tsigai breed gimmers suppressed the growth of the *S. aureus* culture throughout the 10-hour incubation period. The average BSBA value after 2 hours of growth reached 22.31 ± 3.76%, 46.61 ± 2.12% after 4 hours, 43.57 ± 2.45% after 6 hours, 40.90 ± 1.97% after 8 hours, and 35.30 ± 2.64% after 10 hours (see Figure 4a).

Regarding *E. coli* in gimmers, as well as in rams, there was a tendency for gradual decrease in BSBA after 6 hours and more of culture growth. After 2 hours of incubation, the indicator reached 38.67 ± 1.72%, after 4 hours - 41.72 ± 1.57%, after 6 hours - 19.43 ± 0.94%, after 8 hours - 15.36 ± 0.71%, and after 10 hours - 13.35 ± 0.73% (see Figure 4 б).

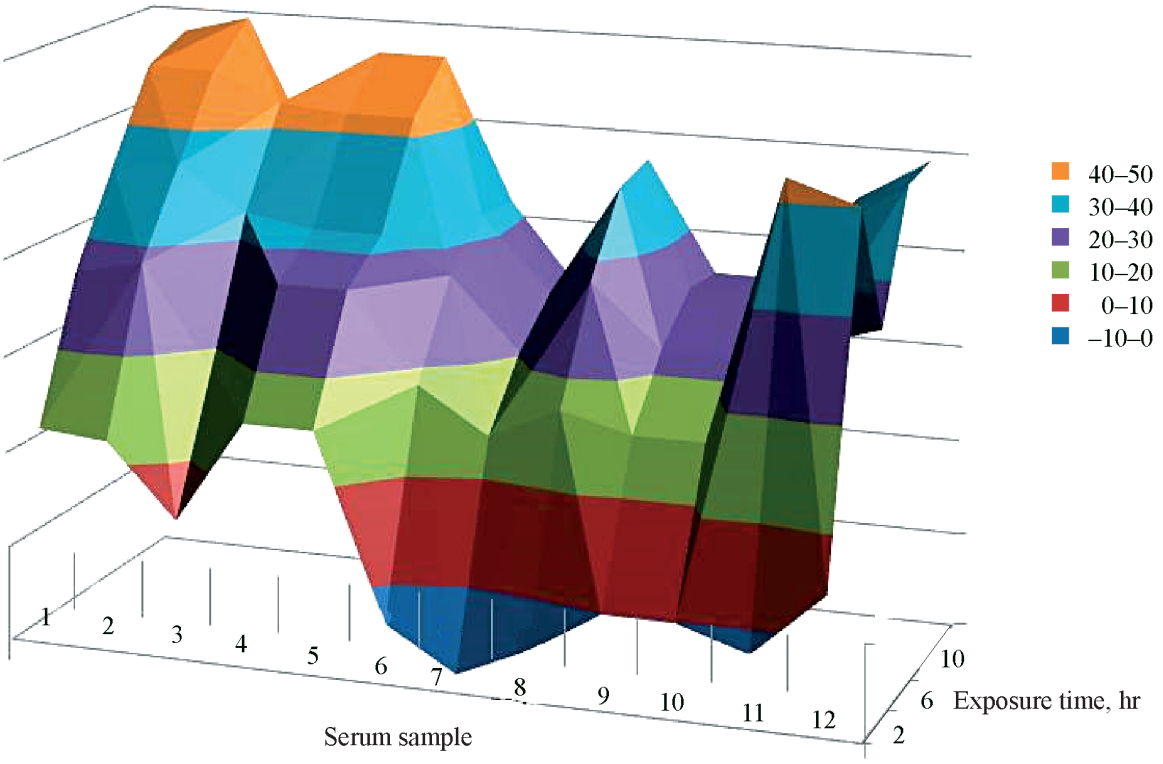
Thus, in Tsigai rams under the conditions of the natural pastures of the Prisivashskaya Lowland in the territory of the Crimean Peninsula, an elevated level of BSBA against *Staphylococcus aureus* and a less pronounced bactericidal activity against *Escherichia coli* are formed. Meanwhile, in the serum of Tsigai gimmers, bactericidal activity is noted against both studied reference cultures. High BSBA values can contribute to maintaining colonization resistance of the gut microbiota and provide resistance to purulent-inflammatory skin infections.

In the study, a positive average correlation level was observed between the body weight and the BSBA in rams with regard to the *S. aureus* test culture, and in gimmers with regard to the *E. coli* test culture (see Figure 5).

Farm animals are distributed according to the magnitude of BSBA as follows (in descending order): large cattle, rabbits, and sheep. This sequence is directly related to the presence of two main agents in the blood of animals that form innate immunity - properdin and lysozyme. While sheep occupy an intermediate position in terms of properdin content between large cattle and rabbits, they rank last in lysozyme content. It should be noted that rabbits have higher BSBA values than sheep[10]. Thus, the obtained data confirm that for further breeding of the Tsigai sheep,

[10]Malev A.A. Bactericidal activity of blood serum of different species of animals, its diagnostic significance: author's abstract of Cand. of Science in Biology. Kazan, 2009. 23 p.

а



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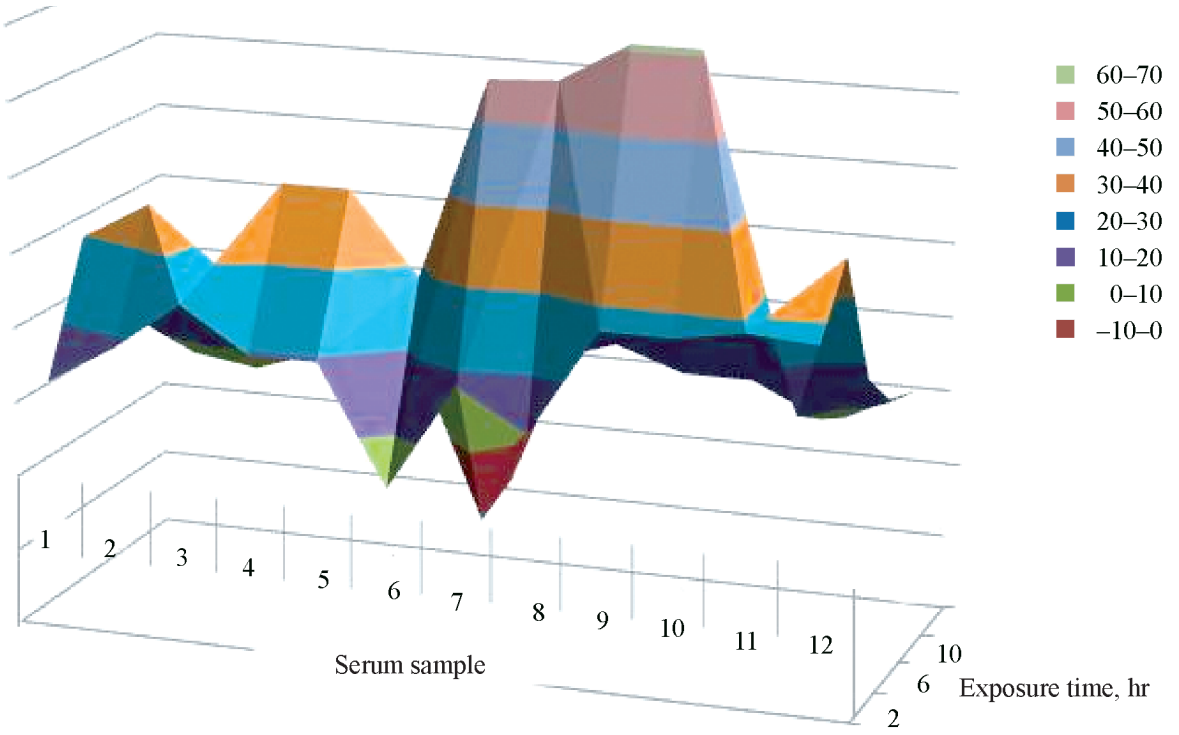
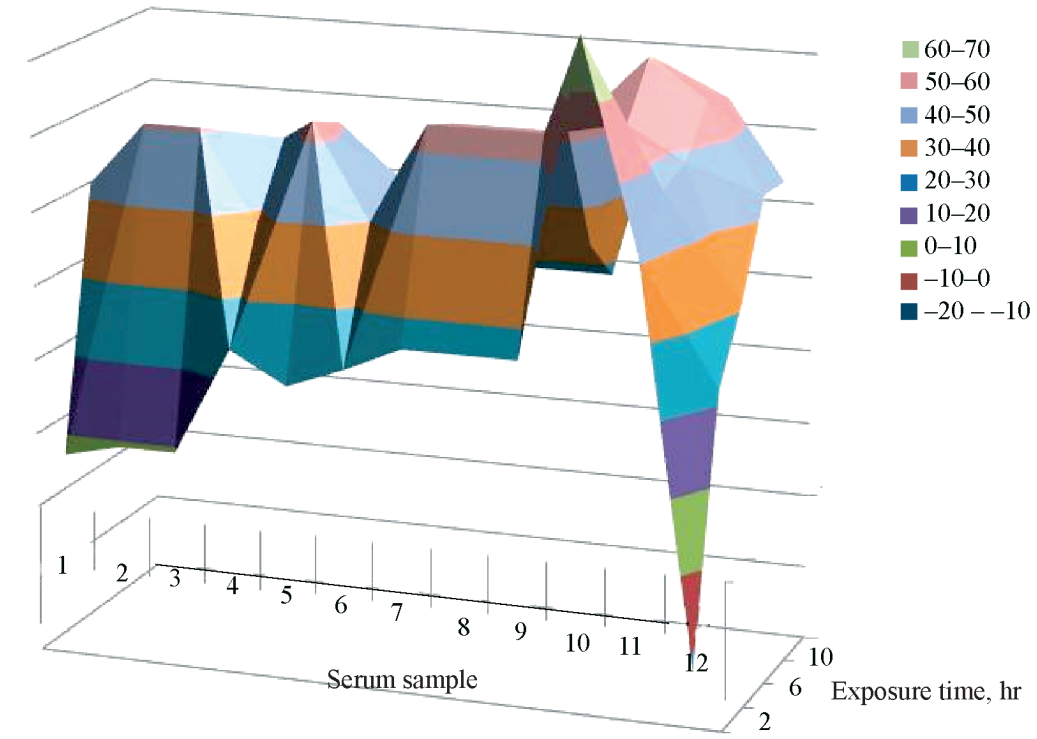


Рис. 3. Значение БАСК баранов в отношении культуры *S. aureus* (*а*) и *E. coli* (*б*)
Fig. 3. Significance of BSBA of rams in relation to *S. aureus* culture (*а*) and *E. coli* (*б*)

а



б

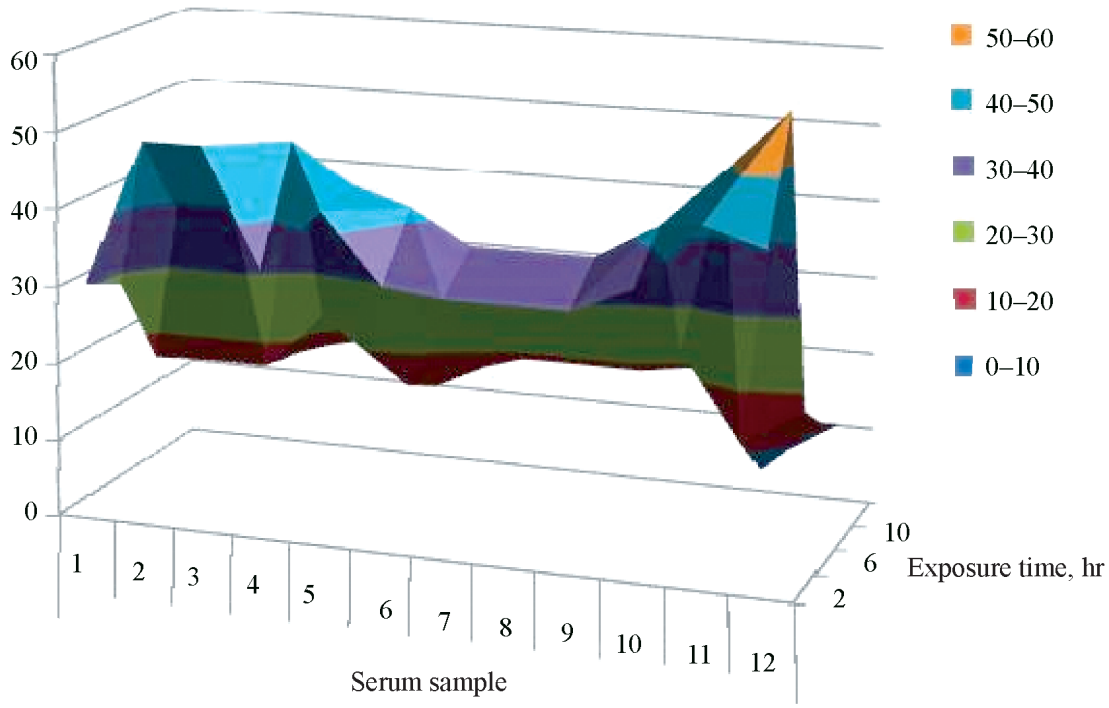


Рис. 4. Значение БАСК ярок в отношении культуры *S. aureus* (*а*) и *E. coli* (*б*)
Fig. 4. Significance of BSBA of gimmers in relation to *S. aureus* culture (*а*) and *E. coli* (*б*)

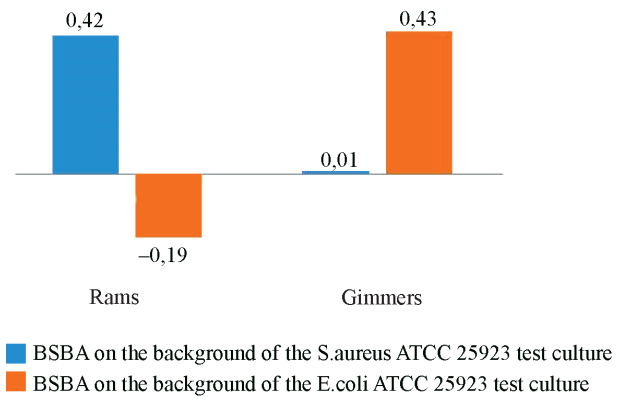


Рис. 5. Сопряженность живой массы животных с показателями БАСК

Fig. 5. Correlation of live weight of animals with BSBA indices

it is advisable to retain the replacement young stock with the highest BSBA values, as environmental conditions have a significant influence on the productivity of these animals.

