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

Volume 52 No 2 2022

SIBERIAN HERALD OF AGRICULTURAL SCIENCE

No 2
Volume 52

MARCH – APRIL 2022

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 6 ISSUES PER YEAR

Volume 52, No 2 (285)
DOI: 10.26898

2022
March – April

www. sibvest.elpub.ru

Editors *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
Address: PO Box 463, office 456, SFSCA RAS Building, Krasnoobsk, Novosibirsk District,
Novosibirsk Region, 630501, Russia. Tel/fax: +7-383-348-37-62
e-mail: sibvestnik@sfsca.ru, vestnik.nsk@ngs.ru; www. sibvest.elpub.ru

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 ШЕСТЬ РАЗ В ГОД

Том 52, № 2 (285) **2022**

DOI: 10.26898 март – апрель

www. sibvest.elpub.ru

Редакторы *Е.В. Мосунова, Г.Н. Ягупова.* Корректор *В.Е. Селянина*. Оператор электронной верстки *Н.Ю. Бориско.* Переводчик *М.Ш. Гаценко*
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: 630501, Новосибирская обл., Новосибирский р-н, р.п. Краснообск, здание СФНЦА РАН, к. 456, а/я 463
Тел./факс (383)348-37-62 e-mail: sibvestnik@sfsca.ru, vestnik.nsk@ngs.ru; https://sibvest.elpub.ru/jour

Вышел в свет 25.05.2022. Формат 60 × 84 1/8. Бумага тип. № 1. Печать офсетная. Печ. л. 14,75.
Уч-изд. л. 15,25. Тираж 300 экз. Цена свободная.

Отпечатано в Сибирском федеральном научном центре агробиотехнологий Российской академии наук

СОДЕРЖАНИЕ

CONTENTS

СОДЕРЖАНИЕ

СОДЕРЖАНИЕ

https://doi.org/10.26898/0370-8799-2022-2-1
УДК: 631.427
Тип статьи: оригинальная
Type of article: original

РАЗЛОЖЕНИЕ ЦЕЛЛЮЛОЗЫ В ПРИКОРНЕВОЙ ЗОНЕ ЯРОВОЙ ПШЕНИЦЫ, ВОЗДЕЛЫВАЕМОЙ С ПРИМЕНЕНИЕМ ПРЕПАРАТОВ БИОВАЙС, ТУРМАКС И АЗОТНОГО УДОБРЕНИЯ

(✉) **Власенко Н.Г., Теплякова О.И.**
Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: nvlasenko@sfsca.ru

Изучено влияние обработки семян препаратами БиоВайс Спринт и ТурМакс на целлюлозолитическую активность чернозема выщелоченного под посевом яровой пшеницы в лесостепной зоне Приобья. Эксперимент проведен в 2020, 2021 гг. в ризосферном слое почвы под посевом пшеницы сорта Новосибирская 31, которую размещали второй культурой после пара по зерновому предшественнику на двух фонах азотного питания – N_0 и N_{60}. Целлюлозолитическую активность почвы определяли стандартным методом – по потере массы внесенного в почву целлюлозосодержащего полотна. Показано, что на данный показатель влияют условия вегетационного периода. В 2021 г. целлюлозолитическая активность почвы в ризосфере пшеницы была выше, чем в 2020 г., как на фоне без внесения удобрения – на 36,6%, так и при их применении – на 119,54%. Распад ткани усиливался в 1,3–1,4 раза, если высевали семена, обработанные БиоВайсом Спринт, и в 1,3 раза при использовании ТурМакса. На удобренном фоне в 2020 г. при применении ТурМакса целлюлозолитическая активность почвы усиливалась в 1,6 раза, БиоВайса – в 1,3 раза. В 2021 г. при обработке семян БиоВайсом показатель увеличивался в 2,8 раза, ТурМаксом – в 2,2 раза. Полученные результаты не позволяют выделить очевидное преимущество одного из двух изучаемых препаратов, но на их основании можно заключить, что обработка семян и ТурМаксом, и БиоВайсом Спринт способна усилить целлюлозолитическую активность почвы, особенно на фоне применения азотного удобрения.

Ключевые слова: целлюлозолитическая активность почвы, прикорневая зона пшеницы, БиоВайс, ТурМакс, азотное удобрение

DECOMPOSITION OF CELLULOSE IN THE ROOT ZONE OF SPRING WHEAT CULTIVATED WITH THE USE OF BIOVAYS, TURMAX AND NITROGEN FERTILIZER

(✉) **Vlasenko N.G., Teplyakova O.I.**
Siberian Federal Scientific Center of Agro-Biotechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia
(✉) e-mail: nvlasenko@sfsca.ru

The effect of BioVays Sprint and TurMax seed treatment on cellulosolytic activity of leached chernozem under spring wheat in the forest-steppe zone of the Priob'ye region was studied. The experiment was conducted in 2020-2021 in the rhizosphere layer of soil under the Novosibirskaya

31 wheat, which was placed as the second crop after the fallow on the grain forecrop on two backgrounds of nitrogen nutrition - N_0 and N_{60}. Cellulosolytic activity of soil was determined by the standard method - by the weight loss of cellulosic cloth introduced into the soil. It was shown that this indicator is influenced by the conditions of the growing season. In 2021, soil cellulosolytic activity in the wheat rhizosphere was higher than in 2020, both in the background without fertilizer application, by 36.6%, and with their application, by 119.54%. Tissue decay increased 1.3-1.4-fold if seeds treated with BioVays Sprint were sown, and 1.3-fold if TurMax was used. On the fertilized background in 2020, the application of TurMax increased the cellulosolytic activity of the soil by 1.6 times, BioVays by 1.3 times. In 2021, seed treatment with BioVays increased the indicator by 2.8 times and with TurMax by 2.2 times. The results obtained do not allow to identify an obvious advantage of one of the two preparations studied, but on their basis, it can be concluded that treatment of seeds with both TurMax and BioVays Sprint is able to increase the cellulolytic activity of the soil, especially against the background of nitrogen fertilizer application.

Keywords: cellulosolytic activity of soil, wheat root zone, BioVays, TurMax, nitrogen fertilizer

Для цитирования: *Власенко Н.Г., Теплякова О.И.* Разложение целлюлозы в прикорневой зоне яровой пшеницы, возделываемой с применением препаратов БиоВайс, ТурМакс и азотного удобрения // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 5–11. https://doi.org/10.26898/0370-8799-2022-2-1. . EDN AIEBMD.

For citation: Vlasenko N.G., Teplyakova O.I. Decomposition of cellulose in the root zone of spring wheat cultivated with the use of BioVays, TurMax and nitrogen fertilizer. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2021, vol. 52, no. 2, pp. 5–11. https://doi.org/10.26898/0370-8799-2022-2-1. EDN AIEBMD.

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

INTRODUCTION

The urgent task of modern agriculture is to obtain high crop yields by means of biologically based agricultural technologies in which energy-intensive agrochemicals are replaced by new-generation preparations [1, 2]. Biopreparation BioVays, which contains a consortium of highly effective strains isolated from the soil strains Azotobacter chroococcum, Bacillus mucilaginosus, B. megaterium, B. subtilis, B. phosphaticum, is a new bacterial fertilizer that improves the provision of nitrogen, phosphorus and silicon for plants. In addition, the drug has fungicidal properties [3]. This preparation showed its effectiveness on spring and winter wheat in the conditions of the south of the Russian Federation and in Siberia [1,2] [4]. The active ingredient in the TurMax preparation is a natural mixture of oligosaccharides, amino acids, phytohormones and vitamins. BioVays was effective on spring wheat crops in Siberia [4], winter wheat in the Altai Territory[3] and in potato cultivation in Tomsk Oblast [5-7].

Inoculation of spring wheat seeds with biological preparations of associative nitrogen fixers, including BioVays, generally has a stimulating effect on the biological activity of the rhizosphere of cultivated wheat, promotes the development of nitrifying and phosphate-mobilizing bacteria useful for plant nutrition, and increases cellulolytic activity of the soil [8].

The intensity of pulp decomposition in the soil is an integrated indicator of its biological activity, which depends on the established fer-

[1] Khamova O.F. From the history of the use of microbial preparations in agriculture of the Omsk Priirtyshye // Collection of scientific articles devoted to the 190th anniversary of experimental work in Siberia, the 100th anniversary of agricultural science in the Omsk Priirtyshye and the 85th anniversary of the Siberian Research Institute of Agriculture. Omsk, 2018. pp. 82-84.

[2]Khamova O.F. Effectiveness of biological preparations in spring wheat crops // Collection of scientific articles devoted to the 70th anniversary of RAS academician Ivan Khramtsov, the 95th anniversary of the department of agriculture FSBSI "Omsk ASC". Omsk, 2020. pp. 118-120.

[3]Usenko V.I., Litvintsev P.A., Litvintseva T.A. Effectiveness of mineral and bacterial fertilizers on winter wheat in the forest-steppe of the Altai territory // Scientific support of grain production in the Altai territory: collection of articles. Barnaul, Altai NIISKh, 2016. pp. 127-132.

tility, as well as on the weather conditions of the growing season. The cellulosolytic capacity of the soil can serve as a characteristic of organic matter transformation, the involvement of hard-to-reach forms of carbon in the biological cycle, and ultimately determines the level of the soil fertility and biota productivity [9].

The purpose of the study was to study the effect of the treatment of seeds with BioVays and TurMax on the process of cellulose decomposition in the soil of the root layer of spring soft wheat in the forest-steppe of the Priob'ye region.

MATERIAL AND METHODS

Studies were conducted in 2020, 2021 in the experimental field of the plant protection laboratory of the Siberian Federal Scientific Center of AgroBioTechnologies RAS. The Soil was leached chernozem, middle loamy, medium-powered. Wheat variety Novosibirskaya 31 was sown as the second crop after the fallow of spring wheat. The autumn tillage was deep loosening with SibIME tines. Sowing - May 14 and 21, by SZS-2,1 seeder with anchor coulters, the seeding rate of 6 million germinated grains/ha. Biovays Sprint and TurMax preparations were used for seed treatment, which was carried out with wetting (10 l/t), the application rate was 0.25 kg/t and 0.25 l/t, respectively. Experiments were placed on two backgrounds of nitrogen nutrition: without fertilizer application; with application of 60 kg d.w. N/ha. During the growing season a herbicide tank mixture treatment with Axial, SE (1.0 l/ha) + Primadonna, SE (0.4 l/ha) + Hextar, VDG (10 g/ha) against monocotyledonous and dicotyledonous weeds was performed in the phase of wheat tillering. Wheat was treated with Titul Duo fungicide, KKR (0.32 l/ha) in the ear formation phase. The intensity of cellulose decomposition was determined by a standard method - by the weight loss of the cellulose web introduced into the soil [10, 11]. Capron bags with the material fixed on a sterile glass (six repetitions) were introduced into the soil section of the rhizosphere layer (0-10 cm) in the phase of full sprouts, adjacent to the plant roots formed at the depth of the seed embedding. The exposure time of the canvases was 90 days. Statistical data processing was performed using Statistica 7.0, Snedecor[4].

The studies were conducted in the years contrasting in humification. The sum of precipitation for May, June, July and August in 2020 was 54.4; 23.8; 84.9 and 82.0 mm, respectively (245 mm total for the growing season 2020), average daily temperature was 16.5; 16.6; 19.7 and 18.6 °C; in 2021 - 34.0; 71.0; 36.0 and 44.0 mm (for the growing season 185.0 mm) and 15.1; 17.2; 21.0 and 19.1 °C respectively.

RESULTS AND DISCUSSION

In 2021 the cellulosolytic activity of the soil in the wheat rhizosphere was higher than in 2020 both against the background without fertilization - on average by 36,6% in the experiment, and with their application - by 119,54% (the degree of influence of the factor year by Snedekor on N0 = 53,4, on N60 = 65,1%) (see the table).

The effect of seed treatment on cellulose decomposition was weaker (the degree of influence by Snedekor on N0 = 29.4, on N60 = 18.2%), but tissue utilization increased by 27.9-38.7 and 56.36-79.38% respectively to the levels of fertilizer application. In both seasons, the percentage of decomposed tissue in the experimental variants increased against the background of nitrogen fertilizer application (see Fig. 1).

In general, during 2 years in the soil, where no fertilizer was applied, the intensity of cellulose decomposition relative to N60 decreased by 1.6 times in the rhizosphere of wheat control variant, in the variant with the application of TurMax - by 1.97, with BioVays - by 2.2 times. Comparing the intensity of cellulose decomposition in the experimental variants it was found that a significant difference between them appeared in 2020 on the background without fertilizer application and in both years on the background of its application. The decomposition of tissue increased by 1.6 and 1.4 times if the seeds treated with BioVays Sprint on the

[4]Sorokin O.D. Applied statistics on the computer. 2nd ed. Novosibirsk, 2012. 282 p.

Разложение целлюлозы под яровой пшеницей, выращиваемой с применением препаратов Био-Вайс Спринт и ТурМакс
Cellulose decomposition under spring wheat grown with BioVays Sprint and TurMax

Nitrogen fertilizer dosage	Seed treatment	Loss of tissue weight, mg		
		2020	2021	Average
N_0	No treatment (control)	83,33 ± 4,21	101,67 ± 4,77	92,50 ± 2,81
	TurMax	93,33 ± 3,33	143,33 ± 6,15	118,33 ± 4,01
	BioVays Sprint	110,00 ± 11,54	146,67 ± 7,15	128,34 ± 7,38
		95,55	130,56	
	LSD_{05} for the factors: year = 6,25, seed treatment = 7,65, partial averages = 10,82			
N_{60}	No treatment (control)	103,33 ± 9,54	171,67 ± 7,03	137,50 ± 3,59
	TurMax	121,67 ± 11,66	308,33 ± 27,74	215,00 ± 14,94
	BioVays Sprint	150,00 ± 11,54	343,30 ± 17,64	246,65 ± 9,46
		125,00	274,43	
	LSD05 for the factors: year = 14,92, seed treatment = 18,27, partial averages = 25,84			

background without fertilizer application, and by 1.5 and 2.3 times against the background of N_{60}. When using TurMax the corresponding figures were 1.3; 1.4 and 1.7 times.

During one day in the experimental variants 0,17-0,58% (TurMax) and 0,22-0,79% (Bio-Weiss Sprint) of the introduced fabric were utilized, which is on the average 1,5-2,0 times higher than in the control (see Fig. 2).

It is known that the application of nitrogen fertilizer to the chernozem soil can almost double the cellulosolytic activity of its upper (0-10 cm) layer [12]. In our experiments, a similar increasing index was 1.5 times (2020) and 1.7 times (2021). As a result, according to Zvyagintsev's scale[5] (very weak - <10%, weak - 10-30, medium - 30-50, strong - 50-80, very strong -> 80%) high intensity of cellulose destruction

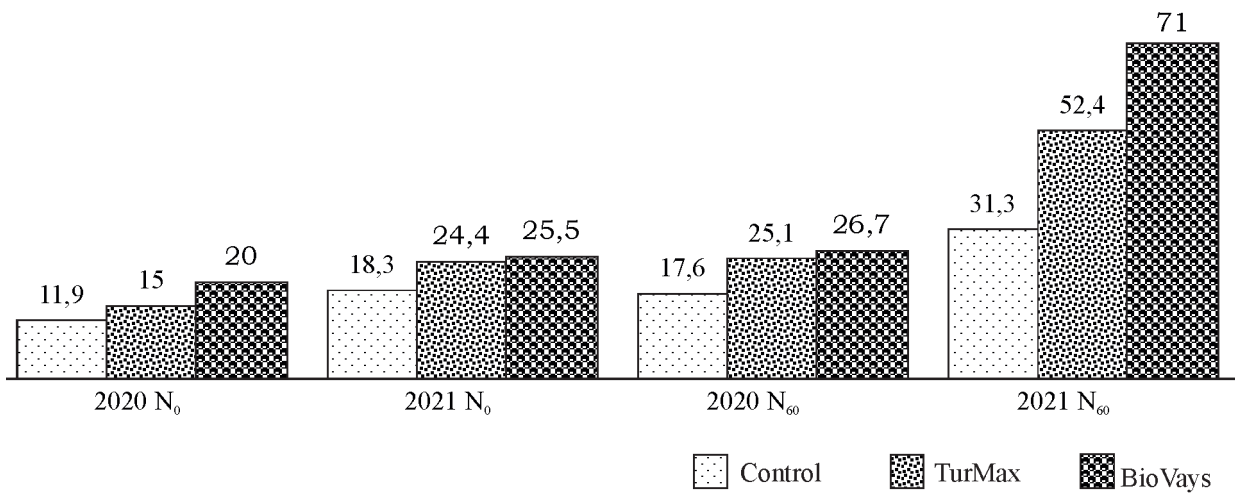

Рис. 1. Количество утилизированной целлюлозы под яровой пшеницей, выращиваемой на двух уровнях азотного питания с применением препаратов ТурМакс и БиоВайс, %

Fig. 1. Amount of utilized cellulose under spring wheat grown on two levels of nitrogen nutrition with application of TurMax and BioVays preparations, %

[5]Methods of soil microbiology and biochemistry: textbook / edited by D.G. Zvyagintsev. Moscow: Publishing house of Moscow State University. 1991. 304 p.

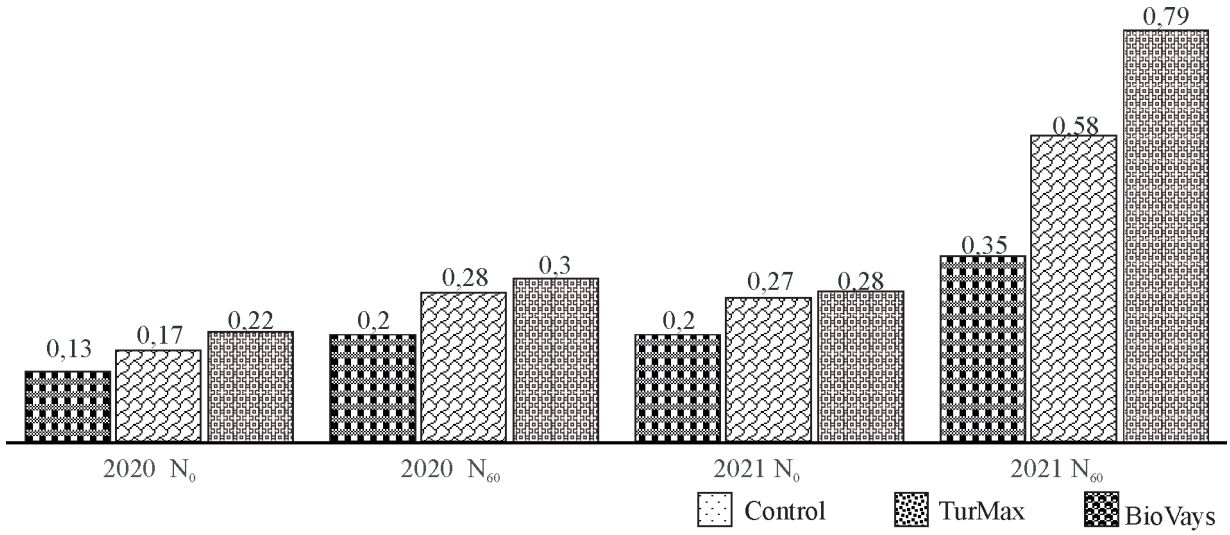

Рис. 2. Ежесуточный процент разложения целлюлозы под яровой пшеницей, выращиваемой на двух уровнях азотного питания с применением препаратов ТурМакс и БиоВайс Спринт, %

Fig.2. Daily percentage of cellulose decomposition in spring wheat grown on two levels of nitrogen nutrition with the use of TurMax and BioVays Sprint, %

was recorded only in one of two seasons - under wheat grown from BioVays Sprint and TurMax treated seeds, on nitrogen fertilized (N_{60}) soil. In the first case, the level of cellulosolytic activity can be characterized as strong, in the second - medium, in the control soil (tissue decay 11.88 and 18.3% of the initial weight of the web) - weak. Daily higher intensity of cellulose decomposition was traced in the variant with BioVays Sprint seed treatment.

CONCLUSION

The study of cellulosylitic activity of soil rhizosphere of spring wheat showed the effect of BioVays and TurMax on this process. The results obtained do not allow us to identify an obvious advantage of one of the two studied preparations, but on the basis of them we can conclude that the treatment of seeds with both TurMax and BioVays Sprint can cause the effect of increasing cellulolytic activity of the soil, especially against the background of nitrogen fertilizer application.

СПИСОК ЛИТЕРАТУРЫ

1. *Дегтярева И.А., Яппаров И.А., Хидиятуллина А.Я.* Биологические подходы к повышению урожайности сельскохозяйственных культур // Ученые записки Казанской государственной академии ветеринарной медицины им. Н.Э. Баумана. 2013. Т. 215. С. 91–96.
2. *Боровая В.П.* Биовайс на посевах озимой пшеницы // Защита и карантин растений. 2013. № 4. С. 30–35.
3. *Ступина Л.А.* Влияние стимуляторов роста и азотных минеральных удобрений на микробиологическую активность чернозема выщелоченного и урожайность яровой пшеницы в условиях Алейской степи Алтайского края // Вестник Алтайского государственного аграрного университета. 2019. № 3 (173). С. 5–11.
4. *Ступина Л.А.* Влияние азотных минеральных удобрений и биостимуляторов «Биовайс» и «Турмакс» на минеральное питание и урожайность яровой пшеницы в условиях Алейской степи Алтайского края // Вестник Алтайского государственного аграрного университета. 2019. № 6 (176). С. 16–21.
5. *Галеев Р.Р., Сергеева О.Н., Перченко Н.А.* Органоминеральный препарат для повышения продуктивности и снижения заболеваемости картофеля в условиях Томской области // Вестник Новосибирского государственного аграрного университета. 2018. № 4 (49). С. 18–24. DOI: 10.31677/2072-6724-2018-49-4-18-24.
6. *Перченко Н.А., Сергеева О.Н.* Эффективность препарата ТурМакс при возделывании картофеля в условиях Томской об-

ласти // Российская сельскохозяйственная наука. 2020. № 5. С. 34–37. DOI: 10.31857/S2500262720050087.
7. *Сергеева О.Н., Перченко Н.А., Шипилин Н.Н.* Применение органоминеральной добавки ТурМакс при возделывании картофеля // Вестник Новосибирского государственного аграрного университета. 2013. № 4 (29). С. 36–40.
8. *Хамова О.Ф., Ледовский Е.Н., Тукмачева Е.В., Шулико Н.Н.* Влияние бактериальных препаратов на биологическую активность чернозема выщелоченного и урожайность зерновых культур // Вестник Омского государственного аграрного университета. 2016. № 3 (23). С. 44–48.
9. *Хасанова Р.Ф., Аблаева А.Р., Суюндуков Я.Т.* Биологическая продуктивность многолетних трав и целлюлозолитическая активность чернозема обыкновенного // Современные проблемы науки и образования. 2012. № 5. С. 283–290.
10. *Буянтуева Л.Б., Никитина Е.П.* Исследование интенсивности процессов микробной деструкции органического вещества в сухостепных почвах Юго-Западного Забайкалья с использованием аппликационных методов // Природа Внутренней Азии. 2018. № 3 (8). С. 28–37. DOI: 10.18101/2542-0623-2018-3-28-37.
11. *Гаврилова В.И., Герасимова М.И.* Целлюлозолитическая активность почв: методы измерения, факторы и экологическая изменчивость // Вестник Московского государственного университета. Сер. 17. Почвоведение. 2019. № 1. С. 23–27.
12. *Еремин Д.И., Попова О.Н.* Влияние минеральных удобрений на интенсивность разложения целлюлозы в пахотном черноземе лесостепной зоны Зауралья // Вестник государственного аграрного университета Северного Зауралья. 2016. № 4 (35). С. 27–33.

REFERENCES

1. Degtyareva I.A., Yapparov I.A., Khidiyatullina A.Ya. Biological approaches to increasing of the productivities of the agricultural cultures. *Uchenye zapiski Kazanskoi gosudarstvennoi akademii veterinarnoi meditsiny im. N.E. Baumana = Scientific Notes Kazan Bauman State Academy of Veterinary medicine*, 2013, vol. 215, pp. 91–96. (In Russian).
2. Borovaya V.P. BioVays on winter wheat crops. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine*, 2013, no. 4, pp. 30–35. (In Russian).
3. Stupina L.A. The influence of growth stimulators and nitrogen mineral fertilizers on microbiological activity of leached chernozem and spring wheat yield in the Aley steppe of the Altai region. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural university*, 2019, no. 3 (173), pp. 5–11. (In Russian).
4. Stupina L.A. The influence of nitrogen mineral fertilizers and biological growth stimulants BioVays and TurMax on mineral nutrition and yield of spring wheat in the Aley steppe of the Altai region. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2019, no. 6 (176), pp. 16–21.
5. Galeev R.R., Sergeeva O.N., Perchenko N.A. Organomineral specimen for increasing potato yield and reducing its disease level under conditions of Tomsk region. *Vestnik Novosibirskogo gosudarstvennogo agrarnogo universiteta = Bulletin of NSAU*, 2018, no. 4 (49), pp.18–24. (In Russian). DOI: 10.31677/2072-6724-2018-49-4-18-24.
6. Perchenko N.A., Sergeeva O.N. Effectiveness of TurMax in potato cultivation under the conditions of the Tomsk region. *Rossiiskaya sel'skokhozyaistvennaya nauka = Russian Agricultural Sciences*, 2020, no. 5, pp. 34–37. (In Russian). DOI: 10.31857/S2500262720050087
7. Sergeeva O.N., Perchenko N.A., Shipilin N.N. Application of TurMax organomineral additive in potato cultivation. *Vestnik Novosibirskogo gosudarstvennogo agrarnogo universiteta = Bulletin of NSAU*, 2013, no. 4 (29), pp. 36–40. (In Russian).
8. Khamova O.F., Ledovskii E.N., Tukmacheva E.V., Shuliko N.N. Influence of bacterial fertilizer on the biological activity of leached chernozem and cereal crops productivity. *Vestnik Omskogo gosudarstvennogo agrarnogo universiteta = Vestnik of Omsk SAU*, 2016, no. 3 (23), pp. 44–48. (In Russian).
9. Khasanova R.F., Ablaeva A.R., Suyundukov Ya.T. Biological productivity of perennial grasses and cellulolytic activity of ordinary chernozem. *Sovremennye problemy nauki i obrazovaniya = Modern problems of science and education*, 2012, no. 5, pp. 283–290. (In Russian).
10. Buyantueva L.B., Nikitina E.P. Investigation of the intensity of organic matter microbial

decomposition in arid steppe soils of South-Western Transbaikal by application methods. *Priroda Vnutrennei Azii = Nature of Inner Asia*, 2018, no. 3 (8), pp. 28–37. (In Russian). DOI: 10.18101/2542-0623-2018-3-28-37.