CONCLUSION

For the replacement young stock of the Tsigai sheep raised in the Prisivashskya Lowland zone of the Republic of Crimea, the blood biochemical indicators are generally within the normal range. This fact indicates that the metabolic processes occurring in their bodies also do not exceed normative values. Slight increase in the level of transaminase enzymes suggests the maintenance of homeostasis against relatively challenging environmental conditions. However, the reduced phosphorus content and lower limits of normal potassium dictate the need for adjustment of the mineral nutrition of the young animals.

Furthermore, it has been established that the gender of the animals influences the blood serum bactericidal activity against the studied test cultures, increasing this indicator in the gimmers. Among the rams, the highest BSBA values were recorded against *S. aureus*, while the growth of *E. coli* is suppressed to a lesser extent, which under specific conditions can lead to digestive problems and the processing of food bolus in the intestines. Additionally, both male and female animals exhibited satisfactory skin conditions, which is further confirmed by the high BSBA level against *Staphylococcus aureus*.

СПИСОК ЛИТЕРАТУРЫ

1. *Катков К.А., Скорых Л.Н., Ефимова Н.И., Копылов И.А.* Использование комплексного показателя продуктивности для оценки генетического потенциала овец разных генотипов // Вестник аграрной науки. 2021. № 5 (92). С. 49–58. DOI: 10.17238/issn2587-666X.2021.5.49.
2. *Хамируев Т.Н., Базарон Б.С., Дашинимаев С.М.* Эколого-физиологические механизмы адаптации молодняка овец в условиях Забайкалья // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 3. С. 61–70. DOI: 10.26898/0370-8799-2022-3-7.
3. *Хамируев Т.Н., Волков И.В., Базарон Б.З.* Продуктивные и племенные качества овец агинской породы зугалайского типа // Сибирский вестник сельскохозяйственной науки. 2019. Т. 49. № 3. С. 62–69. DOI: 10.26898/0370-8799-2019-3-8.
4. *Новгородова И.П., Иолчиев Б.С., Прытков Ю.А.* Сравнительная характеристика биохимических показателей крови молодняка овец в зависимости от породы и возраста // Достижения науки и техники АПК. 2020. Т. 34. № 5. С. 69–72. DOI: 10.24411/0235-2451-2020-10514.
5. *Куликова А.Я.* Динамика морфологических показателей сыворотки и белкового состава крови полутонкорунных пород ягнят молочного периода выращивания // Сборник научных трудов Краснодарского научного центра по зоотехнии и ветеринарии. 2019. Т. 8. № 3. С. 13–18. DOI: 10.34617/1yj2-r139.
6. *Gümüş D., Kalaycı-Yüksek F., Uz G., Bilgin M., Anğ-Küçüker M.* The Possible Effects of Different Hormones on Growth Rate and Ability of Biofilm Formation in Different Types of Microorganisms // Acta Microbiologica Bulgarica. 2018. Vol. 34. Is. 1. P. 47–51.
7. *Агаркова Н.А., Чернобай Е.Н., Ефимова Н.И., Антоненко Т.И., Багамаев Б.М.* Клинические, морфологические и биохимические показатели у овец от внутри- и межлинейного

подбора // Вестник Курской государственной сельскохозяйственной академии. 2019. № 7. С. 130–134.
8. *Еременко В.И., Стасенкова Ю.В.* Показатели естественной резистентности коров, принадлежащих к разным линиям быков // Ученые записки Крымского федерального университета им. В.И. Вернадского. Биология. Химия. 2018. Т. 4 (70). № 2. С. 65–72.
9. *Ефимова Н.И., Шумаенко С.Н., Антоненко Т.И.* Оценка и использование селекционно-генетических параметров в овцеводстве: монография. Ставрополь: Ставрополь-сервис-школа, 2020. 100 с.
10. *Паштецкая А.В., Остапчук П.С., Ильязов Р.Г., Емельянов С.А., Куевда Т.А.* Влияние липосомальной формы антиоксидантов с содержанием органического йода на формирование продуктивных качеств молодняка овец // Овцы, козы, шерстяное дело. 2020. № 1. С. 37–39.
11. *Погодаев В.А., Арилов Н.А., Сергеева Н.В.* Биохимические показатели крови баранчиков породы дорпер в период адаптации к природно-климатическим условиям // Известия Санкт-Петербургского государственного аграрного университета. 2017. № 46. С. 112–116.
12. *Чысыма Р.Б.* Естественная резистентность организма овец, находящихся в зоне с высоким содержанием природной радиации // Известия Международной академии аграрного образования. 2018. № 42-1. С. 74–77.
13. *Кузьменкова С.Н., Самсонович В.А., Ятусевич А.И., Мотузко Н.С.* Особенности обмена веществ у овец различных пород в осенне-зимний период // Ученые записки Витебской государственной академии ветеринарной медицины. 2017. Т. 53. № 1. С. 78–81.
14. *Хитров Н.Б., Роговнева Л.В., Паштецкий В.С.* Изменение засоленности почв и грунтовых вод рисовых систем Присивашской низменности после прекращения орошения // Бюллетень Почвенного института им. В.В. Докучаева. 2020. Вып. 102. С. 70–102. DOI: 10.19047/0136-1694-2020-102-70-102.

REFERENCES

1. Katkov K.A., Skorykh L.N., Efimova N.I., Kopylov I.A. Use of the integrated productivity indicator for the assessment of genetic potential of sheep of different genotypes. *Vestnik agrarnoy nauki = Bulletin of agrarian science*, 2021, no. 5 (92), pp. 49–58. (In Russian). DOI: 10.17238/issn2587-666X.2021.5.49.
2. Khamiruyev T.N., Bazaron B.Z., Dashinimaev S.M. Ecological and physiological mechanisms of adaptation of young sheep in the conditions of Transbaikal. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, no. 52 (3), pp. 61–70. (In Russian). DOI: 10.26898/0370-8799-2022-3-7.
3. Khamiruev T.N., Volkov I.V., Bazaron B.Z. Productive and breeding qualities of the sheep of Aginskaya breed, Zugalai type. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2019, vol. 49, no. 3, pp. 62–69. (In Russian). DOI: 10.26898/0370-8799-2019-3-8.
4. Novgorodova I.P., Iolchiev B.S., Prytkov Yu.A. Comparative characteristics of biochemical parameters of blood of young sheep depending on their breed and age. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2020, vol. 34, no. 5, pp. 69–72. (In Russian). DOI: 10.24411/0235-2451-2020-10514.
5. Kulikova A.Y. Dynamics of morphological indicators of serum and protein blood composition in semi-fine lambs of the milk period of growing. *Sbornik nauchnih trudov Krasnodarskogo nauchnogo centra po zootekhnii i veterinarii = Collection of scientific papers of the Krasnodar Scientific Center for Animal Science and Veterinary Medicine*, 2019, vol. 8, no. 3, pp. 13–18. (In Russian). DOI: 10.34617/1yj2-r139.
6. Gümüş D., Kalaycı-Yüksek F., Uz G., Bilgin M., Anğ-Küçüker M. The Possible Effects of Different Hormones on Growth Rate and Ability of Biofilm Formation in Different Types of Microorganisms. *Acta Microbiologica Bulgarica*, 2018, vol. 34, is.1, pp. 47–51.
7. Agarkova N.A., Chernobay E.N., Efimova N.I., Antonenko T.I., Bagamaev B.M. Clinical, morphological and biochemical indicators of sheep from inside and interline selection. *Vestnik Kurskoy gosudarstvennoy sel'skohozyajstvennoy akademii = Bulletin of the Kursk State Agricultural Academy*, 2019, no. 7, pp. 130–134. (In Russian).
8. Eremenko V.I., Stasenkova Yu.V. Indicators of natural resistance of cows belonging to different lines of the bulls. *Ucheniye zapiski Krymskogo federal'nogo universiteta imeni V.I. Vernadskogo. Biologiya. Himiya = Scientific Notes of V.I. Vernadsky Crimean Federal University. Biology. Chemistry*, 2018, vol. 4 (70), no. 2, pp. 65–72. (In Russian).

9. Efimova N.I., Chumachenko S.N., Antonenko T.I. *Evaluation and use of breeding and genetic parameters in sheep breeding*, Stavropol, 2020, 100 p. (In Russian).
10. Pashtetskaia A.V., Ostapchuk P.S., Ilyazov R.G., Yemelyanov S.A., Kuevda T.A. Influence of liposomal form of antioxidants with organic iodine content on the formation of productive qualities of young sheep. *Ovcy, kozy, sherstyanoye delo = Sheep, goats, wool business*, 2020, no. 1, pp. 37–39. (In Russian).
11. Pogodaev V.A., Arilov A.N., Sergeeva N.V. Biochemical blood parameters in rams of the breed dorper in the period of adaptation to climatic conditions. *Izvestiya Sankt-Peterburgskogo gosudarstvennogo agrarnogo universiteta = Izvestiya Saint-Petersburg State Agrarian University*, 2017, no. 46, pp. 112–116. (In Russian).
12. Chysyma R.B. Natural resistance of the organism of the sheep in the zone with high content of natural radiation. *Izvestiya Mezhdunarodnoy akademii agrarnogo obrazovaniya = Proceedings of the International Academy of Agrarian Education*, 2018, no. 42–1, pp. 74–77. (In Russian).
13. Kuzmenkova S.N., Samsonovich V.A., Yatusevich A.I., Motuzko N.S. Features of metabolism in sheep of various breeds in the autumn-winter period. *Ucheniye zapiski Vitebskoy gosudarstvennoy akademii veterinarnoy medicine = Transactions of the educational establishment "Vitebsk the Order of "the Badge of Honor" State Academy of Veterinary Medicine*, 2017. vol. 53, no. 1, pp. 78–81. (In Russian).
14. Khitrov N.B., Rogovneva L.V., Pashtetskiy V.S. Changes of soil salinity and ground waters at the rice systems in Sivash lowland after irrigation cease. *Byulleten' Pochvennogo instituta imeni V.V. Dokuchaeva = Dokuchaev Soil Bulletin*, 2020, is. 102, pp. 70–102. (In Russian). DOI: 10.19047/0136- 1694-2020-102-70-102.

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Дата поступления статьи / Received by the editors 29.12.2022
Дата принятия к публикации / Accepted for publication 16.03.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-11
УДК: 636.5.084
Тип статьи: оригинальная
Type of article: original

ФУНКЦИОНАЛЬНАЯ ДОБАВКА НА ОСНОВЕ ПРИРОДНОГО ПРЕМИКСА В РАЦИОНЕ ПЕРЕПЕЛОВ

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Представлены результаты эксперимента по использованию в рационе перепелов функциональной добавки на основе природного органоминерального комплекса (сапропеля), обогащенного отрубями пшеничными, хвойной мукой, скорлупой кедрового ореха и ферментным препаратом Фитбест WP. Эксперимент длительностью 60 дней проведен по стандартной методике на перепелах японской породы. Для эксперимента две аналогичные группы по 60 гол. (одна контрольная и одна опытная) сформированы в суточном возрасте птицы. Обе группы получали основной комбикорм, соответствующий физиологическим особенностям и возрасту перепелов. В рационе молодняка опытной группы 10% массы пшеницы заменили функциональной добавкой, состоящей из сапропеля (50%), отрубей пшеничных (20%), хвойной муки (15%) и скорлупы кедрового ореха (15%), обогащенных ферментным препаратом Фитбест WP (100 г/т комбикорма), предназначенным для повышения усвояемости фитатного фосфора. Птицу содержали в клеточной батарее при соблюдении требуемых условий микроклимата. Изучено влияние скармливания экспериментальной добавки на следующие показатели цыплят перепелов: сохранность, среднесуточный прирост живой массы, мясную продуктивность и качество мяса, биохимический состав крови. Введение в комбикорм перепелов функциональной добавки на основе природного премикса (сапропеля) повысило сохранность птицы на 2,00%, прирост живой массы на 6,97% при отсутствии существенных различий в расходе комбикорма на единицу продукции. В мясе птицы, потреблявшей функциональную добавку, увеличилось содержание сухого вещества на 0,85%, золы на 0,61%, кальция и фосфора в 1,05 и 1,30 раза ($p < 0,05$). Межгрупповые различия по содержанию белка, как и жира, незначительны. Гематологические показатели цыплят перепелов в подопытных группах соответствовали физиологической норме.

Ключевые слова: перепела, комбикорм, сапропель, отруби пшеничные, хвойная мука, скорлупа кедрового ореха, препарат Фитбест WP, сохранность, живая масса

FUNCTIONAL ADDITIVE BASED ON NATURAL PREMIX IN THE DIET OF QUAILS

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The results of the experiment on the use of functional additive in the diet of growing quails on the basis of natural organomineral complex (sapropel) enriched with wheat bran, coniferous flour, pine nut shells and enzyme preparation Fitbest WP are presented. The experiment lasting 60 days was conducted according to the standard methodology on Japanese quails. For the experiment, two similar groups of 60 birds each (one control and one experimental group) were formed at one day of age. Both groups received basic mixed fodder corresponding to the physiological characteristics and age of the quails. In the ration of young animals of the experimental group 10% of the wheat mass was replaced by a functional additive consisting of sapropel (50%), wheat bran (20%), coniferous flour (15%) and pine nutshells (15%), enriched with the enzyme preparation Fitbest WP (100 g/t mixed fodder) designed to increase the absorption of phytate phosphorus. The birds were kept in a cage battery under

the required microclimate conditions. The effect of feeding the experimental additive on the following indicators of quail chickens was studied: safety, average daily gain of live weight, meat productivity and meat quality, biochemical composition of blood. Introduction of the functional additive on the basis of natural premix (sapropel) into the mixed fodder of quails increased the safety of birds by 2.00%, live weight gain by 6.97% with no significant differences in the consumption of mixed fodder per unit production. The meat of the poultry that consumed the functional additive increased the dry matter content by 0.85%, ash by 0.61%, calcium and phosphorus by 1.05 and 1.30 times ($p < 0.05$). Intergroup differences in protein content and fat content were insignificant. Hematological parameters of quail chickens in the experimental groups corresponded to the physiological norm.