11. Gavrilova V.I., Gerasimova M.I. Cellulosolytic activity of soils: methods of measuring, factors, and geographic variability. *Vestnik Moskovskogo gosudarstvennogo universiteta. Ser. 17. Pochvovedenie = Bulletin of the Moscow University. Series 17. Soil Science*, 2019, no. 1, pp. 23–27. (In Russian).
12. Eremin D.I., Popova O.N. Influence of mineral fertilizers on the intensity of cellulose decomposition in the arable chernozem steppe Trans-Urals area. *Vestnik gosudarstvennogo agrarnogo universiteta Severnogo Zaural'ya = Bulletin of GAU SZ*, 2016, no. 4 (35), pp. 27–33. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Власенко Н.Г.,** доктор биологических наук, главный научный сотрудник; **адрес для переписки**: Россия, 630501, Новосибирская область, р.п. Краснообск; e-mail: nvlasenko@sfsca.ru

Теплякова О.И., кандидат биологических наук, старший научный сотрудник

AUTHOR INFORMATION

(✉) **Nataliya G. Vlasenko,** Doctor of Science in Biology, Head Researcher; **address:** Krasnoobsk, Novosibirsk region, 630501, Russia; e-mail: nvlasenko@sfsca.ru

Olga I. Teplyakova, Candidate of Science in Biology, Senior Researcher

Дата поступления статьи / Received by the editors 24.12.2021
Дата принятия к публикации / Accepted for publication 21.02.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-2
УДК: 631.53:631.816.1
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ УДОБРЕНИЙ И СРОКОВ ПОСЕВА НА КАЧЕСТВО СЕМЯН ЯРОВОГО ЯЧМЕНЯ В КРАСНОЯРСКОЙ ЛЕСОСТЕПИ

Сурин Н.А., (✉) Бутковская Л.К., Сурина Е.А.
Красноярский научно-исследовательский институт сельского хозяйства – обособленное подразделение Федерального исследовательского центра «Красноярский научный центр Сибирского отделения Российской академии наук»
Красноярск, Россия
(✉) e-mail: lidabut16@yandex.ru

По представленным результатам исследования отзывчивость сортов на внесение разных доз минерального питания оказалась более значительной по сравнению со сроками посевов. Дозы удобрений $N_{60}P_{30}K_{60}$ и $N_{90}P_{30}K_{60}$ повышали урожайность сортов ячменя Такмак, Абалак, Буян и перспективного образца Д-5-7022 на 1,2–1,8 т/га, массу 1000 зерен – на 2–6 г, всхожесть – на 1–4% по сравнению с контролем (без удобрений). Сорт Буян превысил урожайность всех изучаемых сортов на 0,2 т/га на удобренных фонах и в данной группе проявил себя как интенсивный (прибавка урожая к контролю – 1,8 т/га, *bi* (коэффициент линейной регрессии урожайности) = 1,34). Урожайность нового образца Д-5-7025 была выше районированных сортов в контроле без удобрений на 0,3–0,4 т/га. С внесением удобрений урожайность сортов Абалак, Такмак выравнивалась в среднем до 5,68 т/га при $N_{60}P_{30}K_{60}$ и до 5,85 т/га при $N_{90}P_{30}K_{60}$. Они менее требовательны к условиям возделывания и более пластичны. Элементы структуры урожайности, продуктивный стеблестой, озерненность колоса и масса 1000 зерен в целом влияли на ее повышение во втором сроке посева на интенсивных агрофонах. Величина развитости проростков семян, как и урожайность, в меньшей степени зависела от сроков посева, а больше – от внесения удобрений. При дозе $N_{90}P_{30}K_{60}$ все показатели развитости проростков увеличились на 1,2–2,5 см по сравнению с контролем. Использование оптимального срока посева (27 мая) при сумме активных температур 182,8° и рекомендованная доза удобрений $N_{90}P_{30}K_{60}$ позволили увеличить выход семян сортов ячменя Такмак, Абалак, Буян и нового образца Д-5-7022 в среднем на 20–30%.

Ключевые слова: яровой ячмень, посевные качества, минеральное питание, сроки посева, дозы удобрений, развитость проростков

INFLUENCE OF FERTILIZERS AND SOWING DATES ON THE QUALITY OF SPRING BARLEY SEEDS IN THE KRASNOYARSK FOREST-STEPPE

Surin N.A., (✉) Butkovskaya L.K., Surina E.A.
Krasnoyarsk Research Institute of Agriculture - separate division of FRC KSC SB RAS
Krasnoyarsk, Russia
(✉) e-mail: lidabut16@yandex.ru

According to the presented results of the study, the responsiveness of varieties to the application of different doses of mineral nutrition was more significant compared to the sowing dates. Doses of fertilizers $N_{60}P_{30}K_{60}$ and $N_{90}P_{30}K_{60}$ increased the barley yield of varieties Takmak, Abalak, Buyan and a promising sample D-5-7022 by 1,2-1,8 t/ha, weight of 1000 grains by 2-6 g, germination - by 1-4% as compared to the control (without fertilizers). The Buyan variety exceeded the yield of all

the varieties studied by 0.2 t / ha on a fertilized background and in this group proved to be intensive (increase in yield to control - 1.8 t / ha, bi (linear regression coefficient of yield) = 1.34). The yield of the new sample D-5-7025 was 0.3-0.4 t/ha higher than the released varieties in the control without fertilizers. With fertilization the yield of Abalak, Takmak varieties leveled off to an average of 5.68 t/ha at $N_{60}P_{30}K_{60}$ and to 5.85 t/ha at $N_{90}P_{30}K_{60}$. They are less demanding to the conditions of cultivation and more plastic. Elements of yield structure, productive stem, ear grain content and 1000 grains weight generally influenced its increase in the second sowing term on intensive agricultural backgrounds. The size of the development of seedlings, as well as the yield was less dependent on the sowing dates, but more on the application of fertilizers. At a dose of $N_{90}P_{30}K_{60}$ all indicators of seedling development increased by 1.2-2.5 cm compared with the control. The use of optimal sowing date (May 27) with the sum of active temperatures of 182,8° and the recommended dose of fertilizers $N_{90}P_{30}K_{60}$ made it possible to increase the yield of barley seeds of Takmak, Abalak, Buyan and the new sample D-5-7022 on average by 20-30%.

Keywords: spring barley, sowing qualities, mineral nutrition, sowing time, fertilizer doses, seedlings development

Для цитирования: *Сурин Н.А., Бутковская Л.К., Сурина Е.А.* Влияние удобрений и сроков посева на качество семян ярового ячменя в красноярской лесостепи // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 12–21. https://doi.org/10.26898/0370-8799-2022-2-2. EDN ANZIDI.

For citation: Surin N.A., Butkovskaya L.K., Surina E.A. Influence of fertilizers and sowing dates on the quality of spring barley seeds in the Krasnoyarsk forest-steppe. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 2, pp. 12–21. https://doi.org/10.26898/0370-8799-2022-2-2. EDN ANZIDI.

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

INTRODUCTION

Crop seed quality is the primary basis for effective use of modern varieties in production. Creation of favorable agrotechnical conditions (sowing dates, seeding rates, fertilizer systems) for the growth and development of crop varieties allows to some extent reduce the dependence of plants on the effects of adverse environmental factors and to form quality seeds [1].

It is possible to create optimal moisture supply and favorable nutritional conditions for grain crops in the forest-steppe zone of the Krasnoyarsk region through the rational use of summer precipitation by changing the timing of sowing, as well as through the selection of optimal doses of fertilizers and forecrops [2, 3].

Among the many technological processes that affect the formation of yield and seed quality, the most significant and controllable techniques are the use of mineral fertilizers, the use of different rates and timing of sowing [4].

The timing of sowing influences the yield, sowing qualities, and yield properties of seeds to the extent that they coincide with favorable environmental conditions. The study of crop varieties shows that for some varieties a late sowing date is impossible, while for others it is acceptable. The timing of sowing is decided taking into account the onset of biological and physical ripeness of the soil, the distribution of heat and moisture during the growing season, etc. Therefore, the effect of the timing of sowing on the yield is often more effective than other agronomic techniques [5].

In the conditions of the Krasnoyarsk region a high yield of seeds with good sowing qualities can be obtained only with a balanced ratio of nutrients. The germination energy of spring barley seeds grown on a fertilized background often increases by 14% and germination - by 10% in comparison with those grown on an unfertilized one. High results in obtaining high-quality seeds provide phosphate fertilizers, increasing field germination, contributing to accelerated and uniform maturation of plants, increasing resistance to lodging. Seeds on such a background are formed with high sowing and yield qualities [6]. In wet years, there is a tendency to increase germination in improved conditions of mineral nutrition, and in unfavorable years, the completeness of germination in the presence of fertilizers

decreases. The increase in field germination in fertilized backgrounds can be explained by the greater availability of phosphorus, which is involved in metabolic processes immediately at seed germination [7].

Improvement of mineral nutrition conditions by applying the basic fertilizer has a positive effect on the yield structure. Close connections of yield with such parameters as the number of productive shoots and grain weight per ear were revealed [8].

The main characteristics of seed quality, reflecting their suitability for sowing are germination energy, laboratory and field germination, weight of 1000 grains, etc. For a more in-depth comprehensive assessment of the yield properties of variety seeds, morphophysiological evaluation of seedling organs of cereal crops is additionally used. Such indicators as seedling height, average coleoptile length, length of germinal roots and their number are evaluated [9]. When breeding new varieties, it is necessary to create such conditions that would contribute to the formation of large grains (large mass of 1000 grains), increasing the number of grains in the ear and productive stem per square meter, affecting the amount of the yield [10].

The purpose of the research is to develop a seed-growing technology of cultivation of new barley varieties for seeds depending on the timing of sowing and different doses of fertilizers, providing an increase in the yield of quality barley seeds by 20-30%.

MATERIAL AND METHODS

Weather conditions of the growing season 2020 were characterized by sufficient moisture in all months. Sprouting phase of cereal crops took place with good moisture, in the first decade of May there were abundant rains, which contributed to the appearance of friendly sprouts. The largest amount of precipitation fell in June and July, higher by 53.3 and 83.6 mm compared with the average annual data.

Spring was warm according to temperature distribution. Monthly average temperature in May was 14.2°C, which exceeded the long-term average by 3.2°C. In June and July air temperatures were close to the long-term average annual indicators.

Weather conditions of the growing season 2021 were characterized by a lack of moisture. May and July were particularly dry, with precipitation 13.7 and 28.5 mm below the long-term average. Precipitation in June was 58.8 mm greater than the long-term average. Spring was cool, and mean monthly temperatures in May were 0.5°C below average. Summer months were warm, with average monthly temperatures in June, July and August 1.0-1.7°C above the long-term average.

An important indicator determining the degree and speed of crop ripening is the sum of active temperatures above 10 °C. This indicator averaged 1897.4° in 2020, 2021. This amount of active temperatures allowed to ensure the ripening of the studied varieties of crops. Along with good heat supply during vegetation period 2020, 2021 on average 261.8 mm of precipitation fell. The HTC was 1.38. The average perennial amount of precipitation for the year in the region is 370 mm. The multiyear HTC was 1.25.

Agrotechnical experiments were carried out in the experimental fields of Krasnoyarsk Research Institute of Agriculture (KrasNIISKh) in the village of Minino. The seeds of released barley varieties Takmak, Abalak, Buyan and promising sample of KrasNIISKh selection - D-5-7022 - were used as research objects.

Buyan. Originator - KrasNIISKh Rosselkhozacademy.

Pedigree: Cedar × Jo 1345 (Finland). Nutans variety. Weight of 1000 grains is 43-54 g. Average yield in the region - 24,0 c/ha. In the area recommended for cultivation of the Krasnoyarsk Territory the increase to the standard Acha was 4.3 cwt/ha with an average yield of 47.2 cwt/ha. The maximum yield of 68.9 cwt/ha was obtained in the Krasnoyarsk Territory in 2011. Late maturing, with a vegetation period of 77-99 days, ripening 8-11 days later than the Acha standard. Grain forage. Protein content 8.1-15.2%.

Abalak. Originators and patent holders are KrasNIISKh Rosselkhozakademy, Research Institute of Agriculture of the Northern Trans-Urals.

Pedigree: U-53-8515 × Sa46925. Included in the State Register of breeding achievements for the East Siberian (11) region. Weight of 1000 grains is 42-55 g. The average yield in the tolerance region was 26.8 c/ha, exceeding the average standard by 2.2 c/ha. The maximum yield of 62.6 cwt/ha was obtained in the Krasnoyarsk Territory in 2011. Medium early, growing season 72-89 days, ripening 2-3 days earlier than sort Acha and 2-3 days later than sort Biom. Valuable by quality. Protein content 9.1-14.5%.

Takmak. Pedigree: Priazovsky 9 × [(Wiener × Omsk 13709) × (Wiener × Donetsk 650)]. The variety is included in the State Register of breeding achievements allowed for use in the East Siberian (11) region. Variety Nutans. Weight of 1000 grains is 40-50 g. The maximum yield of 60.8 t/ha was obtained in 2018 in the Krasnoyarsk Territory. Medium-maturing, vegetation period 73-92 days, ripening 3-6 days later than standards Acha and Biom. Valuable by quality. Protein content 11.6-15.9%. Moderately resistant to head smut.

D-5-7022. A promising breeding line of KrasNIISKh breeding. Obtained from crossing the varieties Omsk 95 and Olenek. Variety Nutans. Represents the group of medium-maturing varieties. The mass of 1000 grains of 37-42 g. The yield in the competitive strain testing 4,5-4,9 t / ha. Protein content 14.4%, husk content 9.5%, oil content 2.3%.

Studies on the effect of different doses of fertilizers and timing of sowing on obtaining quality and high-yield barley seeds of varieties Takmak, Abalak, Buyan and the promising sample D-5-7022 were carried out according to the following scheme:

a) control (without mineral fertilizers);

b) fertilizer application ($N_{60}P_{30}K_{60}$), azophoska;

c) fertilizer application ($N_{90}P_{30}K_{60}$), azophoska + ammonium nitrate;

Sowing dates are May 20 (1st - early) and May 27 (2nd - late).

The soil of the experimental plot is represented by alpine heavy loamy leached chernozem, characterized by the following agrochemical parameters: humus content 3.8%, neutral reaction (pH_{sal} = 6.4), hydrolytic acidity 1.3 mg-eq / 100 g, nitrate nitrogen content - very low (3.3 mg / kg), labile phosphorus (by Chirikov) - very high (200-250 mg / kg), potassium - high (145 mg / kg).

Experiments were sown by SSFK-7 seeder, harvesting by Hege harvester. Grain was dried, cleaned from impurities, and weighed. Germination energy and germination rate were determined according to GOST 12036-66. Field experiments and observations were performed according to the methods[1] and recommendations[2].

Determination of the sprout length, coleoptile, germinal roots (central) and their number in the seedlings was carried out after 10 days in order to establish the different qualities of seeds by degree and rate of development as much as possible [9].

RESULTS AND DISCUSSION

In the experiments, different doses of fertilizers were applied at early (May 20) and late (May 27) sowing dates (see Fig. 1).

Generalization of science and practice shows that the choice of the optimal sowing period has a positive impact on the yield increase, seed uniformity, protein content in the grain, sowing qualities and contributes to reducing the total duration of the growing season by 5-7 days [11]. The conditions of mineral nutrition affect the whole complex of plant growth and development at all stages of organogenesis [12].

A later date increased the yield by 0.1-0.2 t/ha in all variants, the weight of 1000 grains increased by 1.1-1.3 g and germination by 1-2%.

The response of varieties to the application of mineral fertilizers was more significant in comparison with the timing of sowing. Doses of fertilizers $N_{60}P_{30}K_{60}$ and $N_{90}P_{30}K_{60}$ increased

[1]Dospekhov B.A. Methodology of field experience. Moscow: Agropromizdat, 1985. 240 p.

[2]Methodical recommendations for the production of elite seeds of grain, legume and cereal crops. M.: VASKHNIL, 1990. 39 p.

the yield of varieties Takmak, Abalak, Buyan and the sample D-5-7022 by 1.2-1.8 t/ha (see Table 1).

Moreover, the weight of 1000 grains increased on average by 2-6 g, and the germination rate increased by 1-4% (see Table 2).

To identify the response to changes in the growing conditions (fertilizer) the coefficient of linear regression of varieties yield (*bi*) according to the method of S.A. Eberhart and V.A. Russell [13] was calculated. The higher the value of the coefficient (*bi*> 1), the more responsiveness the variety has. In case of bi < 1, the variety responds weaker to changes in environmental conditions than the average of the whole set of varieties under study.

Buyan variety exceeded the yield of the studied varieties by 0.2 t/ha when using fertilizers and in this group showed itself as the most intensive (yield increase to the control of 1.8 t/ha, *bi* = 1.34). Varieties Abalak, Takmak, D-5-7022 were less demanding to the conditions of cultivation, the gain to the control without fertilizers respectively amounted to 1,41; 1,47; 1,13 t / ha, linear regression coefficients *bi* equal to 1.12; 1,2; 1,14.

In the control variant (without fertilizers) a promising sample D-5-7022 stood out among the varieties, the yield of which is higher than the released varieties by 0.3-0.4 t / ha.

According to some authors[3], the value of yield depends mainly on the density of the productive stem, the number of grains in the ear and 1000 grains weight. In our experiments with increasing the dose of mineral fertilizer to $N_{90}P_{30}K_{60}$ the productive stemming increased compared with the control on average over time by 45-101 pcs/m^2. The number of grains in the ear increased by 2-4 pcs, productive bushiness - by 0.1-0.5 (see Table 3).

It should be noted that basically all elements of the yield structure, with the exception of productive bushiness, influenced its increase at the late sowing date.

Additional characteristic of the yield properties of the seed lots are the parameters of seedling organs development of the studied varieties (see Table 4).

Рис. 1. Опытные делянки сортов ячменя с различными дозами удобрений
Fig. 1. Experimental plots of barley varieties with different doses of fertilizers

[3]Butkovskaya L.K., Kozulina N.S. Sowing time and seeding rate in the new wheat varieties cultivation for seeds // IOP Conf. Ser.: Earth Environ. Sci. 839. 2021. № 4. P. 1–5.

Табл. 1. Влияние различных доз удобрений на урожайность семян сортов ячменя, 2020, 2021 гг.
Table 1. Effect of different fertilizer doses on barley seed yields, 2020, 2021

Variety	Sowing date	Fertilizer dosage			Addition to the control		*bi*
		control	$N_{60}P_{30}K_{60}$	$N_{90}P_{30}K_{60}$	$N_{60}P_{30}K_{60}$	$N_{90}P_{30}K_{60}$	
Takmak	1st	4,32	5,52	5,82	1,20	1,50	1,20
	2nd	4,40	5,72	5,84	1,32	1,44	
	Average	4,36	5,62	5,83	1,26	1,47	
D-5-7022	1st	4,56	5,63	5,82	1,07	1,26	1,14
	2nd	4,86	5,73	5,88	0,87	1,02	
	Average	4,72	5,68	5,85	0,96	1,13	
Buyan	1st	4,44	5,74	5,91	1,30	1,47	1,34
	2nd	4,49	5,80	6,41	1,31	1,92	
	Average	4,46	5,77	6,26	1,31	1,8	
Abalak	1st	4,38	5,48	5,74	1,10	1,36	1,12
	2nd	4,42	5,69	5,88	1,27	1,46	
	Average	4,40	5,59	5,81	1,19	1,41	

Note. $LSD_{0,5}$ fertilizers – 1,2; $LSD_{0,5}$ variety – 0,3; $LSD_{0,5}$ sowing date – 0,2.

Табл. 2. Влияние различных доз удобрений на посевные качества семян сортов ячменя, 2020, 2021 гг.
Table 2. Influence of different fertilizer doses on the sown quality of barley varieties seeds, 2020, 2021

Variety	Fertilizer dosage	Germination rate, %		Average	Thousand-kernel weight, g		Average
		1st term	2nd term		1st term	2nd term	
Takmak	Control	84	85	84	46,2	46,4	46,3
	$N_{60}P_{30}K_{60}$	88	88	88	47,1	48,0	47,6
	$N_{90}P_{30}K_{60}$	87	89	88	48,0	49,2	48,6
D-5-7022	Control	84	86	85	41,5	45,2	43,4
	$N_{60}P_{30}K_{60}$	85	87	86	46,4	49,1	47,7
	$N_{90}P_{30}K_{60}$	89	89	89	49,2	49,1	49,2
Buyan	Control	84	86	85	48,1	50,1	49,1
	$N_{60}P_{30}K_{60}$	85	87	86	49,6	52,0	50,8
	$N_{90}P_{30}K_{60}$	86	90	88	53,0	53,6	53,3
Abalak	Control	89	91	90	45,8	46,0	45,9
	$N_{60}P_{30}K_{60}$	90	93	91	47,3	48,3	47,8
	$N_{90}P_{30}K_{60}$	90	93	91	48,9	49,7	49,3

Note. $LSD_{0,5}$ of the thousand-kernel weight: sowing date – 0,2; fertilizers – 0,3; variety – 0,2.

In the 1st period of sowing, the height of seedlings at the dose of $N_{90}P_{30}K_{60}$ was higher compared to the control by 0,9-1,5 cm, the length of the main root - by 1,4-2,7 cm, coleoptile length - by 0,2-0,3 cm. In the 2nd period, the height of seedlings was greater by 0.6-2.4 cm compared to the control, the length of the main root - by 0.3-2.0 cm, the length of coleoptile - by 0.5-0.6 cm. It should be noted that seedling development, as well as the yield, was registered higher in the 2nd term and on the fertilized crops.

Analysis of the average experimental data by dates and varieties showed that at higher doses of fertilizers at all stages of sowing, the indicators of seedling development exceeded the control by 1.2-2.5 cm (see Fig. 2).

Табл. 3. Влияние удобрений и сроков посева на структуру урожайности сортов ячменя, 2020, 2021 гг.

Table 3. Influence of fertilizers and sowing dates on the structure of barley varieties yield, 2020, 2021

Variety	Fertilizer dosage	Productive plant stand, pcs. /m²		Average	Number of grains in an ear, pcs.		Productive bushiness	
		Term			Term			
		1st	2nd		1st	2nd	1st	2nd
Takmak	Control	392	394	393	21	21	2,18	1,79
	$N_{60}P_{30}K_{60}$	424	448	435	22	23	2,56	2,07
	$N_{90}P_{30}K_{60}$	436	548	492	24	25	2,72	2,28
D-5-7022	Control	466	488	477	22	23	1,69	1,66
	$N_{60}P_{30}K_{60}$	502	504	503	24	24	1,61	1,55
	$N_{90}P_{30}K_{60}$	540	556	548	26	27	1,95	1,79
Buyan	Control	378	389	384	24	25	2,21	2,01
	$N_{60}P_{30}K_{60}$	404	424	414	26	27	2,61	2,21
	$N_{90}P_{30}K_{60}$	421	438	429	26	28	2,71	2,51
Abalak	Control	369	371	370	21	23	2,19	1,85
	$N_{60}P_{30}K_{60}$	402	414	408	22	24	2,44	2,12
	$N_{90}P_{30}K_{60}$	420	428	424	24	24	2,51	2,28

Note. $LSD_{0,5}$ of the productive plant stand: sowing date – 25; fertilizers – 30; variety – 35.

Табл. 4. Влияние удобрений и сроков посева на развитость проростков сортов ячменя, 2020, 2021 гг.

Table 4. Effect of fertilizers and sowing dates on the development of barley seedlings, 2020, 2021

Variety	Fertilizer dosage	Sprout height, cm		Main spine length, cm		Coleoptyl length, cm	
		Term					
		1st	2nd	1st	2nd	1st	2nd
Takmak	Control	17,2	17,4	6,2	9,3	4,1	4,1
	$N_{60}P_{30}K_{60}$	18,6	18,5	7,1	9,5	4,7	4,7
	$N_{90}P_{30}K_{60}$	18,6	19,8	8,9	9,6	4,8	4,7
D-5-7022	Control	17,0	19,2	5,8	4,8	4,8	4,5
	$N_{60}P_{30}K_{60}$	17,6	18,6	7,2	6,9	4,9	4,5
	$N_{90}P_{30}K_{60}$	17,9	19,8	8,2	6,8	5,0	5,0
Buyan	Control	18,1	18,8	6,8	8,8	4,0	4,2
	$N_{60}P_{30}K_{60}$	19,2	20,1	7,4	8,9	4,5	4,7
	$N_{90}P_{30}K_{60}$	19,6	20,4	7,4	9,0	4,8	4,8
Abalak	Control	17,3	18,0	7,2	8,0	5,0	5,4
	$N_{60}P_{30}K_{60}$	18,4	19,6	8,8	9,0	5,2	5,4
	$N_{90}P_{30}K_{60}$	18,6	19,6	8,9	9,4	5,0	5,2

CONCLUSIONS

1. The barley varieties under study responded more significantly to the application of mineral nutrition compared to the timing of sowing. Doses of fertilizers $N_{60}P_{30}K_{60}$ and $N_{90}P_{30}K_{60}$ increased the barley yield of the barley varieties Takmak, Abalak, Buyan and the promising sample D-5-7022 by 1.2-1.8 t/ha, the weight of 1000 grains by 2-6 g, germination by 1-4% compared to the control.

2. Buyan variety exceeded the yield of the studied varieties by 0.2 t/ha when using fertilizers and in this group showed itself as the

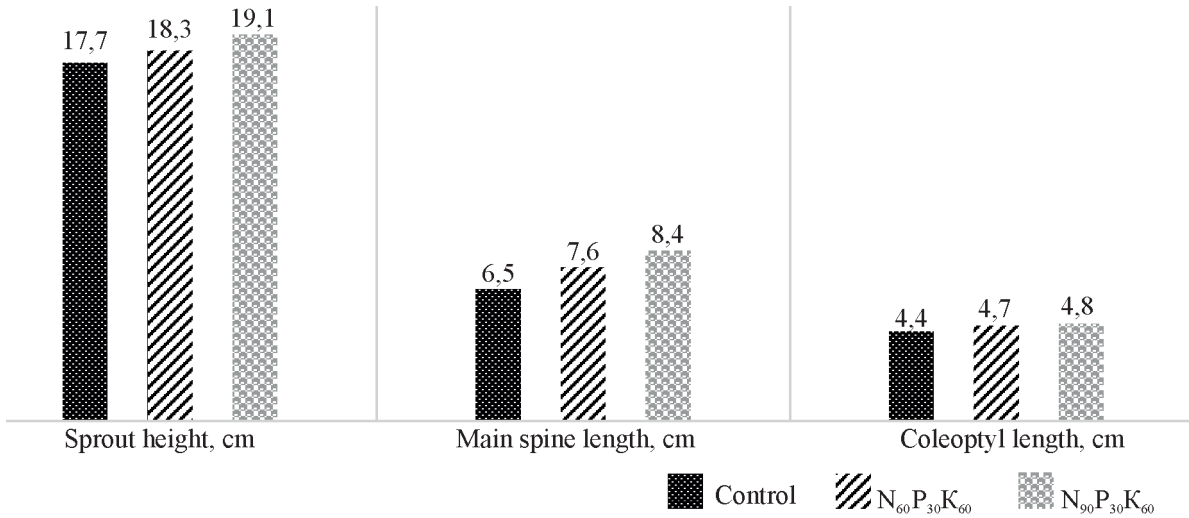

Рис. 2. Влияние различных доз удобрений на развитость проростков образцов ячменя, 2020, 2021 гг.
Fig. 1. Effect of different fertilizer doses on the development of barley sample seedlings, 2020, 2021

most intensive (yield increase to control - 1.8 t/ha, *bi* = 1.34). Varieties Abalak, Takmak, D-5-7022 were less demanding to the conditions of cultivation, the gain to the control without fertilizers were 1,41; 1,47; 1,13 t / ha, linear regression coefficients bi equal to 1.12; 1,2; 1,14 respectively. The yield of the new sample D-5-7022 is higher than the released varieties in the control without fertilizers by 0.3-0.4 t/ha.