Keywords: quail, compound feed, sapropel, wheat bran, coniferous flour, pine nut shell, Fitbest WP preparation, preservation, live weight

Для цитирования: *Рогачёв В.А., Мерзлякова О.Г., Чегодаев В.Г., Пилипенко Н.И., Магер С.Н.* Функциональная добавка на основе природного премикса в рационе перепелов // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 90–96. https://doi.org/10.26898/0370-8799-2023-5-11

For citation: Rogachev V.A., Merzlyakova O.G., Chegodaev V.G., Pilipenko N.I., Mager S.N. Functional additive based on natural premix in the diet of quails. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2023, vol. 53, no. 5, pp. 90–96. https://doi.org/10.26898/0370-8799-2023-5-11

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

In the organization of proper feeding for livestock, rations enriched with various balancing additives (either synthetic or biogenic) are utilized. Among effective organomineral premixes in this regard, sapropels are considered unique natural bottom sediment deposits of freshwater reservoirs, containing 10–60% of organic and biologically active substances [1]. These renewable natural resources represent advanced organomineral complexes formed by microbiological, biochemical, and physical processes. Sapropels are formed under complex anaerobic conditions from the products of phyto- and zooplankton degradation, as well as from flora and fauna of higher orders and mineral compounds brought to the water surface. Overall, the composition and properties of lake deposits are determined by natural geographic conditions of the region: climate, geological, geomorphological, hydrological factors, vegetation characteristics, and human activities [2]. Sapropels contain bitumoids, a carbohydrate complex, natural antibiotics, growth stimulants and hormones, minerals, enzymes, lignin humus, carotenoids, and other compounds that facilitate more efficient utilization of feed nutrients. The microelement composition of sapropels is linked to the geological structure of the area, soil runoff composition in water bodies, and the composition of hydrobionts, which form organic matter in lake deposits after their demise. The accumulation of microelements on geochemical and biogeochemical barriers, developed in lakes over hundreds and thousands of years of existence, is crucial. Various physico-chemical and biochemical transformations of substances continuously take place in water and lake bottom deposits [1, 3–5]. The protein content in sapropel ranges from 6.5% to 9.7%, calcium from 3.5% to 8.3%, phosphorus from 0.2% to 0.3%, asparagine and glutamic acid at 10.8% and 8.8% g/kg of dry matter, respectively [6].

The positive impact of sapropel on the metabolism and productivity of animals is influenced by several factors, including the activation of digestive enzymes and the improvement of the chemical composition of chyme due to minerals present in easily absorbable forms. The introduction of the feed additive "Sapropel" into the quail ration increased live weight gain by 6.0% at 70 days of age, dressed carcass weight by 9.9%, and total muscle mass by 4.1% [7]. Adding sapropel to the ration of dairy cows at the rate of 1.2 kg/head per day increased milk productivity by 10.3–11.7% and milk fat content by

0.03–0.04% [8]. The inclusion of dried bottom sediment-based feed additive in the amount of 3.0% of the feed mass in the composition of the feed for laying hens increased the productivity of young birds by 4.5% [9]. Sapropel is characterized by high ion exchange and catalytic properties, which adds to its positive attributes. The diverse components of sapropel contribute to its high multifactor biological activity and wide application as a basis for developing functional additives for various types of livestock [10, 11]. As additional ingredients for additives based on sapropel, it is advisable to use wheat bran (rich in phosphorus and B-group vitamins), pine flour (an auxiliary source of minerals and vitamins), pine nut shells (a source of biologically active substances), and the preparation Fitbest WP (enzyme complex to enhance digestibility of compound feeds and phytate phosphorus).

The purpose of the research is to assess the feasibility of using a functional feed additive based on a natural organomineral complex (sapropel) enriched with wheat bran, pine flour, pine nut shells, and the enzyme preparation Fitbest WP in the quail feed for birds raised up to 60 days old.

The experiment's task is to determine the effect of feeding quails with the functional additive on their survival rate, average daily weight gain, feed conversion ratio, meat productivity, meat quality, and hematological indicators.

MATERIAL AND METHODS

A 60-day experiment was conducted using a standard protocol in 2022 at the quail farm of the Physiological Courtyard of the Siberian Research and Technological Design Institute of Animal Husbandry, part of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SibNIPTIzh SFSCA RAS). The experiment involved Japanese quails, hatched and grouped at the age of one day, which were divided into two analogous groups (control and experimental) of 60 birds each[1] (see Table 1).

The birds were kept in cage batteries under required microclimate conditions (temperature ranging from 20 to 22 °C, humidity 60–70%). The quails in the experiment were provided with identical basic compound feed, tailored to their physiological traits and age. The difference between the groups was as follows: the control group received only the basic compound feed, while the quails in the experimental group consumed a compound feed in which 10% of the wheat mass was replaced with a functional additive based on a natural organomineral complex (sapropel) enriched with wheat bran, pine flour, pine nut shells, and the enzyme preparation Fitbest WP.

The rations were formulated according to the standards of the All-Russian Research and Technological Poultry Institute RAS[2,3]. The compound feeds contained the required amount of metabolic energy and essential nutrients. In the first 5 days of life, the chicks were additionally fed boiled quail eggs along with the compound feed to enhance their adaptation to the external environment. Feed intake was recorded daily by weighing the provided feed and the remains. Daily observations were made on the behavior and health of the quails. Weighing of the birds

Табл. 1. Схема опыта
Table 1. Scheme of the experiment

Group	Number of heads	Feeding conditions
Control	60	BD (basic diet – mixed fodder)
Experimental	60	BD in which 10% of wheat weight was replaced by a functional additive consisting of sapropel (50%), wheat bran (20%), pine flour (15%), pine nut shell (15%) enriched with enzyme preparation Fitbest WP (100 g/t of mixed fodder)

[1]Methodology of scientific and production research on poultry feeding / edited by V.I. Fisinin and Sh.A. Imangulov. Sergiev Posad, 2000. 33 p.

[2]Recommendations on feeding poultry / edited by V.I. Fisinin and Sh.A. Imangulov, I.A. Egorov, T.M. Okolelova. Sergiev Posad, 2003. 142 p.

[2]Recommendations on feeding poultry / edited by V.I. Fisinin and Sh.A. Imangulov, I.A. Egorov, T.M. Okolelova. Sergiev Posad, 2003. 142 p.

was carried out at the start of the experiment, at 30 days of age, and at 2 months of age at the end of the rearing period. At the age of 60 days, cockerels were slaughtered, with 3 birds selected from each group based on average live weight (see footnote 3). The chemical composition of the compound feed, functional additive, and quail cockerel meat was analyzed in the biochemical laboratory of SibNIPTIzh SFSCA RAS using standard methods of zootechnical analysis. The biochemical composition of quail (cockerel) blood was determined in the biotechnology laboratory of the Institute of Experimental Veterinary Science of Siberia and the Far East SFSCA RAS. The digital data obtained from the experiment were processed using variation statistics on a personal computer using Microsoft Office Excel.

RESULTS AND DISCUSSION

The quail compound feed was formulated taking into account their age and in accordance with the primary requirements for this type of birds: optimal grinding degree, high caloric content, and balanced composition (see Table 2). The compound feed was administered based on the feed intake.

The functional feed additive based on sapropel contained 5.72 MJ/kg of metabolizable energy and 3.03% digestible protein (see Table 3).

In terms of energy content (MJ of metabolizable energy), the main compound feed and the compound feed containing the functional additive were practically equal (difference of 0.78%).

It was found that feeding chicks with compound feed in which 10% of the wheat mass was replaced by the functional additive had a positive effect on the survival and growth rate of the birds (see Table 4).

The survival rate of the chicks in the experimental group increased by 2.00% compared to the control, and the average daily live weight gain increased by 6.97% ($p > 0.05$), with no significant differences in feed consumption per unit of production (intergroup difference of 1.65%). The consumption of compound feed by the quails in the experimental group increased by 8.58% over the 60-day experiment compared to the control counterparts.

Табл. 2. Структура и питательность комбикормов для перепелов

Table 2. Structure and nutritional value of compound feeds for quails

Component	Age, days	
	0–30	30–60
Structure, %		
Forage wheat	60,0	58,0
Extruded soybeans	10,0	10,0
Sunflower oil cake	10,0	10,0
Meat and bone flour	5,0	10,0
Fish flour	5,0	–
Forage yeast	5,0	5,0
Premix	1,0	1,0
Forage chalk	2,0	2,0
Tricalcium phosphate	2,0	2,0
Shell	–	2,0
100 g of mixed fodder contains		
Exchangeable energy, MJ	1,27	1,07
Crude protein, g	22,1	22,8
Digestible protein, g	18,60	19,40
Crude fat, g	11,80	5,00
Crude fiber, g	3,00	2,90
NFES, g	47,00	45,40
Starch, g	31,30	30,30
Sugars, g	2,20	2,19
Calcium, g	1,58	1,66
Phosphorus, g	1,18	1,07

Based on the results of the slaughter, it was determined that the dressed carcass weight in the experimental group was higher than in the control by 9.09% ($p > 0.05$) (see Table 5). The differences between the groups in terms of slaughter yield were insignificant, with a variation of 1.76%.

The inclusion of the functional additive in the compound feed had an impact on the chemical composition of the quail meat (see Table 6). The experimental group exhibited higher concentrations of dry matter in the meat by 0.85%, ash by 0.61%, calcium, and phosphorus by 1.05 and 1.30 times, respectively ($p < 0.05$). Intergroup differences in protein and fat content were not substantial.

No significant differences were observed between the groups in terms of the amino acid bal-

Табл. 3. Питательность и химический состав функциональной добавки на основе сапропеля

Table 3. Nutritional value and chemical composition of a functional sapropel-based supplement

Indicator	Actual value
Exchangeable energy, MJ/kg	5,72
Dry matter, %	90,29
Crude protein, %	3,48
Digestible protein, %	3,03
Crude fat, %	1,74
Crude ash, %	34,88
Crude fiber, %	27,0
NFES, %	23,19
Calcium, %	4,26
Phosphorus, %	0,28

Табл. 4. Сохранность, прирост живой массы цыплят-перепелов и расход корма на 1 кг прироста

Table 4. Safety, live weight gain of quail chickens and feed consumption per 1 kg of gain

Indicator	Group	
	control	experimental
Mortality, %	81	83
Live weight, g:		
at the beginning of the experiment	8,63 ± 0,11	8,58 ± 0,10
at the age of 30 days	62,47 ± 1,51	71,27 ± 1,92
at the age of 60 days	155,12 ± 2,03	164,98 ± 2,48
Live weight gain for 60 days, g:		
absolute	146,49 ± 1,92	156,40 ± 2,35
daily average	2,44 ± 0,03	2,61 ± 0,04
Feed consumption for 60 days per 1 head, kg	0,886	0,962
Feed costs per 1 kg of gain, g	6,05	6,15

ance of quail meat. The amino acid indices of the meat from the control and experimental groups were identical (difference of 1.72%).

The results of the biochemical blood tests conducted on the quails in the experimental groups showed that all chicks were healthy (see Table 7).

There was an increase in total protein by 5.57%, albumin-globulin ratio by 12.21% ($p < 0.05$), and calcium by 21.43% ($p < 0.05$) in the blood of the quails from the experimental group. Other indicators of the biochemical blood composition remained within the physiological norm.

Табл. 5. Результаты контрольного убоя подопытной птицы

Table 5. Results of control slaughter of the experimental poultry

Indicator	Group	
	control	experimental
Preslaughter live weight, g	155,0 ± 2,19	165,0 ± 3,21
Weight of gutted carcass, g	110,0 ± 2,60	120,0 ± 2,91
Slaughter yield, %	70,97 ± 0,85	72,73 ± 0,33

Табл. 6. Химический и аминокислотный состав мяса перепелов, %

Table 6. Chemical and amino acid composition of quail chickens meat, %

Indicator	Group	
	control	experimental
Preslaughter live weight, g	155,0 ± 2,19	165,0 ± 3,21
Weight of gutted carcass, g	110,0 ± 2,60	120,0 ± 2,91
Slaughter yield, %	70,97 ± 0,85	72,73 ± 0,33
Ash	3,26 ± 0,08	3,87 ± 0,05
Calcium	0,894 ± 0,005	0,942 ± 0,004
Phosphorus	0,148 ± 0,006	0,192 ± 0,005
Amino acids:		
sum of essential amino acids (arginine, valine, histidine, lysine, leucine, isoleucine, tryptophan, threonine, tyrosine, phenylalanine, methionine, cystine)	10,285	9,844
sum of non-essential amino acids (alanine, asparagine, glycine, glutamine, proline, serine)	9,331	8,782
amino acid index	1,102	1,121

CONCLUSIONS

1. A recipe for a functional feed additive for quails based on a natural organomineral complex (sapropel) has been developed. The composition of the additive includes: sapropel 50%, wheat bran 20%, pine flour 15%, cedar nut shell 15%, enzymatic preparation Fitbest WP (0.1 g/

Табл. 7. Биохимические показатели крови цыплят перепелов

Table 7. Biochemical blood parameters of quail chickens

Indicator	Group	
	control	experimental
Total protein, g/l	35,91 ± 1,13	37,91 ± 0,52
Albumin, g/l	16,46 ± 0,74	18,47 ± 0,60
Globulin, g / l	19,54 ± 0,82	20,44 ± 0,59
Albumin/globulin ratio	0,84 ± 0,07	0,90 ± 0,02
Triglycerides, μmol/l	1,87 ± 0,04	1,91 ± 0,02
Uric acid, μmol/l	166,31 ± 5,52	171,85 ± 5,52
Phosphorus, mmol/l	2,26 ± 0,05	2,33 ± 0,24
Calcium, mmol/l	1,82 ± 0,07	2,21 ± 0,10
AST, u/l	192,71 ± 4,47	190,61 ± 2,87
ALT, u/l	14,57 ± 1,21	14,58 ± 1,45
Direct bilirubin, μmol/l	0,23 ± 0,04	0,23 ± 0,07
Creatinine, μmol/l	25,98 ± 3,56	26,28 ± 3,56

kg of compound feed).