3. Elements of the yield structure: productive stem, ear grain content and the weight of 1000 grains generally influenced its increase in the 2nd sowing date and on intensive agrofonts. The value of seedling development, as well as the yield, depended less on the timing of the sowing, and more on the application of fertilizers. At a dose of $N_{90}P_{30}K_{60}$ all indicators of the seedling development increased by 0,2-2,5 cm compared with the control.

4. The use of optimal sowing date (May 27) at the sum of active temperatures of 182,8o and the recommended dose of fertilizers $N_{90}P_{30}K_{60}$ increased the yield of barley seeds of Takmak, Abalak, Buyan and the new sample D-5-7022 varieties on average by 20-30%.

СПИСОК ЛИТЕРАТУРЫ

1. *Яркулова З., Кадиров А.* Влияние сроков посева и норм минеральных удобрений на выживаемость сортов озимого ячменя // Кронос: естественные и технические науки. 2020. С. 15–17.
2. *Чувилина В.А., Пархатова О.С.* Влияние сроков посева на кормовую и зерновую продуктивность ячменя в условиях острова Сахалин // Вестник Дальневосточного отделения Российской академии наук. 2021. № 3. С. 119-123.
3. *Корчагин А.А., Щукин И.М., Окоркова Л.А., Щукина В.И., Шаркевич В.В.* Влияние систем удобрения и обработки почвы на урожайность зерновых культур в адаптивно ландшафтных системах земледелия владимирского ополья // Владимирский земледелец. 2021. № 3. С. 38–44.
4. *Ламажап Р.Р.* Изучение влияния норм высева и сроков посева на урожайность сортов ярового ячменя // The Scientific Heritage. 2021. № 74. С. 8–10.
5. *Гребенщиков В.Ю., Копылова В.С., Верхотуров В.В.* Влияние нормы высева и сроков посева на урожайность ячменя в условиях Присаянья Иркутской области // Вестник Ульяновской государственной сельскохозяйственной академии. 2019. № 4. С. 29–34.
6. *Келер В.В., Хижняк С.В.* Аспекты повышения продуктивности и рентабельности производства зерна яровой пшеницы в Красноярском крае // Вестник Красноярского государственного аграрного университета. 2019. № 6. С. 28–34.
7. *Синявский И.В., Плотников А.М., Созинов А.В., Гущенская Н.Д.* Оценка зависимости урожайности зерновых культур в севообороте от применения сапропелей, извести, азотного и фосфорного удобрения // Вестник Курганской ГСХА. 2021. № 3. С. 13–20.

8. *Коваленко А.А., Забугина Т.М.* Влияние минеральных удобрений на урожайность и окупаемость прибавкой урожая зерновых культур // Плодородие. 2019. № 5. С. 6–9.
9. *Ларионов Ю.С.* Оценка урожайных свойств и урожайного потенциала семян зерновых культур. Челябинск: ЧГАУ, 2000. 100 с.
10. *Фадеева И.Д., Тагиров М.Ш., Газизов И.Н.* Влияние сроков посева и норм высева на урожайность новых сортов озимой пшеницы // Земледелие. 2019. № 3. С. 21–24.
11. *Шешегова Т.К., Щенникова И.Н., Кокина Л.П.* Влияние технологических приемов возделывания на урожайность и качество семян ячменя сорта Родник Прикамья // Достижения науки и техники АПК. 2018. № 10. С. 28–32.
12. *Амиров М.Ф., Толокнов Д.И.* Влияние уровня минерального питания микроэлементов на формирование урожая яровой пшеницы // Достижения науки и техники АПК. 2019. № 5. С. 18–20.
13. *Eberhart S.A., Russell W.A.* Stability parameters for comparing varieties // Ctop. sci. 1966. Vol. 6. N 1. P. 36–40.

REFERENCES

1. Yarkulova Z., Kadirov A. Impact of sowing dates and mineral fertilizer standards on the survival of winter barley varieties. *Kronos: estestvennye i tekhnicheskie nauki = Kronos: natural and technical sciences*, 2020, pp. 15–17. (In Russian).
2. Chuvilina V.A., Parkhatova O.S. Influence of sowing dates on forage and grain productivity of barley under conditions of the Sakhalin Island. *Vestnik Dal'nevostochnogo otdeleniya Rossiiskoi akademii nauk = Vestnik of the Far Eastern Branch of the Russian Academy of Sciences*, 2021, no. 3, pp. 119–123. (In Russian).
3. Korchagin A.A., Shchukin I.M., Okorkova L.A., Shchukina V.I., Sharkevich V.V. Influence of fertilizer and tillage systems on grain crop yields in adaptive landscape farming systems of the Vladimir high plains. *Vladimirskii zemledelets = Vladimir agricolist*, 2021, no. 3, pp. 38–44. (In Russian).
4. Lamazhap R.R. Study of the effect of seeding rates and sowing dates on the yield of spring barley varieties. *The Scientific Heritage*, 2021, no. 74, pp. 8–10. (In Russian).
5. Grebenshchikov V.Yu., Kopylova V.S., Verkhoturov V.V. Influence of seeding amount and seeding period on barley yield in the conditions of Transsayans of the Irkutsk region. *Vestnik Ul'yanovskoi gosudarstvennoi sel'skokhozyaistvennoi akademii = Vestnik of Ulyanovsk State Agricultural Academy,* 2019, no. 4, pp. 29–34. (In Russian).
6. Keler V.V., Khizhnyak S.V. The aspects of productivity and profitability increasing in of spring wheat grain production in the Krasnoyarsk Region. *Vestnik Krasnoyarskogo gosudarstvennogo agrarnogo universiteta = The Bulletin of KrasGAU*, 2019, no. 6, pp. 28–34. (In Russian).
7. Sinyavsky I.V., Plotnikov A.M., Sozinov A.V., Gushchenskaya N.D. Estimating of crop yield dependence in crop rotation from the use of sapropels, lime, nitrogen and phosphorus fertilizer. *Vestnik Kurganskoi GSKhA = Bulletin of the Kurgan State Agricultural Academy*, 2021, no. 3, pp. 13–20. (In Russian).
8. Kovalenko A.A., Zabugina T.M. Influence of mineral fertilizers on yield and payback increase in grain crops. *Plodorodie = Plodorodie,* 2019, no. 5, pp. 6–9. (In Russian).
9. Larionov Yu.S. *Assessment of crop properties and crop potential of grain seeds.* Chelyabinsk, CHGAU Publ., 2000, 100 p. (In Russian).
10. Fadeeva I.D., Tagirov M.Sh., Gazizov I.N. Influence of seeding terms and rates on the yield of new winter wheat varieties. *Zemledelie*, 2019, no. 3, pp. 21–24. (In Russian).
11. Sheshegova T.K., Shchennikova I.N., Kokina L.P. Influence of cultivation technology on yield and grain quality of barley “Rodnik Prikamia”. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2018, no. 10, pp. 28–32. (In Russian).
12. Amirov M.F., Toloknov D.I. Influence of mineral nutrition level and trace elements on the formation of the spring wheat yield. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2019, no. 5, pp. 18–20. (In Russian).
13. Eberhart S.A., Russell W.A. Stability parameters for comparing varieties. *Ctop. sci*, 1966, vol. 6, no. 1, pp. 36–40.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Сурин Н.А., доктор сельскохозяйственных наук, академик РАН, главный научный сотрудник

(✉) **Бутковская Л.К.,** кандидат сельскохозяйственных наук, ведущий научный сотрудник**; адрес для переписки:** Россия, 660041, Красноярск, пр. Свободный, 66; e-mail: secretary@sh.krasn.ru

Сурина Е.А., младший научный сотрудник

AUTHOR INFORMATION

Nikolay A. Surin, Doctor of Science in Agriculture, Academician RAS, Head Researcher

(✉) **Lidiya K. Butkovskaya,** Candidate of Science in Agriculture, Lead Researcher; **address:** 66, Svobodny Ave., Krasnoyarsk, 660041, Russia; e-mail: secretary@sh.krasn.ru

Ekaterina A. Surina, Junior Researcher

Дата поступления статьи / Received by the editors 20.11.2021
Дата принятия к публикации / Accepted for publication 16.03.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-3
УДК: 631.53.01:633.11

Тип статьи: оригинальная
Type of article: original

АНАЛИЗ МОРФОМЕТРИЧЕСКИХ И ОПТИЧЕСКИХ ПАРАМЕТРОВ СЕМЯН ПОДРОДА СЕРА (*ALLIUM* L., ALLIACEAE) МЕТОДОМ ЦИФРОВОГО СКАНИРОВАНИЯ

(✉) **[1]Мусаев Ф.Б., [2]Прияткин Н.С., [3]Иванова М.И., [3]Бухаров А.Ф., [3]Кашлева А.И.**
[1]Федеральный научный центр овощеводства
Московская область, Россия
[2]Агрофизический научно-исследовательский институт
Санкт-Петербург, Россия
[3]Всероссийский научно-исследовательский институт овощеводства – филиал Федерального научного центра овощеводства
Московская область, Россия
(✉) e-mail: musayev@bk.ru

Представлены результаты исследования морфологии семян из подрода Сера: секции Сера (Mill.) Prokh. – *Allium fistulosum* L., *A. altaicum* Pall., *A. galanthum* Kar. & Kir., *A. oschaninii* O. Fedtsch., *A. pskemense* B. Fedtsch.; секции *Schoenoprasum* Dum. – *A. altyncolicum*, *A. ledebourianum*, *A. oliganthum*, *A. schoenoprasum* L.; секции *Condensatum* N. Friesen – *A. condensatum.* Морфологические признаки семян могут быть использованы в качестве дополнительных таксономических показателей в идентификации и различения таксонов в пределах подрода Сера рода *Allium*. Семена имели длину 2,74–3,50 мм, ширину 1,33–2,14 мм. Измерение морфометрических и оптических параметров семянок осуществляли путем анализа изображений с помощью программного обеспечения. Цифровые изображения семянок получены с использованием цифрового планшетного сканера HP Scanjet 200, разрешение 600 dpi, формат файлов JPG. Определены морфометрические и оптические параметры семян, в том числе площадь проекции (см^2), длина, ширина, периметр, средний размер (мм), средний диаметр Фере, факторы округлости, удлиненности, эллипса, изрезанности (отн. ед.), параметры яркости, тональности, насыщенности цвета (отн. ед.). По результатам исследования составлены ряды распределения видов в порядке убывания по каждому из изученных признаков. В пределах секции Сера максимальные линейные размеры, периметр и площадь сечения имели семена *A. pskemense*. Среди представителей секции *Schoenoprasum* максимальную длину имели семянки *A. altyncolicum*. Максимальные ширина, периметр, площадь сечения, средний диаметр Фере семян зафиксированы у *A. ledebourianum*. В секции Сера среднее значение RGB в порядке убывания составило ряд: *A. pskemense* > *A. galanthum* > *A. fistulosum* > *altaicum* > *A. oschaninii*. В секции *Schoenoprasum* этот ряд имеет вид: *A. schoenoprasum* > *A. ledebourianum* > *A. altyncolicum* > *A. oliganthum*.

Ключевые слова: *Allium* L., морфология, цифровой анализ изображений, цветовые признаки в системе RGB

ANALYSIS OF MORPHOMETRIC AND OPTICAL PARAMETERS OF SEEDS OF THE SUBGENUS CEPA (*ALLIUM* L., ALLIACEAE) BY DIGITAL SCANNING

(✉) **[1]Musaev F.B., [2]Priyatkin N.S., [3]Ivanova M.I., [3]Bukharov A.F., [3]Kashleva A.I.**
[1]Federal Scientific Vegetable Center
Moscow region, Russia
[2]Agrophysical Research Institute
Saint-Petersburg, Russia
[3]All-Russian Research Institute of Vegetable Growing – branch of the Federal Scientific Vegetable Center
Moscow region, Russia
(✉) e-mail: musayev@bk.ru

The results of the study of seed morphology from the subgenus Cepa: section Cepa (Mill.) Prokh. - *Allium fistulosum* L., *A. altaicum* Pall., *A. galanthum* Kar. & Kir., *A. oschaninii* O. Fedtsch., *A. pskemense* B. Fedtsch.; section *Schoenoprasum* Dum. - *A. altyncolicum*, *A. ledebourianum*, *A.*

oliganthum, *A. schoenoprasum* L.; section *Condensatum* N. Friesen - *A. condensatum* are presented. Morphological characters of seeds can be used as additional taxonomic indicators in the identification and distinction of taxa within the subgenus Cepa of the genus *Allium*. The seeds were 2.74-3.50 mm long and 1.33-2.14 mm wide. The morphometric and optical parameters of seeds were measured by analyzing images using software. Digital images of seeds were obtained using an HP Scanjet 200 digital flatbed scanner, 600 dpi resolution, JPG file format. Morphometric and optical parameters of seeds were determined, including projection area (cm^2), length, width, perimeter, mean size (mm), average feret diameter, factors of roundness, elongation, ellipse, indentation (relative units), parameters of brightness, tonality, color saturation (relative units). According to the results of the study, a series of distribution of species in descending order for each of the studied traits are formed. Within the Cepa section, *A. pskemense* seeds had the maximum linear size, perimeter, and cross-sectional area. Among the representatives of *Schoenoprasum* section, the maximum length of the seeds was found in *A. altyncolicum*. Maximum width, perimeter, cross-sectional area, average feret diameter of the seeds were recorded in *A. ledebourianum.* In the Cepa section, the average RGB value in descending order was as follows*: A. pskemense > A. galanthum > A. fistulosum > altaicum > A. oschaninii.* In the *Schoenoprasum* section this series has the form*: A. schoenoprasum > A. ledebourianum > A. altyncolicum > A. oliganthum.*

Keywords: *Allium* L., seeds, morphology, digital image analysis, color signs in the RGB system

Для цитирования: *Мусаев Ф.Б., Прияткин Н.С., Иванова М.И., Бухаров А.Ф., Кашлева А.И.* Анализ морфометрических и оптических параметров семян подрода Cepa (*Allium* L., Alliaceae) методом цифрового сканирования // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 22–31. https://doi.org/10.26898/0370-8799-2022-2-3. EDN BQLNWV.

For citation: Musaev F.B., Priyatkin N.S., Ivanova M.I., Bukharov A.F., Kashleva A.I. Analysis of morphometric and optical parameters of seeds of the subgenus Cepa (*Allium* L., Alliaceae) by digital scanning. Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science, 2022, vol. 52, no. 2, pp. 22–31. https://doi.org/10.26898/0370-8799-2022-2-3. EDN BQLNWV.

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

INTRODUCTION

Imaging methods in agriculture and plant science have been used to analyze images captured by remote sensing techniques involving aircraft, satellites, and at close range, which have then been processed and analyzed using computers. With new technological advances in image capture and data processing, imaging methods address a variety of practical problems in biology, medicine, and agriculture. Different types of imaging methods, such as thermal imaging, fluorescence imaging, hyperspectral imaging, and photometric imaging, have contributed significantly to the advancement of various aspects of plant phenotyping. One of these is colorimetry, or RGB-based imaging, because of its dependence on color changes in various biological objects. In recent years, significant progress in the application of RGB-based imaging has been noted in various areas of agriculture and plant science. RGB analysis has been successfully used for identifying weed plants [1], mapping the weediness of crops [2], assessing the condition of lawns [3], analyzing physiological processes in leaves [4], and testing seeds for the degree of maturation [5].

The modern level of scientific knowledge in the study of seeds of agricultural crops requires the use of innovative instrumental methods characterized by high informativeness and speed of execution. The introscopic methods of seed quality assessment associated with the peculiarities of the internal structure of seeds are successfully used [6, 7]. Computer analysis technologies of seed images are actively used [8].

Morphometric parameters determine the shape of seeds, which, in turn, characterizes their viability and, ultimately, the productivity and quality of crop yield. Seed counting and

"manual" morphometry are time-consuming and labor-intensive to perform. In this regard, various effective approaches of computer seed morphometry using image processing techniques have been proposed [9]. Most of these approaches are implemented using desktop PC software to analyze images of seeds on a light background obtained with a digital camera or scanner [10]. These approaches allow users to estimate a large number of morphometric parameters of the seed describing shape and color [11], which provide improved methods for variety identification using seed images, seed moisture content determination, and yield prediction [12].

Image processing methods for seed morphometry and classification have been used since the 1980s. Updates of these methods occur constantly, including in recent years [13]. Various optical sensing methods are being developed to assess seed quality and safety [14], and describe complex seed shapes using 2D images [15]. Revolutionary 3D imaging technology and robotics [16] or X-ray computer tomography [17] can be implemented to accurately assess seed shape. However, there is still a need for seed phenotyping using simple and accessible tools with high throughput [18].

Dimensional characteristics determining the shape of seeds, shades of their surface color suitable for further processing make modern imaging methods highly adaptable. The biomorphological properties of seeds can be analyzed using computer image analysis systems, and the data can be quickly processed and saved, and plotted on the graph [19].

Argus-BIO company (St. Petersburg) has developed a new morphometric method for the analysis of digital scanned images of seeds using the serial software "VideoTestMorphology". The new program is completely devoid of subjectivity, eliminates operator errors, significantly speeds up the analysis time and adds new parameters for evaluation of the examined material.

Allium L. is a large, diverse and taxonomically complex genus of monocotyledons. The genus includes more than 800 species belonging to 15 subgenera and more than 70 sections [20], many cultivated species - mainly vegetable and ornamental plants, some with medicinal properties [21]. A high level of morphological diversity of seed coat in the genus *Allium* was established, whose details are clearly visible under a scanning electron microscope. Differences in seed size, shape, color and cell structure of the seed coat served as taxonomic and/or phylogenetic markers [22].

The purpose of the study was to study the geometric parameters and optical characters of seeds of the subgenus Cepa (*Allium* L., Alliaceae) from the biocollection of the All-Russian Research Institute of Vegetable Growing (VNIIO), a branch of the Federal Scientific Vegetable Center, by digital scanning.

MATERIAL AND METHODS

Seeds of *Allium* L. from the subgenus Cepa: section Cepa (Mill.) Prokh. - *A. fistulosum* L., *A. altaicum* Pall., *A. galanthum* Kar. & Kir., *A. oschaninii* O. Fedtsch., *A. pskemense* B. Fedtsch.; *Schoenoprasum* Dum. section - *A. altyncolicum*, *A. ledebourianum*, *A. oliganthum*, *A. schoenoprasum* L.; *Condensatum* N. Friesen section - *A. condensatum* from the biocollection of VNIIO (Moscow Region) were the object of research. Plants were 4-5 years old.

Image analysis software allows automatic and manual measurements from images. Measurement of morphometric and optical parameters of the seeds was performed by image analysis using "VideoTest-Morphology" software developed by LLC "Argus-BIO" (St. Petersburg). Digital images of seeds were obtained using a digital flatbed scanner HP Scanjet 200, resolution 600 dpi, file format JPG. The program measures linear parameters of seeds with high accuracy (up to 1/1000 fractions of mm). The number of seeds of each species is 100 pcs.

The program is able to distinguish objects of interest (from the background) by pixel values in the RGB and HSB color systems (color hue, saturation, lightness). The RGB color model was used to describe the chromaticity when analyzing digital images. This color model allows up to 28 (256) gradations of brightness for each

of the three base colors. The brightness in any of the channels of the digital image at a given point reflects the intensity of the light in the red, green and blue regions of the spectrum hitting the matrix of the scanner's recording device. According to the color model R, G and B can take absolute values from 0 to 255.

Average RGB value (R value + G value + B value) / 3.

The following morphometric parameters of seeds were determined:

– the projected area, cm^2;

– linear dimensions: length, width, perimeter, average size, mm;

– factors of roundness, elongation, ellipse, indentation, relative units;

– brightness parameters: brightness, tonality, saturation, relative units;

The roundness factor (r.u.) is the ratio of the perimeter of a seed to the perimeter of a circle with the same area. For a circle, the index is close to one. The elongation factor (r.u.) shows the ratio of the overall length of the seed to the overall width. The projection of an image of a seed not shaped like a circle, measured as the distance between the tangents to the contour of the image drawn parallel to the chosen direction (average diameter of Fere).

Confidence intervals of the mean values of the studied attributes with a significance level of 0.01 were calculated [22].

RESULTS AND DISCUSSION

Allium is one of the largest monocotyledonous genera. The subgenus Cepa includes five sections. In the present study, we describe the seeds of 10 species from three sections. The genus *Allium* is characterized by umbrella-shaped inflorescences, with a veil at the base. The ovary is monocotyledonous with six or numerous seed buds. The fruit is a boll, which explodes in dissepiments. The fruit contains up to six achenes; rare species have more than 10.

Seed polyvariaty is a necessary condition for the adaptive strategy of plant species in native phytocenoses, but in agrocenoses, its manifestation is limited by the level of applied technologies of crop cultivation. The variation of morphometric parameters of seeds, as well as any other traits, is genospecific, hence selective significant [23].

The seeds of *A. fistulosum*, *A. altaicum*, *A. galanthum*, *A. oschaninii*, and *A. pskemense* were analyzed from the Cepa section. Within the section, the achenes of *A. pskemense* were the longest (3.09 mm) and the shortest was that of *A. fistulosum* (2.88 mm). The maximum width of the achene was recorded for *A. pskemense* (2.14 mm), the minimum for *A. altaicum* (1.89 mm). The distribution of the average size and area of the achene within the section was in descending order: *A. pskemense* > *A. oschaninii* > *A. galanthum* > *A. fistulosum* > *A. altaicum*. Seeds of all the species studied are elliptical: the ellipse factor is 0.99 r.u., in *A. altaicum* it is 0.98 r.u., which has the lowest roundness (0.61 r.u.) and the highest elongation (1.57 r.u.). The distribution of the perimeter and the seed angularity within the section was in the descending order: *A. pskemense* > *A. oschaninii* > *A. galanthum* > *A. altaicum* > *A. fistulosum* (see Table 1).

The seeds of *A. altyncolicum*, *A. ledebourianum*, *A. oliganthum*, and *A. schoenoprasum* were studied in the *Schoenoprasum* section. Within the section, the achenes of *A. altyncolicum* were the longest (3.26 mm) and the shortest were those of *A. oliganthum* (2.74 mm). The maximum width of the achene was recorded for *A. ledebourianum* (1.89 mm), the minimum for *A. oliganthum* (1.33 mm). The distribution of the area, perimeter, width, average size, and average diameter of the achene within a section was in the descending order: *A. ledebourianum* > *A. altyncolicum* > *A. schoenoprasum* > *A. oliganthum*.

The distribution of the length and maximum Fere diameter of the achene within the section was in the descending order: *A. altyncolicum* > *A. ledebourianum* > *A. schoenoprasum* > *A. oliganthum*. Seed elongation was 2.08 p.u. in *A. oliganthum* and *A. schoenoprasum* species, 2.05 in *A. altyncolicum*, and 1.64 p.u. - in *A. ledebourianum*. Seeds of all the studied species

are elliptical: ellipse factor 0.99 r.u., indentation 0.01 r.u.

In our studies, the *Condensatum* section was represented by the *A. condensatum* species. The achene length was 3.5 mm, the width was 1.95 mm, and the average size was 2.73 mm. The perimeter was recorded at 8.86 mm, and the indentation was 0.03 r.u. The seeds were elliptic: ellipse factor 0.99 r.u.

The analysis of seed indentation of the studied *Allium* species from the three sections showed that the value of this trait is maximum (0.03 r.u.) in *A. pskemense* and *A. codensatum* species. The confidence intervals of the mean values of the trait "elongation" for the sections Cepa (1.46-1.50), *Schoenoprasum* (1.93-1.99) and *Condensatum* (1.77-1.87) did not overlap, therefore, seed elongation can be the primary marker trait for the section identification.

The software can also extract and export color information from an image. Color analysis has become very important in the field of plants in recent years. It allows identifying variations in the accumulation of different pigments, diagnosing plant diseases, comparing mutant phenotypes and taxonomic variations [23].

Based on the intensity of all individual color components and the average RGB value, differences in values between sections and species were determined (see Table 2). In the Cepa section, the average RGB value in descending order was as follows: *A. pskemense* > *A. galanthum* > *A. fistulosum* > *A. altaicum* > *A. oschaninii*. In the *Schoenoprasum* section this series is as follows: *A. schoenoprasum* > *A. ledebourianum* > *A. altyncolicum* > *A. oliganthum*. The highest average RGB value was found for *A. schoenoprasum* (63.31 luminance units) and *A. condensatum* (63.07 luminance units).

A series of RGB values in descending order was revealed: in the Cepa section and in the *A. condensatum* section, R > G > B. In the *Schoenoprasum* section these values are ambiguous: in *A. altyncolicum*, *A. oliganthum,* and *A. schoenoprasum* - B > R > G, in *A. ledebourianum* - R > G > B. The maximum tonality of achenes was found in the *Schoenoprasum* section: in *A. altyncolicum* - 0.73 r.u., in *A. schoenoprasum* - 0.72 r.u.

In the Cepa section, *A. altaicum* showed high values of maximum brightness (241.68 units of brightness) and saturation (0.04 relative units). However, in the *Schoenoprasum* section the opposite regularity was found: in *A. schoenoprasum* at the lowest value of maximum brightness (226.75 units of brightness), high saturation (0.04 relative units) was observed.

CONCLUSION

The geometrical parameters and optical characters of seeds of the subgenus Cepa (*Allium* L., *Alliaceae*) from the biocollection of the All-Russian Research Institute of Vegetable Breeding (VNIIO), a branch of the Federal Scientific Center of Vegetable Breeding, were studied by digital scanning. Within the Cepa section, the seeds of *A. pskemense* had the maximum linear size, perimeter, and cross-sectional area. Among the representatives of the *Schoenoprasum* section, the seeds of *A. altyncolicum* had the maximum length. The maximum width, perimeter, cross-sectional area, and average diameter of Fere seeds were recorded for *A. ledebourianum*. In the Cepa section, the average RGB value in descending order was as follows: *A. pskemense* > *A. galanthum* > *A. fistulosum* > *A. altaicum* > *A. oschaninii*. In the *Schoenoprasum* section this series is as follows: *A. schoenoprasum* > *A. ledebourianum* > *A. altyncolicum* > *A. oliganthum*.

СПИСОК ЛИТЕРАТУРЫ

1. *Ahmad I., Muhamin A., Naeem Islam M.* Real-time specific weed recognition system using histogram analysis, Proc // World academy of science, engineering and technology. 2006. N 16. P. 145–148.
2. *Aitkenhead M.J., Dalgetty I.A., Mullins C.E., McDonald A.J.S., St. Rachan, N.J.C.* Weed and crop discrimination using image analysis and artificial intelligence methods // Computers and Electronics in Agriculture. 2003. N 39. P. 157–171.
3. *Karcher D.E., Rechardson M.D.* Quantifying turf grass color using digital image analysis // Crop Science. 2003. N 3. P. 943–951.