2. Feeding quails with compound feed during the rearing period (age 1-60 days), in which 10% of the wheat grain is replaced with the functional additive, had a positive impact on certain zootechnical indicators. The survival rate of the chicks in the experimental group increased by 2.00% compared to the control counterparts, and the average daily live weight gain increased by 6.97% ($p > 0.05$), with a negligible difference (1.65%) in feed consumption per unit of production. The dressed carcass weight of the chicks in the experimental group was higher by 9.09% compared to the control group ($p > 0.05$).

3. The meat of the quails in the experimental group contained more dry matter by 0.85%, ash by 0.61%, calcium, and phosphorus by 1.05 and 1.30 times, respectively, compared to the control counterparts ($p < 0.05$). Intergroup differences in protein and fat content were not substantial. The biochemical blood parameters of the chicks in the experimental groups were within the physiological norm.

СПИСОК ЛИТЕРАТУРЫ

1. *Мостович Е.А.* Состояние и перспективы использования и добычи сапропеля // Московский экономический журнал. 2020. № 8. С. 116–125.
2. *Титова В.И., Баранов А.И., Белоусова Е.Г.* Использование сапропеля при выращивании кукурузы на серых лесных почвах Нижегородской области // Агрохимия. 2019. № 1. С. 36–41.
3. *Успенская О.Н., Васючков И.Ю.* Микроэлементы в сапропелях – природном материале на удобрение для органического земледелия // Агрохимия. 2019. № 10. С. 52–57.
4. *Дроздов И.А., Беленков А.И., Васильев А.С., Голубев В.В., Никифоров М.В.* Влияние различных видов и доз сапропеля на содержание и состав органического вещества в дерново-подзолистой почве // Агрохимический вестник. 2019. № 1. С. 20–24.
5. *Шпынова С.А., Ядрищенская О.А., Басова Е.Е., Гирло Г.А.* Влияние сапропеля на продуктивность перепелов // Эффективное животноводство. 2019. № 3. С. 74–75.
6. *Аржанкова Ю.В., Лисица П.В., Васина А.Ю., Кириллова Е.В.* Перспективы использования сапропеля в птицеводстве // Известия Великолукской ГСХА. 2019. № 1. С. 7–12.
7. *Редькин С.В., Колоезд А.Л.* Ветеринарно-санитарная экспертиза перепелиного мяса и яйца при использовании кормовой добавки «Сапропель» // Молодой учёный. 2021. № 4 (346). С. 126–129.
8. *Панкратов В.В., Черноградская Н.М., Степанова С.И., Григорьев М.Ф., Григорьева А.И.* Научное обоснование использования местных нетрадиционных кормовых добавок в животноводстве Якутии // Ветеринария, зоотехния и биотехнология. 2019. № 1. С. 94–101.
9. *Кононеко С.И., Юрина Н.А., Максим Е.А.* Природная кормовая добавка для ремонтного молодняка кур-несушек // Зоотехническая наука Беларуси. 2018. Т. 53. № 2. С. 41–49.
10. *Baranova G., Girlo G., Basova E., Selina T., Shpynova S., Yadrishchenskaya O.* Sapropel in compound feeds for quails // Compound feed. 2018. N 9. P. 71–73.
11. Shpynova S.A., Selina T.V., Yadrishchenskaya O.A., Basova E.A., Girlo G.A. The influence of sapropel on the productivity of quails // Efficient animal husbandry. 2019. N 3. P. 74–75.

REFERENCES

1. Mostovich E.A. Status and prospects of sapropel use and production. *Moskovsky ekonomichesky*

zhurnal = Moscow Economic Journal, 2020, no. 8, pp. 116–125. (In Russian).
2. Titova V.I., Baranov A.I., Belousova E.G. Assessment of sapropel application for corn cultivation on gray forest soils of the Nizhny Novgorod region. *Agrokhimiya = Agricultural Chemistry*, 2019, no. 1, pp. 36–41. (In Russian).
3. Uspenskaya O.N., Vasyuchkov I.Yu. Trace elements in sapropels – natural material for fertilizer for organic farming. *Agrokhimiya = Agricultural Chemistry*, 2019, no. 10, pp. 52–57. (In Russian).
4. Drozdov I.A., Belenkov A.I., Vasil'ev A.S., Golubev V.V., Nikiforov M.V. Influence of different types and doses of sapropel on organic matter content in soddy-podzolic soil. *Agrokhimicheskii vestnik = Agrochemical Bulletin*, 2019, no. 1, pp. 20–24. (In Russian).
5. Shpynova S.A., Yadrishchenskaya O.A., Basova E.E., Girlo G.A. The influence of sapropel on the productivity of quails. *Effektivnoe zhivotnovodstvo = Efficient Animal Husbandry*, 2019, no. 3. pp. 74–75. (In Russian).
6. Arzhankova Yu.V., Lisitsa P.V., Vasina A.Yu., Kirillova E.V. Prospects for the use of sapropel in poultry farming. *Izvestiya Velikolukskoi GSKhA = Izvestiya of Velikiye Luki State Agricultural Academy*, 2019, no. 1, pp. 7–12. (In Russian).
7. Red'kin S.V., Koloezd A.L. Veterinary and sanitary examination of quail meat and eggs when using the feed additive "Sapropel". *Molodoi uchenyi = Young scientist,* 2021, no. 4 (346), pp. 126–129. (In Russian).
8. Pankratov V.V., Chernogradskaya N.M., Stepanova S.I., Grigor'ev M.F., Grigor'eva A.I. Scientific substantiation of the use of local non-traditional feed additives in animal husbandry of Yakutia. *Veterinariya, zootekhniya i biotekhnologiya = Veterinary, Zootechnics and Biotechnology*, 2019, no. 1, pp. 94–101. (In Russian).
9. Kononeko S.I., Yurina N.A., Maksim E.A. Natural feed additive for the repair of laying hens. *Zootekhnicheskaya nauka Belarusi = Zootechnical Science of Belarus*, 2018, vol. 53, no. 2, pp. 41–49. (In Russian).
10. Baranova G., Girlo G., Basova E., Selina T., Shpynova S., Yadrishchenskaya O. Sapropel in compound feeds for quails. *Compound feed*, 2018, no. 9, pp. 71–73. (In Russian).
11. Shpynova S.A., Selina T.V., Yadrishchenskaya O.A., Basova E.A., Girlo G.A. The influence of sapropel on the productivity of quails. Efficient animal husbandry, 2019, no. 3, pp. 74–75. (In Russian).

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Дата поступления статьи / Received by the editors 13.03.2023
Дата принятия к публикации / Accepted for publication 12.05.2023
Дата публикации / Published 20.06.2023

https://doi.org/10.26898/0370-8799-2023-5-12
УДК: 636.082.11:616.1:637.054:637.051
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ ЖИРА СВИНЕЙ РАЗНОГО ХИМИЧЕСКОГО СОСТАВА В РАЦИОНЕ ПЕРЕПЕЛОК НА ПРОДУКТИВНОСТЬ И БИОХИМИЧЕСКИЙ СОСТАВ ТКАНЕЙ

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Представлены результаты исследований перепелок, находящихся на рационах с использованием в кормовых добавках подкожного жира свиней, разводимых в Сибири, различных по морфологическому, химическому составу, а также органолептическим качествам. Изучены следующие показатели: интенсивность роста, жизнеспособность, яйценоскость, биохимические особенностям крови (триглицериды, общий холестерин, липопротеины высокой плотности, липопротеины низкой плотности, атерогенный индекс, уровень свободнорадикального окисления и антиоксидантов). Исследованы породы: кемеровская (К) и пьетрен (П) – и их жир. У породы К толщина сала составила 35,1 мм, у породы П – 21,1 мм, насыщенных жирных кислот в жире было соответственно 41,56 и 38,28%, полиненасыщенных жирных кислот (ПНЖК) 15,18 и 19,42%, линолевой кислоты 15,08 и 19,22%, холестерина 0,16 и 0,26%. Органолептические качества сала составили соответственно 3,9 и 2,4 балла. Жир этих пород свиней, а также подсолнечное масло (контроль) добавляли в корм цыплятам перепелок трех групп по 60 особей в каждой до 23-недельного возраста (3,0–3,5% от массы рациона). Перепелки, получавшие жир породы К, быстрее росли, у них была выше яйценоскость и средняя масса яйца. У перепелок, получавших жир породы П, содержащий высокий уровень общего холестерина, богатый ПНЖК и линолевой кислотой, в сыворотке крови оказалось значительно больше липопротеинов низкой плотности (44,9 ± 9,01 мг/дл против 29,0 ± 5,51 в группе К и 28,6 ± 4,81 мг/дл в контроле), выше перекисное окисление липидов и самый высокий атерогенный индекс. Полученные данные свидетельствуют о том, что жир породы К более полезен для питания животных, чем жир свиней породы П, и может быть приоритетным в питании человека. Это дает основу для проверки и подтверждения полученных результатов на людях, а также для селекции свиней в направлении улучшения жирно-кислотного состава мяса и сала в сторону увеличения концентрации насыщенных жирных кислот.

Ключевые слова: сало, порода, перепелки, интенсивность роста, НЖК, холестерин, атерогенный индекс

INFLUENCE OF PIG FAT OF DIFFERENT CHEMICAL COMPOSITION IN THE DIET OF QUAILS ON THE PRODUCTIVITY AND BIOCHEMICAL COMPOSITION OF TISSUES

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The results of the studies of quails kept on diets using subcutaneous fat of pigs bred in Siberia in feed additives, different in morphological, chemical composition, as well as organoleptic qualities, are presented. The following parameters were studied: growth rate, viability, egg laying rate, biochemical blood characteristics (triglycerides, total cholesterol, high-density lipoproteins, low-density lipoproteins, atherogenic index, free radical oxidation and antioxidants levels). The following breeds were studied: Kemerovo (K) and Pietrain (P) and their fat. In breed K, the fat thickness was 35.1 mm; in breed P, 21.1 mm, saturated fatty acids (SFA) in fat were 41.56 and 38.28%, respectively, polyunsaturated fatty acids (PUFA) - 15.18 and 19.42%, linoleic acid 15.08 and 19.22%, cholesterol 0.16 and 0.26%. The organoleptic qualities of the fat were 3.9 and 2.4 points, respectively. The fat of these pig breeds, as well as sunflower oil (control), was added to the feed of quail chickens of three groups of 60 individuals each up to 23 weeks of age (3.0 - 3.5% of the weight of the diet). The quails that received K-breed fat grew faster, they had higher egg production, and the average egg weight. In the quails treated with fat of breed P containing a high level of total cholesterol, rich in PUFA and linoleic acid, there were significantly more low-density lipoproteins in the blood serum (44.9 ± 9.01mg / dl versus 29.0 ± 5.51 in group K and 28.6 ± 4.81 in the control), higher peroxidation lipids and the highest atherogenic index. The data obtained indicate that the fat of breed K is more useful for animal nutrition than the fat of pigs of breed P and may be a priority in human nutrition. This provides the basis for testing and confirming the results obtained in humans, as well as for pig breeding in the direction of improving the fatty acid composition of meat and fat in the direction of increasing the concentration of saturated fatty acids.

Keywords: fat, breed, quails, growth rate, SFA, cholesterol, atherogenic index

Для цитирования: *Бекенёв В.А., Аришин А.А., Каштанова Е.В., Полонская Я.В., Мерзлякова О.Г., Чегодаев В.Г., Бекенева К.А.* Влияние жира свиней разного химического состава в рационе перепелок на продуктивность и биохимический состав тканей // Сибирский вестник сельскохозяйственной науки. 2023. Т. 53. № 5. С. 97–108. https://doi.org/10.26898/0370-8799-2023-5-12

For citation: Bekenev V.A., Arishin A.A., Kashtanova E.V., Polonskaya Ya.V., Merzlyakova O.G., Chegodaev V.G., Bekeneva K.A. Influence of pig fat of different chemical composition in the diet of quails on productivity and biochemical composition of tissues. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2023, vol. 53, no. 5, pp. 97–108. https://doi.org/10.26898/0370-8799-2023-5-12

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

Благодарность
Работа выполнена в рамках бюджетных тем по Государственным заданиям: № 0533-2021-0014; № 122031700094-5.
Acknowledgments
The work was carried out within the framework of budget topics under the State assignments: No. 0533-2021-0014; No. 122031700094-5.

INTRODUCTION

Improving the population's nutrition with meat products is a crucial global issue, encompassing not only quantity but also quality considerations. These quality aspects are influenced by diverse factors such as animal species, breeds, feed composition, husbandry conditions, genetic traits, growth intensity, and more. Swine of different breeds vary significantly in carcass fat content, organoleptic properties, biological value, chemical composition, and particularly in terms of fatty acids [1].

However, delineating breed differences in fat quality does not address the impact of products with varying fat and cholesterol compositions on human health. According to researchers, a closer integration between agricultural sciences and human nutrition science is necessary, as there is

a close interplay between dietary intake and the pathogenesis of various prevalent diseases[1].

Therefore, the following measures are necessary to obtain high quality meat products with optimal nutrient content. Firstly, a detailed investigation into cholesterol levels, fatty acids in meat and lard, oxidative traits of blood from the most distinct swine breeds and hybrids is necessary. Secondly, trials involving lard from swine breeds with significantly differing fatty acid compositions and cholesterol levels should be conducted for both animal feeding and human nutrition. Currently, our knowledge is insufficient about the optimal levels and types of fatty acids and antioxidants for human nutrition and health maintenance [2-5]. According to research, chicks are a suitable animal model for studying atherosclerosis in humans, as their plasma cholesterol levels and high-density and low-density lipoproteins are comparable. The advantage lies in the fact that chickens are omnivorous and can develop spontaneous atherosclerosis akin to humans [6]. Some scientists suggest that birds are akin to physically active humans in terms of energy metabolism and exhibit similar characteristics to humans in terms of free radical generation by mitochondria during fatty acid breakdown [7].

The purpose of the research is to determine the influence of introducing subcutaneous lard from swine with differing carcass compositions, particularly fatty acid profiles, into animal feed supplements; to investigate the impact on viability, productivity, tissue biochemical composition of poultry, followed by interpreting results for potential use of lard in human nutrition.

The research objectives are to identify the differences among quails on diets with varying sources of pork fat and vegetable oil, concerning growth intensity, viability, egg production, blood biochemical traits: triglycerides (TG), total cholesterol (TC), high-density lipoproteins (HDL), low-density lipoproteins (LDL), atherogenic index, levels of free radical oxidation, and antioxidants.

MATERIAL AND METHODS

To obtain swine meat that is most beneficial for public health and for subsequent targeted animal breeding, an assessment of carcass quality, physico-chemical properties of subcutaneous fat, meat, organoleptic attributes, and blood biochemical composition of five swine breeds was conducted. These breeds were maintained under similar feeding and husbandry conditions at the “Chistogorsky” large industrial complex in the Kemerovo region.

Previously, an evaluation of finishing and meat qualities of several swine breeds – Kemerovo (K), Large White (LW), Landrace (L), Pietrain (P), and Duroc (D) – was carried out. These breeds were provided identical feeds simultaneously. For analysis, five carcasses from each breed with a live weight of 95–100 kg at slaughter were used [8].

Two significantly differing breeds in slaughter traits, subcutaneous fat (lard) quality, fatty acid composition, and cholesterol levels – K and P – were chosen for introducing their lard into the diets of quails used as a model object in the experiment.

For dietary quality investigations of subcutaneous fat, three groups of randomly selected quail chicks (60 birds per group) were formed immediately after hatching (see Table 1). The housing conditions adhered to zootechnical recommendations. Quails in Group 1 were administered sunflower oil, Group 2 received subcutaneous fat from K breed swine, and Group 3 received subcutaneous fat from P breed swine. The sunflower oil used had the following fatty acid composition (%): palmitoleic acid C 16:1 – 0.1, palmitic acid C 16:0 – 6.2, linolenic acid C 18:3 – 0.1, linoleic acid C 18:2 – 68.1, oleic acid C 18:1 – 19.5, stearic acid C 18:0 – 4.4, gondoic acid 20:1 – 0.2, arachidic acid 20:0 – 0.4, behenic acid 22:0 – 0.7, erucic acid C 22:1 – 0.1, lignoceric acid C 24:0 – 0.2. The fatty acid composition, cholesterol content of swine subcutaneous fat, and fatty acids of sunflower oil were determined through lipid extraction using

[1]*Christophersen O.A. and Haug A*. Animal products, diseases and drugs: a plea for better integration between agricultural sciences, human nutrition and human pharmacology // Lipids in Health and Disease. 2011. vol. 10. p. 16. DOI: 10.1186/1476-511X-10-16.

Табл. 1. Схема опыта

Table 1. Scheme of the experiment

Group	Number of animals, heads	Feeding conditions
1 (control)	60	BD + vegetable oil
2 (experimental)	60	BD + K breed subcutaneous fat
3 (experimental)	60	BD + P breed subcutaneous fat

Note. BD– basic diet balanced according to VNIITIP norms[2].

the chloroform/methanol method according to Folch, 1957. The purity of lipids was confirmed and separated through flash chromatography. Analysis of the fatty acid composition of muscle tissue and adipose tissue was performed using a gas chromatograph HP 6890 (Hewlett Packard, Germany).

The quail feed was prepared in accordance with the primary requirements: balance, high caloric content, and the necessary degree of grinding (see footnote 2). The composition and nutritional content of the quail feed, meeting the standards, are presented in Table 2.

The experiment was conducted according to the widely accepted methodology. The structure and nutritional content of the quail feed adhered to the norms[3].

The growth rate of the quails, their egg production, and egg mass were studied. Blood serum analysis for total cholesterol, HDL and LDL cholesterol, triglycerides, total protein, albumin, glucose, antioxidants, lipid peroxidation products (LP) levels in LDL, and LDL oxidative resistance was performed on 10 birds from each group, slaughtered at 8 and 23 weeks of age. Determination of the antioxidant activity of the blood serum was conducted using the FORM Plus 3000 analyzer (Italy) with the Callegari 1930 kits for FORD (Free Oxygen Radicals Defence) determination (Italy), following the kit instructions.

Табл. 2. Структура и питательность комбикормов для перепелок, %

Table 2. Structure and nutritional value of compound feed for quails, %

Component	Age of quails, days	
	0–30	31–60 and older
Forage wheat	44,5	57,0
Extruded soybeans	20,0	12,0
Sunflower oil cake	10,0	10,0
Meat and vegetable flour	–	10,0
Fish flour	12	–
Forage yeast	7	5
Fat (vegetable/animal)	3,5	3,0
Premix	1,0	1,0
Forage chalk	1,0	1,0
Tricalcium phosphate	1,0	1,0
100 g of mixed fodder contains, %		
Exchangeable energy, MJ	1,258	1,256
Crude protein	26,4	23,2
Lysine	1,49	1,21
Methionine + cystine	0,90	0,79
Crude fiber	3,7	3,8
Calcium	1,46	1,84
Available phosphorus	0,86	1,01
Sodium	0,48	0,48

The baseline level of LP products in LDL and *in vitro* LDL oxidative resistance in serum were determined using the method by Y.I. Ragino et al.[4]. Serum LDL was obtained through heparin-buffer precipitation, washed, and dissolved in a 1 M NaCl solution. The oxidative modification of LDL was performed in an isotonic NaCl solution containing Cu^{2+} ions at 37°C. The de-

[2]Recommendations on feeding poultry // RASKhN; ISTC "Plemptitsa"; GNU VNITIP / edited by V.I. Fisinin and Sh.A. Imangulov, I.A. Egorov, T.M. Okolelova. Sergiev Posad. 2003. 142 p.

[3]Methods of scientific and production research on poultry feeding // RASKhN; ISTC "Plemptitsa"; SSI VNITIP / edited by V.I. Fisinin and Sh.A. Imangulov. Sergiev Posad. 2000. 33 p.

[4]Patent No. 2216738 RF. Method of estimation of antioxidant potential of low-density lipoproteins / Yu.I. Ragino, E.V. Berezovskaya, Yu.P. Nikitin. Priority from 14.09.2001.

gree of LDL oxidation was evaluated using the fluorometric method based on the concentration of one of the end products of LPO – malondialdehyde (MDA) – at the beginning (before oxidation) and after 3, 6, 15, and 30 minutes of incubation using a Versafluor spectrophotometer. Concentrations of TG, TC, HDL cholesterol, glucose, and aspartate aminotransferase were determined using enzymatic methods with "Thermo Fisher Scientific" kits (Finland) on a biochemical analyzer "Konelab Prime 30i" (Thermo Fisher Scientific, Finland). LDL cholesterol was calculated using the Friedewald formula. Statistical analysis of results was carried out using the Statistical 6.1 software package for Windows. Results are presented as mean values with their standard errors (M ± SE). The differences were considered statistically significant at $p \leq 0.05$.

RESULTS CAND DISCUSSION

Characteristics of different pig breeds' fat

Pigs of the studied breeds significantly differed in backfat thickness and qualitative characteristics of the salt-cured fat. The backfat thickness at the level of the 6th and 7th thoracic vertebrae with a live weight of 100 kg was as follows (mm):

LW – 32.9, K – 35.1, L – 32.3, D – 32.7, and P – 21.1. Thus, in terms of all investigated parameters (appearance, tenderness, taste), the fat from pigs of the breed K looked the best (see Table 3). The fat from pigs of the breed P was very thin and lacked the characteristic pink hue of good fat. The salt-cured fat obtained from pigs of the breed K was rated the best in terms of taste by Siberian tasters across all parameters.

Subcutaneous fat from pigs of the breed K contained more fat than that from P (88.1 ± 4.80% vs. 80.4 ± 1.93%) (see Table 4). In the fat from breed K, there were more saturated fatty acids (41.56 vs. 38.28%), especially palmitic acid – 25.62 ± 0.87% vs. 23.0 ± 0.59% in breed P ($p < 0.05$), and myristic acid – 1.4 ± 0.16% vs. 1.1 ± 0.13%. However, linoleic polyunsaturated fatty acid content was lower in breed K – 15.08 ± 0.72% vs. 19.22 ± 1.6% ($p < 0.05$). The fat from breed K contained 0.16 ± 0.02% total cholesterol compared to 0.26 ± 0.02% ($p < 0.01$) in breed P, which is 1.5 times less. The fat content of cholesterol in 100 g of fat was 140 mg for breed K and 209 mg for breed P.

Growth, Development, and Productivity of Quails

The development of quails was studied from hatching to 165 days of age (23.6 weeks). There was no significant difference between the groups, although a tendency towards higher body weight in group 2 (K) at 60 days of age and lower feed consumption for growth was noted. At 60 days of age, the body weight of the quails in group 1 was 204.3 g, group 2 – 213.5 g, and group 3 – 208.7 g, with group 2 being

Табл. 3. Качество соленого сала свиней разных пород
Table 3. The quality of salted fat of pigs of different breeds

Number of taste testers	Breed	Taste	Tenderness	Appearance	Average grade
14	Pietren	2,6 ± 0,3*	1,9 ± 0,2**	2,8 ± 0,3*	2,4 ± 0,2**
14	Large White	3,3 ± 0,2	2,4 ± 0,3*	3,0 ± 0,3*	2,9 ± 0,3*
14	Duroc	3,4 ± 0,2	2,9 ± 0,2	3,5 ± 0,3	3,2 ± 0,2
14	Landrace	3,2 ± 0,1*	2,5 ± 0,2*	3,0 ± 0,2**	2,9 ± 0,2*
14	Kemerovo	3,9 ± 0,2	3,5 ± 0,3	4,2 ± 0,2	3,9 ± 0,2

Here and in Table 4, 6:
* The difference compared to breed K is reliable at $p < 0,05$.
** At $p < 0,01$.

Табл. 4. Жирные кислоты сала, %
Table 4. Fatty acids of fat, %

Fatty acid	Pig breed	
	Kemerovo (n = 5)	Pietren (n = 5)
Myristic C 14 : 0	1,4 ± 0,07	1,1 ± 0,13
Pentadecanoic C 15 : 0	0	0,1 ± 0
Palmitic C 16 : 0	25,62 ± 0,87	23 ± 0,59*
Heptadecanoic C 17 : 0	0,3 ± 0,03	0,42 ± 0,06
Stearic C 18 : 0	13,72 ± 0,3	13,34 ± 0,95
Arachic C 20 : 0	0,52 ± 0,16	0,32 ± 0,07
SAFA amount	41,56	38,28
Palmitoleic C 16 : 1	2,36 ± 0,14	2,08 ± 0,2
Heptadecynoic C 17 : 1	0,28 ± 0,04	0,34 ± 0,04
Oleinic C 18 : 1	34,78 ± 0,63	33 ± 0,91
Octadecenic C 18 : 1 (oleic)	4,84 ± 0,49	4,98 ± 0,35
Eicosenoic C 20 : 1 (gondoinic)	0,84 ± 0,29	1,3 ± 0,31*
MUFA amount	43,1	41,7
Linoleic C 18 : 2 (ώ-6)	15,08 ± 0,72	19,22 ± 1,6*
Eicosatrienoic C 20 : 3 (ώ-6)(γ- linolenic)	0	0
Arachidonic C 20 : 4 (ώ-6)	0,1 ± 0	0,1 ± 0
Docosapentaenoic C 22 : 5 (ώ-3)	0	0,1 ± 0
Decosahexanoic C 22 : 6 (ώ-3)	0	0
PUFA amount	15,18	19,42
Cholesterol, %	0,16 ± 0,02	0,26 ± 0,02**
Fat content, %	88,1 ± 2,14	80,4 ± 1,93*

4.5% higher ($p < 0.1$). Feed consumption per unit growth during the rearing period was 8.2, 7.5, and 8.0 g for groups 1, 2, and 3, respectively (see Table 5).

Quails that had subcutaneous fat from breed K in their diet tended to have higher body weight and growth rate at 60 days of age compared to the control groups. Feed consumption per unit growth was 8.2% lower in group 2. At 70 days of age, 10–13 male quails and 6 female quails were randomly selected from all groups for further rearing and eventual slaughter. Over the 90-day rearing period, reaching 165 days of age, the body weight of male quails increased by 8.3 g in group 1, 4.9 g in group 2, and 7.9 g in group 3. At 165 days of age, their body weight was 194.5 g in group 1, 200.9 g in group 2, and 195.7 g in group 3, with group 2 having a slightly higher body weight. In terms of the chemical composition of breast muscle at 165 days of age, there was no significant difference between the groups in most parameters.