Табл. 1. Морфометрический анализ семянок некоторых видов *Allium* L. (n = 100)
Table 1. Morphometric analysis of the seeds of some species of *Allium* L. (n = 100)

Parameter	Cepa (Mill.) Prokh. section					*Schoenoprasum* Dum. section				*Condensatum* N. Friesen section
	A. fistulosum	*A. altaicum*	*A. galanthum*	*A. oschaninii*	*A. pskemense*	*A. altyncolicum*	*A. ledebourianum*	*A. oliganthum*	*A. schoenoprasum*	*A. condensatum*
Surface area, mm^2	4,10/0,07	4,01/0,08	4,19/0,07	4,57/0,15	4,72/0,08	3,58/0,06	4,34/0,08	2,53/0,06	3,06/0,06	4,77/0,10
Perimeter, mm	7,71/0,06	7,73/0,08	7,80/0,07	8,11/0,14	8,42/0,08	7,66/0,06	8,03/0,07	6,45/0,07	7,15/0,06	8,86/0,14
Length, mm	2,88/0,02	2,95/0,03	2,90/0,02	3,02/0,06	3,09/0,03	3,26/0,02	3,06/0,02	2,74/0,03	3,02/0,02	3,50/0,05
Width, mm	1,98/0,02	1,89/0,02	1,99/0,02	2,06/0,03	2,14/0,02	1,60/0,02	1,89/0,03	1,33/0,02	1,47/0,02	1,95/0,03
Average size, mm	2,43/0,02	2,42/0,02	2,45/0,02	2,54/0,04	2,61/0,02	2,43/0,02	2,47/0,02	2,04/0,02	2,24/0,02	2,73/0,03
Fere maximum diameter, mm	2,84/0,02	2,90/0,03	2,86/0,02	2,97/0,06	3,04/0,03	3,19/0,02	3,02/0,02	2,67/0,03	2,95/0,02	3,45/0,05
Fere average diameter, mm	2,43/0,02	2,44/0,02	2,44/0,02	2,54/0,04	2,61/0,02	2,43/0,02	2,53/0,02	2,04/0,02	2,24/0,02	2,75/0,03
Circle factor, relative units	0,86/0,00	0,84/0,01	0,86/0,01	0,87/0,01	0,84/0,01	0,77/0,01	0,84/0,01	0,76/0,01	0,75/0,01	0,77/0,02
Ellipse factor, relative units	0,99/0,00	0,98/0,00	0,99/0,00	0,99/0,00	0,99/0,00	0,99/0,00	0,99/0,00	0,99/0,00	0,99/0,00	0,99/0,00
Roundness, relative units	0,65/0,01	0,61/0,01	0,65/0,01	0,66/0,01	0,65/0,01	0,45/0,01	0,60/0,01	0,45/0,01	0,45/0,01	0,52/0,01
Elongation, relative units	1,47/0,02	1,57/0,02	1,47/0,02	1,46/0,02	1,45/0,02	2,05/0,03	1,64/0,03	2,08/0,03	2,08/0,03	1,82/0,05
Indentation, relative units	0,01/0,00	0,01/0,00	0,02/0,00	0,02/0,00	0,03/0,00	0,01/0,00	0,01/0,00	0,01/0,00	0,01/0,00	0,03/0,01

Note. Value / - confidence interval.

Табл. 2. Величины цветовых составляющих семянок некоторых видов *Allium* L. по модели RGB (n = 100)
Table 2. Values of color components of the seeds of some species of *Allium* L. by RGB model (n = 100)

Parameter	Cepa (Mill.) Prokh.section					*Schoenoprasum* Dum. section				*Condensatum* N. Friesen section
	A. fistulosum	*A. altaicum*	*A. galanthum*	*A. oschaninii*	*A. pskemense*	*A. altyncolicum*	*A. ledebourianum*	*A. oliganthum*	*A. schoenoprasum*	*A. condensatum*
Average brightness, unit of brightness	58,12/0,56	56,62/0,84	58,35/0,82	54,17/0,64	61,83/0,88	52,80/0,78	61,64/0,79	51,99/0,61	61,59/0,75	62,61/1,11
Brightness deviation, unit of brightness	26,44/0,26	27,60/0,35	27,04/0,31	25,00/0,34	29,62/0,47	31,82/0,34	32,31/0,30	32,30/0,35	40,39/0,29	30,13/0,39
Minimum brightness, unit of brightness	9,70/0,46	9,80/0,56	10,10/0,54	10,35/0,59	9,59/0,54	6,00/0,60	7,71/0,47	7,90/0,58	9,86/0,48	8,01/0,63
Maximum brightness, unit of brightness	239,00/0,20	241,68/0,22	239,56/0,23	237,43/0,17	238,55/0,29	242,24/0,30	243,45/0,25	243,22/0,23	226,75/0,08	240,98/0,47
Red, unit of brightness	60,37/0,62	59,88/0,97	60,71/0,86	56,76/0,71	63,35/0,90	53,45/0,81	64,69/0,80	52,19/0,63	62,40/0,80	64,62/1,18
Green, unit of brightness	57,84/0,55	55,94/0,82	58,00/0,82	53,68/0,62	61,79/0,88	52,75/0,77	60,95/0,79	52,08/0,61	61,08/0,74	62,34/1,09
Blue, unit of brightness	57,20/0,51	55,18/0,72	57,60/0,77	53,54/0,57	61,63/0,86	55,24/0,77	60,93/0,81	55,17/0,63	66,44/0,70	62,24/1,02
Average value of RGB, unit of brightness	58,47/0,56	57,00/0,84	58,77/0,82	54,66/0,63	62,26/0,88	53,81/0,78	62,19/0,80	53,15/0,62	63,31/0,75	63,07/1,10
Tone range, relative units	0,27/0,04	0,29/0,06	0,40/0,05	0,46/0,07	0,41/0,05	0,73/0,01	0,46/0,06	0,68/0,01	0,72/0,01	0,46/0,07
Saturation, relative units	0,03/0,00	0,04/0,00	0,03/0,00	0,03/0,00	0,02/0,00	0,02/0,00	0,03/0,00	0,03/0,00	0,04/0,00	0,02/0,00

Note. Value / - confidence interval.

4. *Aldea M., Frank T.D., Delucia E.H.* A method for quantitative analysis for spatially variable physiological processes across leaf surfaces // Photosynthesis Research. 2006. N 90. P. 161–172.
5. *Dana W., Ivo W.* Computer image analysis of seed shape and seed color of flax cultivar description // Computers and Electronics in Agriculture. 2008. N 61. P. 126–135.
6. *Musaev F.B., Priyatkin N.S., Shchukina P.A., Ivanova M.I., Jafarov I.H., Nowar M.* Geometrical parameters and colour index of chive (Allium schoenoprasum) seed // Research on Crops. 2020. Vol. 21. N 4. P. 775–782.
7. *Мусаев Ф.Б., Иванова М.И., Прияткин Н.С., Кузнец С.В.* Цифровая морфометрия семян луковых культур // Овощи России. 2021. № 3. С. 44–48.
8. *Kapadia V.N., Sasidharan N., Patil K.* Seed Image Analysis and Its Application in Seed Science Research // Advances in Biotechnology and Microbiology. 2017. Vol. 7. Iss. 2. P. 1–3.
9. *Tanabata T., Shibaya T., Hori K., Ebana K., Yano M.* SmartGrain: high-throughput phenotyping software for measuring seed shape through image analysis // Plant physiology. 2012. N 4. P. 1871–1880. DOI: 10.1104/pp.112.205120.
10. *Whan A.P., Smith A.B., Cavanagh C.R., Ral J.P.F., Shaw L.M., Howitt C.A.* GrainScan: a low cost, fast method for grain size and colour measurements // Plant Methods. 2014. N 10. P. 1. DOI: 10.1186/1746-4811-10-2310.4225/08/ 536302C43FC28.
11. *Bai X.D., Cao Z.G., Wang Y., Yu Z.H., Zhang X.F., Li C.N.* Crop segmentation from images by morphology modeling in the CIE L*a*b color space // Computers and Electronics in Agriculture. 2013. N 99. P. 21–34. DOI: 10.1016/j.compag.2013.08.022.
12. *Zapotoczny P.* Discrimination of wheat grain varieties using image analysis and neural networks, Part I, single kernel texture // Journal of Cereal Science. 2011. N 54. P. 60–68. DOI: 10.1016/j.jcs.2011.02.012.
13. *Sankaran S., Wang M., Vandemark G.J.* Image-based rapid phenotyping of chickpeas seed size // Eng Agric Environ Food. 2016. N 9. P. 50–55. DOI: 10.1016/j.eaef.2015.06.001.
14. *Huang M., Wang Q.G., Zhu Q.B., Qin J.W., Huang G.* Review of seed quality and safety tests using optical sensing technologies // Seed Science and Technology. 2015. N 43. P. 337–366. DOI: 10.15258/sst.2015.43.3.16.
15. *Cervantes E., Martín J.J., Saadaoui E.* Updated methods for seed shape analysis // Scientifica. 2016. N 42. P. 1569–1825. DOI: 10.1155/2016/5691825.
16. *Roussel J., Geiger F., Fischbach A., Jahnke S., Scharr H.* 3D surface reconstruction of plant seeds by volume carving: performance and accuracies // Frontiers in Plant Science. 2016. N 7. P. 745. DOI: 10.3389/fpls.2016.00745.
17. *Strange H., Zwiggelaar R., Sturrock C., Mooney S.J., Doonan J.H.* Automatic estimation of wheat grain morphometry from computed tomography data // Functional Plant Biology. 2015. N 42. P. 452–459. DOI: 10.1071/FP14068.
18. *Fritsch R.M., Blattner F.R., Gurushidze M.* New classification of *Allium* L. subg. *Melanocrommyum* (Webb & Berthel) Rouy (Alliaceae) based on molecular and morphological characters // Phyton. 2010. N 49. P. 145–220.
19. *Иванова М.И., Бухаров А.Ф., Балеев Д.Н., Бухарова А.Р., Кашлева А.И., Середин Т.М., Разин О.А.* Биохимический состав листьев видов *Allium* L. в условиях Московской области // Достижения науки и техники АПК. 2019. Т. 33. № 5. С. 47–50.
20. *Bednorz L., Krzymińska A., Czarna A.* Seed morphology and testa sculptures of some *Allium* L. species (Alliaceae) // Acta Agrobotanica. 2011. Vol. 64 (2). P. 33–38.
21. *Choi H.J., Giussani L.M., Jang C.G., Oh B.U., Cota-Sánchez J. Hugo.* Systematics of disjunct northeastern Asian and northern North American Allium (Amaryllidaceae) // Botany. 2012. N 90 (6). P. 491–508. DOI:10.1139/b2012-031.
22. *Лакин Г.В.* Биометрия: монография. М.: Высшая школа, 1990. 352 с.
23. *Kasajima I.* Measuring plant colors // Plant Biotechnology. 2019. N 36. P. 63–75. DOI: 10.5511/plantbiotechnology.19.0322a.

REFERENCES

1. Ahmad I., Muhamin A., Naeem Islam M. Real-time specific weed recognition system using histogram analysis, Proc. *World academy of science, engineering and technology*, 2006, no. 16, pp. 145–148.
2. Aitkenhead M.J., Dalgetty I.A., Mullins C.E., McDonald A.J.S., St. Rachan N.J.C. Weed and crop discrimination using image analysis and artificial intelligence methods. *Computers*

and Electronics in Agriculture, 2003, no. 39, pp. 157–171.