Egg production per quail over a period of 92 days was 62.7 eggs in group 1, 71.3 eggs in group 2, and 63.5 eggs in group 3. Feed consumption per 10 eggs was 0.525 kg, 0.412 kg, and 0.507 kg for groups 1, 2, and 3, respectively. The average egg mass was the highest in group 2 hens – 11.38 ± 0.16 g compared to 11.23 ± 0.18 g in the control and 10.65 ± 0.09 g in group 3 ($p < 0.01$).

Табл. 5. Сохранность, прирост живой массы и затраты корма на прирост перепелок
Table 5. Survival, live weight gain and feed costs for the growth of quails

Indicator	Group		
	1st (control)	2nd (experimental)	3rd (experimental)
Number of quails, heads	60	60	60
Mortality, %	95	95	97
Live weight at hatching, g	9,03 ± 0,13	9,13 ± 0,14	9,08 ± 0,14
Live weight at 30 days of age	118,3 ± 2,04	124,2 ± 2,22	126,3 ± 1,96
Live weight at 60 days of age	204,3 ± 3,45	213,5 ± 3,47	208,7 ± 2,89
Average daily gain for 60 days, g	3,25 ± 0,05	3,41 ± 0,06	3,33 ± 0,05
Average daily gain to the control, %	100	104,9	102,5
Feed inputs (g per 1 g of growth)	8,2	7,5	8,0

In the yolks of quail eggs receiving pig fat in their feed from both breeds, there were more valine and isoleucine amino acids than in the control group. In the egg white of group 3, there was 0.23% more histidine ($p < 0.01$) but 0.14% less isoleucine ($p < 0.01$) compared to the control. Thus, it can be preliminarily concluded that the feed additive containing pig fat from breed K for growing quail juveniles, which has higher saturated fatty acids and lower cholesterol content, leads to increased growth rate, improved egg production, and larger egg size compared to other groups.

Blood Biochemical Composition Results for Quails at 8 and 23 Weeks of Age

Quails receiving pig fat in their feed had higher levels of triglycerides in their blood serum at 23 weeks of age compared to the birds receiving vegetable oil (see Table 6).

In group K, the level of triglycerides was 123.7 ± 11.39 mg/dL, compared to 90.0 ± 9.23 mg/dL in the control group ($p < 0.01$) and 107.8 ± 12.02 mg/dL in group P. There were no significant differences in total cholesterol content between the age groups, with some tendency towards higher levels in groups 2 and 3 compared to the control at 23 weeks of age.

Quails receiving vegetable oil as an additive showed a tendency towards increased levels of high-density lipoproteins (HDL) in their blood serum at both 8 and 23 weeks of age, especially when compared to birds receiving fat from breed P. Conversely, low-density lipoprotein (LDL) levels were slightly lower in this group (see Table 6).

Blood serum lipid peroxidation (LP) studies revealed that at 23 weeks of age the initial level of peroxidation products in low-density lipoproteins (LDL) was the highest in the birds receiving fat from breed P (1.91 nmol MDA/mg protein) compared to 1.14 nmol MDA/mg protein in the control (vegetable oil) ($p < 0.01$), and 1.65 nmol MDA/mg protein in the quails receiving fat from breed K.

Thirty minutes after forced oxidation, the level of peroxidation products (MDA) in birds receiving vegetable oil supplements increased by 3.31 times compared to the baseline ($p <$

Табл. 6. Биохимический состав крови перепелок в 23-недельном возрасте
Table 6. The biochemical composition of the blood of quails at 23 weeks of age

Indicator	Indicator	Indicator	Indicator
TG, мг/дл	TG, мг/дл	TG, мг/дл	TG, мг/дл
TC, мг/дл	TC, мг/дл	TC, мг/дл	TC, мг/дл
FORD, mmol/l	FORD, mmol/l	FORD, mmol/l	FORD, mmol/l
LP (0 min) nmol MDA/mg protein	LP (0 min) nmol MDA/mg protein	LP (0 min) nmol MDA/mg protein	LP (0 min) nmol MDA/mg protein
LP (30 min) nmol MDA/mg protein	LP (30 min) nmol MDA/mg protein	LP (30 min) nmol MDA/mg protein	LP (30 min) nmol MDA/mg protein
HDL, mg/dl	HDL, mg/dl	HDL, mg/dl	HDL, mg/dl
LDL, mg/dl	LDL, mg/dl	LDL, mg/dl	LDL, mg/dl
AI, c.u.	AI, c.u.	AI, c.u.	AI, c.u.
TP, g/l	TP, g/l	TP, g/l	TP, g/l
Al, g/l	Al, g/l	Al, g/l	Al, g/l
Gl, mmol/l	Gl, mmol/l	Gl, mmol/l	Gl, mmol/l

Note. LW - live weight, TG - triglycerides, TC - total cholesterol, AOA (FORD) - antioxidant activity, LP 0 - lipid peroxidation, baseline, LP 30 - oxidative resistance of LDL, HDL - high-density lipoproteins, LDL - low-density lipoproteins, TP - total protein, Al - albumin, Gl - glucose, AI - atherogenic index.

0.001), whereas the levels increased by 2.73 times ($p < 0.001$) and 2.01 times ($p < 0.001$) in the quails receiving supplements containing fat from breed K and fat from breed P, respectively. Thus, LDL in blood serum under forced oxidation appeared to be more susceptible to peroxidation under the influence of vegetable oil, and least susceptible under the influence of fat from breed P. According to the data from the experiment involving 32 observational studies on dietary fat supplements (involving 530,525 participants), the following was established: the relative risk of ischemic heart disease (IHD) was 1.02 for saturated fats, 0.99 for monounsaturated fats, 0.93 for long-chain polyunsaturated fats (ω-3), 1.01 for ω-6 polyunsaturated fats, and 1.16 for trans fats [2]. Thus, the association between coronary artery diseases and the consumption of total saturated fatty acids (SFA) was not confirmed.

A convincing link between saturated fats and mortality from IHD was not found in a subsequent systematic review and meta-analysis of observational studies [9]. The conclusion was drawn that saturated fats are not associated with mortality from cardiovascular diseases (CVD), IHD, ischemic stroke, or type 2 diabetes, but the evidence is heterogeneous with methodological limitations. Milk fat, which contains a significant amount of saturated fatty acids, actually reduces the risk of developing cardiovascular diseases[5].

In our studies, the pig fat from breeds K and P, which was fed to quails, significantly differed in the concentration of myristic, palmitic, and linoleic fatty acids. While myristic and palmitic fatty acids were higher in breed K, linoleic fatty acid was more abundant in breed P.

Some researchers believe that palmitic acid (C 16: 0) is associated with adverse cardiovascular events, and high levels of it in the blood are linked to a high risk of developing and progressing IHD [10]. According to other studies, higher consumption of linoleic acid (LA) is associated with a lower dose-dependent risk of IHD [11].

In our studies, quails in group 3 received pig fat with a high concentration of polyunsaturated fatty acids (PUFAs), especially linoleic fatty acid, which is a major source of lipid peroxidation. It is known that this leads to high concentrations of lipid peroxidation products in the blood and tissues, including malondialdehyde (MDA), which destabilizes cell membranes, triggers atherosclerotic changes, and worsens under stress conditions and an imbalance between free radical formation and scavenging [12–14].

The obtained data indicate no differences in the antioxidant activity (AOA) of serum cholesterol in quails depending on the type of fat they were fed (see Table 6). Meanwhile, the initial level of lipid peroxidation products was higher in quails in group 3 ($p < 0.05$), which were fed fat from breed P, characterized by a higher content of PUFAs (1.9 ± 0.23 nmol MDA/mg protein in group 3, 1.7 ± 0.31 in group 2, and 1.1 ± 0.20 nmol MDA/mg protein in control group 1).

The levels of total cholesterol (TC) in the blood of 23-week-old quails, influenced by prolonged feeding of fat supplements, significantly decreased compared to 8-week-old quails. This decrease was observed in all experimental groups, including a 1.49-fold reduction in the control group ($p < 0.001$), 1.58-fold reduction in group 2 ($p < 0.001$), and 1.32-fold reduction in group 3 ($p < 0.05$). While a positive correlation between triglycerides (TG) and TC was noted across all groups ($r = 0.73$), in groups where birds received pig fat, an increase in TG levels was accompanied by a decrease in TC. Significant differences in TC between the groups were not observed at both 8 and 23 weeks of age. The levels of LDL and HDL decreased significantly with age in all quail groups. In 23-week-old quails, the level of LDL was highest in those receiving fat from breed P, characterized by higher content of PUFAs and cholesterol (44.9 mg/dl compared to 29.0 in group 1 and 28.6 mg/dl in group 2).

Despite the elevated level of palmitic acid in the fat from breed K pigs, which is capable of retaining "bad" cholesterol (LDL) and causing

[5]Peter Elwood. The myth of fat-reduced milk and dairy foods. NFU Cymru Briefing 5th February 2015. URL: https://www.nfucymru. org.uk/milk-health-website-piece/.

an increase in blood sugar in quails consuming this fat as part of their diet, there was no increase in blood glucose levels. At 8 weeks of age, the blood glucose levels in quails of group 1 (control) were 11.2 ± 0.96 mmol/L, in group 2 - 10.2 ± 1.33, and in group 3 - 9.7 ± 1.16 mmol/L. Similarly, at 23 weeks of age, the levels were 10.0 ± 1.32; 9.2 ± 0.88; and 10.5 ± 0.93 mmol/L, respectively. The glucose content in the blood serum exhibited a relatively strong correlation with total cholesterol (TC) (r = 0.44), triglycerides (TG) (r = 0.38), HDL (r = 0.66), and total protein (TP) (r = 0.38).

The atherogenic index (AI), defined as (TC-HDL)/HDL, representing the risk of developing ischemic heart disease, was the highest ($p < 0.01$) in quails with elevated LDL levels receiving pig fat from breed P (0.93 compared to 0.57 and 0.69 in other groups). This group also exhibited a decreased level of polyunsaturated fatty acids (PUFAs) (see Table 6). In the experiments conducted by Mondé Aké Absalome, Lohoues Essis Claude, Gauze-Gnagne-Agnero Chantal et al. [6], who studied the effects of different types of oils (traditional, industrial, yellow refined palm oil, peanut, cottonseed, and soybean), it was demonstrated that palm oil in all its forms, with a high level of saturated fatty acids, reduces triglyceride, LDL cholesterol, and increases HDL cholesterol levels in chickens fed with it. Arterial lesions were fewer in chickens fed palm oil. The authors concluded that palm oil is one of the plant oils that has a protective effect against atherosclerosis.

The obtained data suggest that fats containing a high amount of PUFAs and lower levels of cholesterol, including subcutaneous fat from breed pigs and palm oil, could be beneficial for preventing atherosclerosis.

CONCLUSION

The use of different types of fat as dietary supplements allows for certain conclusions to be drawn about their effects on growth and development of animals throughout their life span from birth to adulthood. Quails that were supplemented with fat from Kemerovo breed pigs (group 2) grew faster and had a higher body weight at 2 months of age compared to the control group, which received vegetable oil in their diet. Quails consuming fat from breed K pigs showed increased egg laying, producing 8 more eggs in 92 days compared to those receiving fat from breed P pigs and vegetable oil. Biochemical analysis of quail blood revealed certain differences. Birds receiving fat with higher levels of polyunsaturated fatty acids (PUFAs) had a tendency to exhibit higher total cholesterol (TC) levels. The initial level of lipid peroxidation (LP), expressed in the level of the end product malondialdehyde (MDA), was significantly higher ($p < 0.05$) in birds consuming fat with the highest level of PUFAs (1.9 nmol/mg protein) compared to 1.7 in group 2 and 1.1 nmol/mg protein in the control group. However, LDL responded more to oxidative modification in birds that received a diet with vegetable oil, where LP increased 3.4 times, compared to 2.6 times in group 2 and 2 times in group 3. The AI was highest ($p < 0.01$) in quails of group 3, which received a diet containing fat from breed P pigs with high levels of TC and rich in PUFAs, at 0.93 compared to 0.69 in group 2 and 0.57 in the control group 1.

Fat from breed K pigs caused lower AI than fat from breed P pigs. Preliminary conclusions can be drawn that fats containing a higher amount of PUFAs but lower cholesterol and linoleic fatty acid content, such as subcutaneous fat from breed pigs and palm oil, are more beneficial in the nutrition of animals and humans, which requires further research. For the first time, evidence has been obtained on a model subject that animal fat containing more PUFAs but fewer PUFAs, especially linoleic fatty acid and cholesterol, has a positive rather than a negative impact on the productivity and cardiovascular system of animals.

The results obtained in the study on birds (quails), which share characteristics with humans in terms of mitochondrial free radical release during fatty acid metabolism [7], provide a basis for validating the obtained data in humans and for pig breeding aiming at increasing saturated fatty acid content in their fat.

СПИСОК ЛИТЕРАТУРЫ

1. *Jie Zhang, Jie Chai, Zonggang Luo, Hang He, Lei Chen, Xueqin Liu,* Qinfei Zhou. Meat and nutritional quality comparison of purebred and crossbred pigs // Animal Science Journal. 2018. Vol. 89. N 1. P. 202–210. DOI: 10.1111/asj.12878.
2. *Rajiv Chowdhury, Samantha Warnakula, Setor Kunutsor, Francesca Crowe, Heather A Ward, Laura Johnson, Oscar H Franco, Adam S Butterworth, Nita G Forouhi, Simon G Thompson, Kay-Tee Khaw, Dariush Mozaffarian, John Danesh, Emanuele Di Angelantonio.* Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis // Annals of Internal Medicine. 2014. Vol. 160. P. 398–406. DOI: 10.7326/M13-1788.
3. *Fumiaki Ito and Tomoyuki Ito.* High-Density Lipoprotein (HDL) Triglyceride and Oxidized HDL: New Lipid Biomarkers of Lipoprotein-Related Atherosclerotic Cardiovascular Disease // Antioxidants. 2020. Vol. 9. N 5. P. 362. DOI: 10.3390/antiox9050362.
4. *Alexandra T. Wade, Courtney R. Davis, Kathryn A. Dyer, Jonathan M. Hodgson, Richard J. Woodman, Hannah A.D. Keage, Karen J Murphy.* A Mediterranean Diet with Fresh, Lean Pork Improves Processing Speed and Mood: Cognitive Findings from the Med Pork Randomised Controlled Trial // Nutrients. 2019. Vol. 11. N 7. P. 1521. DOI: org/10.3390/nu11071521.
5. *Vittoria Cammisotto, Cristina Nocella, Simona Bartimoccia, Valerio Sanguigni, Davide Francomano, Sebastiano Sciarretta, Daniele Pastori, Mariangela Peruzzi, Elena Cavarretta, Alessandra D'Amico, Valentina Castellani, Giacomo Frati, Roberto Carnevale and SMiLe Group.* The Role of Antioxidants Supplementation in Clinical Practice: Focus on Cardiovascular Risk Factors // Antioxidants. 2021. Vol. 10. N 2. P. 146. DOI: 10.3390/antiox10020146.
6. *Mondé Aké Absalome, Lohoues Essis Claude, Gauze-Gnagne-Agnero Chantal, Camara-Cissé Massara, Diomandé Mohenou Isidore, Djessou Sossé Prosper, Sess Essiagne Daniel.* Relationship Between Lipid Assessment and Arterial Lesions Observed in Farm Chickens Fed on Different Vegetable Oils // Journal of Food and Nutrition Sciences. 2016. Vol. 4. N 5. P. 126–130. DOI: 10.11648/j.jfns.20160405.12.
7. *Лu Hoy.* Эгоистичная митохондрия. Как сохранить здоровье и отодвинуть старость: монография. Санкт-Петербург: Питер. 2020. 304 с.
8. *Bekenev V.A., Garcia A., Arishin A.A., Ragino Yu.I., Polonskaya Ya.V., Bolshakova-botsan I.V.* The ratio of qualitative indicators of pork with lipid metabolism in pigs of different breeds Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2018. Vol. 9. N 5. P. 2326–2334.
9. *de Souza R.J., Mente A., Maroleanu A., Adriana I. Cozma, Ha Vanessa, Kishibe Teruko, Elizabeth Uleryk, Patrick Budylowsk, Holger Schünemann, Joseph Beyene, Sonia S. Anand.* Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies // British Medical Journal. 2015. Vol. 11. P. 351:h3978. DOI: 10.1136/bmj.h3978.
10. *Shramko V.S., Polonskaya Y.V., Kashtanova E.V., Stakhneva E.M., Ragino Y.I.* The Short Overview on the Relevance of Fatty Acids for Human Cardiovascular Disorders // Biomolecules. 2020. Vol. 10. P. 1127. DOI: 10.3390/biom10081127.
11. *Farvid M.S., Ding M., Pan A., Sun Q., Chiuve S.E., Steffen L.M, Willett 1., Frank B.* Dietary Linoleic Acid and Risk of Coronary Heart Disease: A Systematic Review and Meta-Analysis of Prospective Cohort Studies // Circulation. 2014. Vol. 130. P. 1568–1578. DOI: 10.1161/circulationaha.114.010236.
12. *Silvana Hrelia and Cristina Angeloni.* New Mechanisms of Action of Natural Antioxidants in Health and Disease // Antioxidants. 2020. Vol. 9. N 4. P. 344. DOI: 10.3390/antiox9040344.
13. *Elodie Bacou, Carrie Walk, Sebastien Rider, Gilberto Litta and Estefania Perez-Calvo.* Dietary Oxidative Distress: A Review of Nutritional Challenges as Models for Poultry, Swine and Fish // Antioxidants. 2021. Vol. 10, N 4. P. 525. DOI: 10.3390/antiox10040525.
14. *Jean-Marc Zingg, Adelina Vlad and Roberta Ricciarelli.* Oxidized LDLs as Signaling Molecules // Antioxidants. 2021. Vol. 10. N 8. P. 1184. DOI: 10.3390/antiox10081184

REFERENCES

1. Jie Zhang, Jie Chai, Zonggang Luo, Hang He, Lei Chen, Xueqin Liu, Qinfei Zhou. Meat and nutritional quality comparison of purebred and crossbred pigs // *Animal Science Journal*. 2018. vol. 89, no. 1, pp. 202–210. DOI:10.1111/asj.12878.
2. Rajiv Chowdhury, Samantha Warnakula, Setor Kunutsor, Francesca Crowe, Heather A Ward, Laura Johnson, Oscar H Franco, Adam S Butterworth, Nita G Forouhi, Simon G Thompson, Kay-Tee Khaw, Dariush Mozaffarian, John Danesh, Emanuele Di Angelantonio. Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis. *Annals of Internal Medicine*, 2014, vol. 160, pp. 398–406. DOI: 10.7326/M13-1788.
3. Fumiaki Ito and Tomoyuki Ito. High-Density Lipoprotein (HDL) Triglyceride and Oxidized HDL: New Lipid Biomarkers of Lipoprotein-Related Atherosclerotic Cardiovascular Disease. *Antioxidants,* 2020, vol. 9, no. 5, pp. 362. DOI: 10.3390/antiox9050362.
4. Alexandra T. Wade, Courtney R. Davis, Kathryn A. Dyer, Jonathan M. Hodgson, Richard J. Woodman, Hannah A. D. Keage, Karen J Murphy. A Mediterranean Diet with Fresh, Lean Pork Improves Processing Speed and Mood: Cognitive Findings from the Med Pork Randomised Controlled Trial. *Nutrients,* 2019, vol. 11, no. 7, p. 1521. DOI: 10.3390/nu11071521.
5. Vittoria Cammisotto, Cristina Nocella, Simona Bartimoccia, Valerio Sanguigni,Davide Francomano, Sebastiano Sciarretta, Daniele Pastori, Mariangela Peruzzi, Elena Cavarretta, Alessandra D'Amico, Valentina Castellani, Giacomo Frati, Roberto Carnevale and SMiLe Group. The Role of Antioxidants Supplementation in Clinical Practice: Focus on Cardiovascular Risk Factors. *Antioxidants*, 2021, vol. 10, no. 2, p. 146. DOI: 10.3390/antiox10020146.
6. Mondé Aké Absalome, Lohoues Essis Claude, Gauze-Gnagne-Agnero Chantal, Camara-Cissé Massara, Diomandé Mohenou Isidore, Djessou Sossé Prosper, Sess Essiagne Daniel. Relationship Between Lipid Assessment and Arterial Lesions Observed in Farm Chickens Fed on Different Vegetable Oils. *Journal of Food and Nutrition Sciences,* 2016, vol. 4, no. 5, pp. 126–130. DOI: 10.11648/j.jfns.20160405.12.
7. Lee Know. *Selfish mitochondrion. How to maintain health and push back old age.* St. Petersburg, Peter. 2020. 304 p. (In Russian).
8. Bekenev V.A., Garcia A., Arishin A.A., Ragino Yu.I., Polonskaya Ya.V., Bolshakova-botsan I.V. The ratio of qualitative indicators of pork with lipid metabolism in pigs of different breeds Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2018, Vol. 9, no. 5, pp. 2326–2334.
9. de Souza R.J., Mente A., Maroleanu A., Adriana I. Cozma, Ha Vanessa, Kishibe Teruko, Elizabeth Uleryk , Patrick Budylowski, Holger Schünemann, Joseph Beyene, Sonia S. Anand. Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies. *British Medical Journal*, 2015, vol. 11, pp. 351:h3978. DOI: 10.1136/bmj.h3978.
10. Shramko V.S., Polonskaya Y.V., Kashtanova E.V., Stakhneva E.M and Ragino Y.I. The Short Overview on the Relevance of Fatty Acids for Human Cardiovascular Disorders. *Biomolecules,* 2020, vol. 10, pp. 1127. DOI: 10.3390/biom10081127.
11. Farvid M.S., Ding M., Pan A., Sun Q., Chiuve S.E., Steffen L.M., Willett 1., Frank B. Dietary Linoleic Acid and Risk of Coronary Heart Disease: A Systematic Review and Meta-Analysis of Prospective Cohort Studies. *Circulation*, 2014, vol. 130, pp. 1568–1578. DOI: 10.1161/circulationaha.114.010236.
12. Silvana Hrelia and Cristina Angeloni. New Mechanisms of Action of Natural Antioxidants in Health and Disease. *Antioxidants*, 2020, vol. 9, no. 4, p. 344. DOI: 10.3390/antiox9040344.
13. Elodie Bacou, Carrie Walk, Sebastien Rider, Gilberto Litta and Estefania Perez-Calvo. Dietary Oxidative Distress: A Review of Nutritional Challenges as Models for Poultry, Swine and Fish. *Antioxidants,* 2021. vol. 10, no. 4, pp. 525. DOI: 10.3390/antiox10040525.
14. Jean-Marc Zingg, Adelina Vlad and Roberta Ricciarelli. Oxidized LDLs as Signaling Molecules. *Antioxidants*, 2021, vol. 10, no. 8, p. 1184. DOI: 10.3390/antiox10081184.

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Дата поступления статьи / Received by the editors 29.03.2023
Дата принятия к публикации / Accepted for publication 17.05.2023
Дата публикации / Published 20.06.2023

ПРАВИЛА ДЛЯ АВТОРОВ

Правила для авторов составлены на основе этических принципов, общих для членов научного сообщества, и правил публикации в международных и отечественных научных периодических изданиях, а также в соответствии с требованиями ВАК для периодических изданий, включенных в Перечень российских рецензируемых научных журналов, в которых должны быть опубликованы основные научные результаты диссертаций на соискание ученой степени доктора и кандидата наук.

Журнал публикует оригинальные статьи по фундаментальным и прикладным проблемам по направлениям:

- общее земледелие и растениеводство;
- селекция, семеноводство и биотехнология растений;
- агрохимия, агропочвоведение, защита и карантин растений;
- кормопроизводство;
- инфекционные болезни и иммунология животных;
- частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства;
- разведение, селекция, генетика и биотехнология животных;
- технологии, машины и оборудование для агропромышленного комплекса;
- пищевые системы.

Статья, направляемая в редакцию, должна соответствовать тематическим разделам журнала «Сибирский вестник сельскохозяйственной науки»:

Наименование рубрики	**Шифр и наименование научной специальности в соответствии с Номенклатурой научных специальностей, по которым присуждаются ученые степени**
Земледелие и химизация	4.1.1. Общее земледелие и растениеводство 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Растениеводство и селекция	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений
Защита растений	4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Кормопроизводство	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений
Зоотехния и ветеринария	4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных
Механизация, автоматизация, моделирование и информационное обеспечение	4.3.1. Технологии, машины и оборудование для агропромышленного комплекса
Переработка сельскохозяйственной продукции	4.3.3. Пищевые системы
Проблемы. Суждения Научные связи Из истории сельскохозяйственной науки Краткие сообщения Из диссертационных работ	4.1.1. Общее земледелие и растениеводство 4.1.2. Селекция, семеноводство и биотехнология растений 4.1.3. Агрохимия, агропочвоведение, защита и карантин растений 4.2.3. Инфекционные болезни и иммунология животных 4.2.4. Частная зоотехния, кормление, технологии приготовления кормов и производства продукции животноводства 4.2.5. Разведение, селекция, генетика и биотехнология животных 4.3.1. Технологии, машины и оборудование для агропромышленного комплекса 4.3.3. Пищевые системы

В журнале также публикуются обзоры, краткие сообщения, хроника, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых.

Число публикаций одного автора в номере журнала не должно превышать двух, при этом вторая статья допустима лишь в соавторстве.

К рассмотрению принимаются материалы от различных категорий исследователей, аспирантов, докторантов, специалистов и экспертов в соответствующих областях знаний.

Все статьи рецензируются и имеют зарегистрированный в системе CrossRef индекс DOI.

Публикации для авторов **бесплатны**.

При направлении статьи в редакцию журнала «Сибирский вестник сельскохозяйственной науки» рекомендуем руководствоваться следующими правилами.

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Перед отправкой статьи на рассмотрение необходимо убедиться, что в файле (файлах) содержится вся необходимая информация на русском и английском языках, указаны источники информации, размещенной на рисунках и в таблицах, все ссылки оформлены корректно.

ПОРЯДОК НАПРАВЛЕНИЯ РУКОПИСЕЙ СТАТЕЙ

1. Отправка статьи осуществляется через электронную редакцию на сайте журнала **https://sibvest.elpub.ru/jour/index.** После предварительной регистрации автора в правом верхнем углу страницы выбрать опцию «Отправить рукопись». Затем загрузить рукопись статьи (в формате *.doc или *.docx) и сопроводительные документы к ней. После завершения загрузки материалов обязательно выбрать опцию «Отправить письмо», в этом случае редакция автоматически будет уведомлена о получении новой рукописи.

Сопроводительные документы к рукописи статьи:

- скан-копия письма от организации с подтверждением авторства и разрешением на публикацию (образец на **http://sibvest.elpub.ru/**);
- скан-копия авторской справки по представленной форме (образец на **http://sibvest.elpub.ru/**), в которой должно быть выражено согласие на открытое опубликование статьи в печатном варианте журнала и его электронной копии в сети Интернет;
- скан-копия рукописи с подписями авторов. Автор, подписывая рукопись и направляя ее в редакцию, тем самым передает авторские права на издание этой статьи СФНЦА РАН;
- анкеты авторов на русском и английском языках (образец на **http://sibvest.elpub.ru/**);
- скан-копия справки из аспирантуры (для очных аспирантов).

2. Все поступающие в редакцию рукописи статей регистрируются через систему электронной редакции. В личном кабинете автора отражается текущий статус рукописи.

3. Нерецензируемые материалы (материалы научной хроники, рецензии, книжные обозрения, материалы по истории сельскохозяйственной науки и деятельности учреждений и ученых) направляются на e-mail: **sibvestnik@sfsca.ru** и регистрируются ответственным секретарем.

ПОРЯДОК ОФОРМЛЕНИЯ СТАТЬИ

Текст рукописи оформляется шрифтом Times New Roman, кеглем 14 с интервалом 1,5, все поля 2,0 см, нумерация страниц внизу. Объем статьи не более 15 страниц (включая таблицы, иллюстрации и библиографию); статей, размещаемых в рубриках «Из диссертационных работ» и «Краткие сообщения», – не более 7 страниц.

Структура оформления статьи:

1. **УДК**
2. **Заголовок статьи на русском и английском языках (не более 70 знаков).**
3. **Фамилии и инициалы авторов, полное официальное название научного учреждения, в котором проведены исследования, на русском и английском языках.**

Если в подготовке статьи принимали участие авторы из разных учреждений, необходимо указать принадлежность каждого автора к конкретному учреждению с помощью надстрочного индекса.

4. **Реферат на русском и английском языках.** Объем реферата не менее 200–250 слов. Реферат является кратким и последовательным изложением материала статьи по основным разделам и должен отражать основное содержание, следовать логике изложения материала и описания результатов в статье с приведением конкретных данных. Не следует включать впервые введенные термины, аббревиатуры (за исключением общеизвестных), ссылки на литературу. В реферате не следует подчеркивать новизну, актуальность и личный вклад автора; место исследования необходимо указывать до области (края), не упоминать конкретные организации.
5. **Ключевые слова на русском и английском языках.** 5–7 слов по теме статьи. Желательно, чтобы ключевые слова дополняли реферат и название статьи.
6. **Информация о конфликте интересов либо его отсутствии.** Автор обязан уведомить редактора о реальном или потенциальном конфликте интересов, включив информацию о конфликте интересов в соответствующий раздел статьи. Если конфликта интересов нет, автор должен также сообщить об этом.

Пример формулировки: «Автор заявляет об отсутствии конфликта интересов».

7. **Благодарности на русском и английском языках.** В этом разделе указываются все источники финансирования исследования, а также благодарности людям, которые участвовали в работе над статьей, но не являются ее авторами.
8. **Основной текст статьи.** При изложении оригинальных экспериментальных данных рекомендуется использовать подзаголовки:

ВВЕДЕНИЕ (постановка проблемы, цели, задачи исследования)

МАТЕРИАЛ И МЕТОДЫ (условия, методы (методика) исследований, описание объекта, место и время проведения)

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

ЗАКЛЮЧЕНИЕ или **ВЫВОДЫ**

СПИСОК ЛИТЕРАТУРЫ. Количество источников не менее 15. В список литературы включаются только рецензируемые источники: статьи из научных журналов и монографии. Самоцитирование не более 10% от общего количества. Библиографический список должен быть оформлен в виде общего списка в порядке упоминания в тексте, желательны ссылки на источники 2–3-летнего срока давности. Правила оформления списка литературы – в соответствии с ГОСТ Р 7.05–2008 (требования и правила составления библиографической ссылки). В тексте ссылка на источник отмечается порядковой цифрой в квадратных скобках, например [1]. Литература в списке дается на тех языках, на которых она издана. В библиографическое описание публикации необходимо вносить всех авторов, не сокращая их одним, тремя и т.п. Недопустимо сокращение названий статей, журналов, издательств.

Если необходимо сослаться на авторефераты, диссертации, сборники статей, учебники, рекомендации, учебные пособия, ГОСТы, информацию с сайтов, статистические отчеты, статьи в общественно-политических газетах и прочее, то такую информацию следует оформить в *сноску* в конце страницы. Сноски нумеруются арабскими цифрами, размещаются постранично сквозной нумерацией.

Внимание! Теоретические, обзорные и проблемные статьи могут иметь произвольную структуру, но обязательно должны содержать реферат, ключевые слова, список литературы.

ПРИМЕРЫ ОФОРМЛЕНИЯ СПИСКА ЛИТЕРАТУРЫ, REFERENCES И СНОСОК

СПИСОК ЛИТЕРАТУРЫ:

Монография

Климова Э.В. Полевые культуры Забайкалья: монография. Чита: Поиск, 2001. 392 с.

Часть книги

Холмов В.Г. Минимальная обработка кулисного пара под яровую пшеницу при интенсификации земледелия в южной лесостепи Западной Сибири // Ресурсосберегающие системы обработки почвы. М.: Агропромиздат, 1990. С. 230–235.

Периодическое издание

Пакуль А.Л., Лапшинов Н.А., Божанова Г.В., Пакуль В.Н. Технологические качества зерна мягкой яровой пшеницы в зависимости от системы обработки почвы // Сибирский вестник сельскохозяйственной науки. 2018. Т. 48. № 4. С. 27–35. DOI: 10.26898/0370-8799-2018-4-4.

REFERENCES:

Составляется в том же порядке, что и русскоязычный вариант, по следующим правилам:

Фамилии И.О. авторов в устоявшемся способе транслитерации, англоязычное название статьи, *транслитерация названия русскоязычного источника (например, через сайт: https://antropophob.ru/translit-bsi) = англоязычное название источника.* Далее оформление для монографии: город, англоязычное название издательства, год, количество страниц; для журнала: год, том, номер, страницы. (In Russian).

Пример: Avtor A.A., Avtor B.B., Avtor C.C. Title of article.

Транслитерация авторов. Англоязычное название статьи

Zaglavie jurnala = Title of Journal, 2012, vol. 10, no. 2, pp. 49–54.

Транслитерация источника = Англоязычное название источника

Монография

Klimova E.V. *Field crops of Zabaikalya*. Chita, Poisk Publ., 2001, 392 p. (In Russian).

Часть книги

Kholmov V.G. Minimum tillage of coulisse-strip fallow for spring wheat with intensification of arable agriculture in southern forest-steppe of Western Siberia. *Resource-saving tillage systems*, Moscow, Agropromizdat Publ., 1990, pp. 230–235. (In Russian).

Периодическое издание

Pakul A.L., Lapshinov N.A., Bozhanova G.V., Pakul V.N. Technological grain qualities of spring common wheat depending on the system of soil tillage. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2018, vol. 48, no. 4, pp. 27–35. (In Russian). DOI: 10.26898/0370-8799-2018-4-4.

СНОСКИ:

Цитируемый текст[1].

[1]*Климова Э.В., Андреева О.Т., Темникова Г.П.* Пути стабилизации кормопроизводства Забайкалья // Проблемы и перспективы совершенствования зональных систем земледелия в современных условиях: материалы науч.-практ. конф. (Чита, 16–17 октября 2008 г.). Чита, 2009. С. 36–39.

Цифровой идентификатор Digital Object Identifier – DOI (когда он есть у цитируемого материала) необходимо указывать в конце библиографической ссылки.

Пример:

Chu T., Starek M.J., Brewer M.J., Murray S.C., Pruter L.S. Assessing lodging severity over an experimental maize (Zea mays L.) field using UAS images // Remote Sensing. 2017. Vol. 9. P. 923. DOI: 10.3390/rs9090923.

Наличие DOI статьи следует проверять на сайте http://search.crossref.org/ или https://www.citethisforme.com. Для этого нужно ввести в поисковую строку название статьи на английском языке.

РИСУНКИ, ТАБЛИЦЫ, СКРИНШОТЫ И ФОТОГРАФИИ

Рисунки должны быть хорошего качества, пригодные для печати. Все рисунки должны иметь подрисуночные подписи. Подрисуночную подпись необходимо перевести на английский язык. Рисунки нумеруются арабскими цифрами по порядку следования в тексте. Если рисунок в тексте один, то он не нумеруется. Отсылки на рисунки оформляются следующим образом: «На рис. 3 указано, что …» или «Указано, что … (см. рис. 3)». Подрисуночная подпись включает

порядковый номер рисунка и его название: «Рис. 2. Описание жизненно важных процессов». Перевод подрисуночной подписи следует располагать после подрисуночной подписи на русском языке.

Таблицы должны быть хорошего качества, пригодные для печати. Предпочтительны таблицы, пригодные для редактирования, а не отсканированные или в виде рисунков. Все таблицы должны иметь заголовки. Название таблицы должно быть переведено на английский язык. Таблицы нумеруются арабскими цифрами по порядку следования в тексте. Если таблица в тексте одна, то она не нумеруется. Отсылки на таблицы оформляются следующим образом: «В табл. 3 указано, что …» или «Указано, что … (см. табл. 3)». Заголовок таблицы включает порядковый номер таблицы и ее название: «Табл. 2. Описание жизненно важных процессов». Перевод заголовка таблицы следует располагать после заголовка таблицы на русском языке.

Фотографии, скриншоты и другие нерисованные иллюстрации необходимо загружать отдельно в виде файлов формата *.jpeg (*.doc и *.docx – в случае, если на изображение нанесены дополнительные пометки). Разрешение изображения должно быть >300 dpi. Файлам изображений необходимо присвоить название, соответствующее номеру рисунка в тексте. В описании файла следует отдельно привести подрисуночную подпись, которая должна соответствовать названию фотографии, помещаемой в текст.

Следует обратить внимание на написание формул в статье. Во избежание путаницы необходимо греческие (α, β, π и др.), русские (А, а, Б, б и др.) буквы и цифры писать прямым шрифтом, латинские – курсивным (*W*, *Z*, *m*, *n* и др.). Математические знаки и символы нужно писать также прямым шрифтом. Необходимо четко указывать верхние и нижние надстрочные символы (W^1, F_1 и др.).

ВЗАИМОДЕЙСТВИЕ МЕЖДУ ЖУРНАЛОМ И АВТОРОМ

Редакция просит авторов при подготовке статей руководствоваться изложенными выше правилами.

Все поступающие в журнал «Сибирский вестник сельскохозяйственной науки» статьи проходят предварительную проверку на соответствие формальным требованиям. На этом этапе редакция оставляет за собой право:

- принять статью к рассмотрению;
- вернуть статью автору (авторам) на доработку с просьбой устранить ошибки или добавить недостающие данные;
- вернуть статью автору (авторам) без рассмотрения, оформленную не по требованиям журнала;
- отклонить статью из-за несоответствия ее целям журнала, отсутствия оригинальности, малой научной ценности.

Переписка с авторами рукописи ведется через контактное лицо, указанное в рукописи.

Все научные статьи, поступившие в редакцию журнала «Сибирский вестник сельскохозяйственной науки», проходят обязательное двухстороннее «слепое» рецензирование (double-blind – автор и рецензент не знают друг о друге). Рукописи направляются по профилю научного исследования на рецензию членам редакционной коллегии.

В спорных случаях редактор может привлечь к процессу рецензирования нескольких специалистов, а также главного редактора. При положительном заключении рецензента статья передается редактору для подготовки к печати.

При принятии решения о доработке статьи замечания и комментарии рецензента передаются автору. Автору дается 2 месяца на устранения замечаний. Если в течение этого срока автор не уведомил редакцию о планируемых действиях, статья снимается с очереди публикации.

При принятии решения об отказе в публикации статьи автору отправляется соответствующее решение редакции.

Ответственному (контактному) автору принятой к публикации статьи направляется финальная версия верстки, которую он обязан проверить.

ПОРЯДОК ПЕРЕСМОТРА РЕШЕНИЙ РЕДАКТОРА/РЕЦЕНЗЕНТА

Если автор не согласен с заключением рецензента и/или редактора или отдельными замечаниями, он может оспорить принятое решение. Для этого автору необходимо:

- исправить рукопись статьи согласно обоснованным комментариям рецензентов и редакторов;
- ясно изложить свою позицию по рассматриваемому вопросу.

Редакторы содействуют повторной подаче рукописей, которые потенциально могли бы быть приняты, однако были отклонены из-за необходимости внесения существенных изменений или сбора дополнительных данных, и готовы подробно объяснить, что требуется исправить в рукописи для того, чтобы она была принята к публикации.

ДЕЙСТВИЯ РЕДАКЦИИ В СЛУЧАЕ ОБНАРУЖЕНИЯ ПЛАГИАТА, ФАБРИКАЦИИ ИЛИ ФАЛЬСИФИКАЦИИ ДАННЫХ

Редакция научного журнала «Сибирский вестник сельскохозяйственной науки» в своей работе руководствуется традиционными этическими принципами научной периодики и сводом принципов «Кодекса этики научных публикаций», разработанным и утвержденным Комитетом по этике научных публикаций, требуя соблюдения этих правил от всех участников издательского процесса.

ИСПРАВЛЕНИЕ ОШИБОК И ОТЗЫВ СТАТЬИ

В случае обнаружения в тексте статьи ошибок, влияющих на ее восприятие, но не искажающих изложенные результаты исследования, они могут быть исправлены путем замены pdf-файла статьи. В случае обнаружения в тексте статьи ошибок, искажающих результаты исследования, либо в случае плагиата, обнаружения недобросовестного поведения автора (авторов), связанного с фальсификацией и/или фабрикацией данных, статья может быть отозвана. Инициатором отзыва статьи может быть редакция, автор, организация, частное лицо. Отозванная статья помечается знаком «Статья отозвана», на странице статьи размещается информация о причине ее отзыва. Информация об отзыве статьи направляется в базы данных, в которых индексируется журнал.

УВАЖАЕМЫЕ ПОДПИСЧИКИ!

Подписку на журнал «Сибирский вестник сельскохозяйственной науки»
(как на годовой комплект, так и на отдельные номера)
можно оформить одним из следующих способов:

– в агентстве подписки ГК «Урал-Пресс» по индексу 014973. Ссылка на издание https://www.ural-press.ru/catalog/97210/8707659/?sphrase_id=392975. В разделе контакты зайти по ссылке http://ural-press.ru/contact/, где можно выбрать филиал по месту жительства;
– в редакции журнала (телефон 7-383-348-37-62; e-mail: sibvestnik@sfsca.ru).

Полнотекстовая версия журнала
«Сибирский вестник сельскохозяйственной науки»
размещена на сайте Научной электронной библиотеки:
http://www.elibrary.ru.