3. Karcher D.E., Rechardson M.D. Quantifying turf grass color using digital image analysis. *Crop Science*, 2003, no. 3, pp. 943–951.
4. Aldea M., Frank T.D., Delucia E.H. A method for quantitative analysis for spatially variable physiological processes across leaf surfaces. *Photosynthesis Research*, 2006, no. 90, pp. 161–172.
5. Dana W., Ivo W. Computer image analysis of seed shape and seed color of flax cultivar description. *Computers and Electronics in Agriculture*, 2008, no. 61, pp P. 126–135.
6. Musaev F.B., Priyatkin N.S., Shchukina P.A., Ivanova M.I., Jafarov I.H., Nowar M. Geometrical parameters and colour index of chive (Allium schoenoprasum) seed. *Research on Crops*, 2020, vol. 21, no. 4, pp. 775–782.
7. Musaev F.B., Ivanova M.I., Prijatkin N.S., Kuznec S.V. Digital morphometry of onion seeds. *Ovoshchi Rossii = Vegetable crops of Russia,* 2021, no. 3, pp. 44–48. (In Russian).
8. Kapadia V.N., Sasidharan N., Patil K. Seed Image Analysis and Its Application in Seed Science Research. *Advances in Biotechnology and Microbiology*, 2017, vol. 7, iss. 2, pp. 1–3.
9. Tanabata T., Shibaya T., Hori K., Ebana K., Yano M. SmartGrain: high-throughput phenotyping software for measuring seed shape through image analysis. *Plant physiology*, 2012, no. 4, pp. 1871–1880. DOI: 10.1104/pp.112.205120.
10. Whan A.P., Smith A.B., Cavanagh C.R., Ral J.P.F., Shaw L.M., Howitt C.A. GrainScan: a low cost, fast method for grain size and colour measurements. *Plant Methods,* 2014, no. 10, pp. 1. DOI: 10.1186/1746-4811-10-2310.4225/08/ 536302C43FC28.
11. Bai X.D., Cao Z.G., Wang Y., Yu Z.H., Zhang X.F., Li C.N. Crop segmentation from images by morphology modeling in the CIE L^*a^*b color space. *Computers and Electronics in Agriculture*, 2013, no. 99, pp. 21–34. DOI: 10.1016/j.compag.2013.08.022.
12. Zapotoczny P. Discrimination of wheat grain varieties using image analysis and neural networks, Part I, single kernel texture. *Journal of Cereal Science,* 2011, no. 54, pp. 60–68. DOI: 10.1016/j.jcs.2011.02.012.
13. Sankaran S., Wang M., Vandemark G.J. Image-based rapid phenotyping of chickpeas seed size. *Eng Agric Environ Food*, 2016, no. 9, pp. 50–55. DOI: 10.1016/j.eaef.2015.06.001.
14. Huang M., Wang Q.G., Zhu Q.B., Qin J.W., Huang G. Review of seed quality and safety tests using optical sensing technologies. *Seed Science and Technology*, 2015, no. 43, pp. 337–366. DOI: 10.15258/sst.2015.43.3.16.
15. Cervantes E., Martín J.J., Saadaoui E. Updated methods for seed shape analysis. *Scientifica,* 2016, no. 42, pp. 1569–1825. DOI: 10.1155/2016/5691825.
16. Roussel J., Geiger F., Fischbach A., Jahnke S., Scharr H. 3D surface reconstruction of plant seeds by volume carving: performance and accuracies. *Frontiers in Plant Science*, 2016, no. 7, pp. 745. DOI: 10.3389/fpls.2016.00745.
17. Strange H., Zwiggelaar R., Sturrock C., Mooney S.J., Doonan J.H. Automatic estimation of wheat grain morphometry from computed tomography data. *Functional Plant Biology*, 2015, no. 42, pp. 452–459. DOI: 10.1071/FP14068.
18. Fritsch R.M., Blattner F.R., Gurushidze M. New classification of Allium L. subg. Melanocrommyum (Webb & Berthel) Rouy (Alliaceae) based on molecular and morphological characters. *Phyton*, 2010, no. 49, pp. 145–220.
19. Ivanova M.I., Buharov A.F., Baleev D.N., Buharova A.R., Kashleva A.I., The biochemical composition of *Allium* L. leaves under the environmental conditions of the Moscow region. *Dostizhenija nauki i tehniki APK = Achievements of Science and Technology of AIC*, 2019, vol. 33, no. 5, pp. 47–50. (In Russian).
20. Bednorz L., Krzymińska A., Czarna A. Seed morphology and testa sculptures of some Allium L. species (Alliaceae). *Acta Agrobotanica*, 2011, vol. 64 (2), pp. 33–38.
21. *Choi H.J., Giussani L.M., Jang C.G., Oh B.U., Cota-Sánchez J. Hugo.* Systematics of disjunct northeastern Asian and northern North American Allium (Amaryllidaceae). *Botany*, 2012, no. 90 (6), pp. 491–508. DOI:10.1139/b2012-031.
22. Lakin G.V. *Biometrics:* Moscow, Vysshaja shkola Publ., 1990, 352 p. (In Russian).
23. Kasajima I. Measuring plant colors. *Plant Biotechnology*, 2019, no. 36, pp. 63–75. DOI: 10.5511/plantbiotechnology.19.0322a.

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Мусаев Ф.Б. оглы,** доктор сельскохозяйственных наук, ведущий научный сотрудник; **адрес для переписки**: Россия, 143080, Московская область, Одинцовский район, пос. ВНИИССОК, ул. Селекционная, д. 14; e-mail: musayev@bk.ru

Прияткин Н.С., кандидат технических наук, старший научный сотрудник, заведующий сектором

Иванова М.И., доктор сельскохозяйственных наук, профессор, заведующая лабораторией

Бухаров А.Ф., доктор сельскохозяйственных наук, заведующий лабораторией

Кашлева А.И., кандидат сельскохозяйственных наук, старший научный сотрудник

AUTHOR INFORMATION

(✉) **Farkhad B. Musaev,** Doctor of Science in Agriculture, Lead Researcher; **address:** 14, Selekzionnaya St., VNIISSOK settl., Odinzovo district, Moscow region, 143080, Russia; e-mail: musayev@bk.ru

Nikolay S. Priyatkin, Candidate of Science in Engineering, Senior Researcher, Section Leader

Mariya I. Ivanova, Doctor of Science in Agriculture, Professor, Laboratory Head

Alexander F. Bukharov, Doctor of Science in Agriculture, Laboratory Head

Anna I. Kashleva, Candidate of Science in Agriculture, Senior Researcher

Дата поступления статьи / Received by the editors 06.04.2022
Дата принятия к публикации / Accepted for publication 20.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-4
УДК: 632.954: 633.15
Тип статьи: оригинальная
Type of article: original

ИЗУЧЕНИЕ ФИТОТОКСИЧНОСТИ ГЕРБИЦИДА ЛЮМАКС В ПОСЕВЕ КУКУРУЗЫ НА ЗЕРНО В УСЛОВИЯХ ЮГА ДАЛЬНЕГО ВОСТОКА

(✉) **Костюк А.В., Ляшенко Е.В.**
Дальневосточный научно-исследовательский институт защиты растений – филиал Федерального научного центра агробиотехнологий Дальнего Востока им. А.К. Чайки
Приморский край, с. Камень-Рыболов, Россия
(✉) e-mail: dalniizr@ mail.ru

Изучена фитотоксичность гербицида Люмакс, состоящего из трех действующих веществ: С-метолахлора, тербутилазина и мезотриона, к гибридной популяции кукурузы П8521. Исследования проведены в Приморском крае в 2020, 2021 гг. на двух фонах: засоренном и чистом от сорняков, который в течение вегетационных сезонов регулярно пропалывали. Гербицид применяли до всходов, в фазы 2–3 и 5–6 листьев кукурузы в нормах расхода 4 (рекомендованная) и 8 л/га (двукратная от рекомендованной). Почва опытных участков лугово-бурая оподзоленная среднесуглинистая, содержащая в пахотном горизонте 3,8% гумуса, Ph 5,0–5,9. Гербицид Люмакс, примененный в фазу 5–6 листьев, в течение вегетационного сезона оказывал фитотоксичное действие на растения и урожайность зерна кукурузы. Существенное снижение урожая зерна отмечено в 2021 г., когда за II и III декады июня и июль выпало всего 35 мм осадков при норме за этот период 187 мм. При применении гербицида Люмакс в фазу 5–6 листьев существенно уменьшилась длина початка, количество зерен в нем, масса початка и зерна с него, а также масса 1000 зерен. Кукуруза более толерантна к гербициду Люмакс при применении в фазу 2–3 листьев и менее – при использовании в фазу 5–6 листьев.

Ключевые слова: кукуруза, гербицид, фитотоксичность, урожайность, толерантность

STUDY OF PHYTOTOXICITY OF LUMAX HERBICIDE IN GRAIN MAIZE CROPS UNDER CONDITIONS OF THE SOUTH OF THE FAR EAST

(✉) **Kostyuk A.V., Lyashenko E.V.**
The Far Eastern Research Institute of Plant Protection – Branch of Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki
Kamen-Rybolov, Primorsky Territory, Russia
(✉) e-mail: dalniizr@ mail.ru

The phytotoxicity of the herbicide Lumax to the hybrid population of corn P 8521, consisting of three active substances: C-metolachlor, terbutylazine and mesotrion, was studied. The studies were conducted in the Primorsky Territory in 2020 and 2021 on 2 backgrounds: clogged and weed-free which was regularly weeded during the growing seasons. The herbicide was applied before germination, in phases 2-3 and 5-6 of corn leaves at consumption rates of 4 (recommended) and 8 l/ha (twice the recommended). The soil of the experimental plots is meadow-brown podzolized, medium loamy, containing 3.8% humus in the arable horizon, PH 5.0-5.9. The herbicide Lumax, applied in the phase of 5-6 leaves, during the growing season had a phytotoxic effect on plants and corn grain yields. A significant decrease in the grain harvest was noted in 2021 when during the II and III ten-day periods of June and July there were only 35 mm of precipitation, while the norm for this period was 187 mm. When applying Lumax herbicide in the phase of 5-6 leaves, the cob length, the number of grains in it, the weight of the cob and grains from it, as well as the weight of 1000 grains significantly decreased.

Corn is more tolerant to Lumax herbicide when used in the 2-3 leaf phase and less tolerant when used in the 5-6 leaf phase.

Keywords: corn, herbicide, phytotoxicity, yield, tolerance

Для цитирования: *Костюк А.В., Ляшенко Е.В.* Изучение фитотоксичности гербицида Люмакс в посеве кукурузы на зерно в условиях юга Дальнего Востока // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 32–38. https://doi.org/10.26898/0370-8799-2022-2-4. EDN GOYADC.

For citation: Kostyuk A.V., Lyashenko E.V. Study of phytotoxicity of Lumax herbicide in grain maize crops under conditions of the South of the Far East. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 2, pp. 32–38. https://doi.org/10.26898/0370-8799-2022-2-4. EDN GOYADC.

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

INTRODUCTION

The purpose of registration tests is to develop and verify the regulations for the use of pesticides that ensure both efficacy and safety of their application. The preparations must meet the requirements of ecotoxicological safety [1]. Biological safety of plant protection is necessary for adaptive intensification of crop production, its ecologization and biologization. According to the results of protective measures, the consequences of overdoses and accidents with pesticides are predicted [2].

One of the requirements for herbicides in registration trials is the safety of preparations for cultivated plants. It consists in the absence of phytotoxicity of herbicides and in increasing crop yields when using them [3]. The use of the preparation should be studied in specific agrotechnologies and soil and climatic conditions. Currently, such studies have not been conducted in sufficient quantities [4].

There is a close correlation between the impact of a destructive factor and the activity of plant growth processes, which is adjusted by weather conditions. Therefore, the level of initial impact of herbicide and the weather conditions determine the speed of the adaptation process and features of crop yield formation [5].

The modern range of herbicides to protect corn from weeds in the Russian Federation contains more than 200 preparations [6]. In 2016, according to "Agrostat" company in the Russian Federation, 73% of the areas under corn were treated once or more [7]. When developing new herbicides for post-emergence application, the key factor is their selectivity to the crop [8].

In the All-Russian Research Institute of Corn the phytotoxic effects of post-emergent herbicides Meister, Titus Plus, Dublon Super, Stellar, Meister Power have been studied for several years. Visual observations showed no signs of inhibition of corn plants by these herbicides when used at the recommended rates and times of application [9-11]. However, a strong phytotoxic effect on the crop was observed when Meister Power was used in the phase of 8 leaves. The use of herbicide at a later date caused growth retardation, changes in the number of corncobs per plant, corncob weight and grain per corncob [12].

In the Smolensk region, when Titus Plus was applied at temperatures above 25 °C, growth retardation and pinking of corn leaves were observed. Stress exposure to herbicide affected the chemical composition of the feed - a lower content of protein and a higher content of fiber were found [13].

When testing the new herbicide Kreutzer in seed crops of lines and simple hybrids of corn under severe drought conditions with lack of moisture and high air temperatures, an increased manifestation of phytotoxicity on plants at the rate of 0.11 kg/ha was noted [14].

In the Moscow region after the application of herbicide Kelvin Plus in the phase of 7-8 leaves of corn chlorosis and suppression of growth and development were revealed. Subsequently, it reduced the value of the obtained yield relative to the variants with its use in the recommended terms [15].

The Far Eastern Research Institute of Plant Protection used herbicides Dublon Gold, Titus Plus, Meister, Stellar and Adengo at recommended and double recommended rates in corn crops on a clean weed-free background. According to measurements of plant height and green mass, growth and development of corn was slowed down in almost all variants with the application of herbicides. According to their response to the crop, they can be placed in the following descending order: Titus Plus, Adengo, Dublon Gold, Stellar and Meister [16]. It was also found that herbicide Adengo when sprayed in the phase of 5-6 leaves in corn can have a phytotoxic effect on the crop plants and significantly (up to 0.78 t/ha) reduce grain yield [17].

The aim of the research was to study phytotoxicity of Lumax herbicide in the sowing of corn for grain at recommended and double recommended rates in the conditions of the south of the Far East.

MATERIAL AND METHODS

The studies were conducted on the experimental fields of the Far Eastern Research Institute of Plant Protection, a branch of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K. Chaiki, in 2020 and 2021. The soil of the experimental plots was meadow-brown podzolized middle loamy, containing 3.8% humus in the arable horizon, Ph 5.0-5.9.

Climatic conditions in the years of research differed significantly among themselves. Thus, in 2020 in the third ten-day period of May and June, uniform rainfall (145 mm, the norm 106 mm) contributed to the active growth and development of corn plants. Only 70 mm of rain fell in July (with an average of 140 mm). In the first two ten-day periods of September, there was an excess of moisture in the soil (3 times the norm). Precipitation amounted to 35 mm in 2021 during the second and third ten-day periods of June and July, while the long-term average was 187 mm. Daily air temperatures reached 28.1-36.3°C during the second and third ten-day periods of June, and average daily values exceeded the long-term average by 4.6-5.5°C. Precipitation also exceeded the long-term average in August. Precipitation also amounted to only 73.6 mm in August, which was two times less than the long-term average (155 mm).

Agronomic technique of corn cultivation is common for this region on the basis of mouldboard tillage. Corn hybrid population P8521 was sown with the rate of 70 thousand seeds/ha. Mineral fertilizer (dinitroammophoska) in the rate of physical weight of 70 kg/ha was introduced at sowing. The forecrop was soybeans.

The experiments were set up on two backgrounds: weedy and weed-free. The latter plot was regularly weeded during the growing season. Lumax herbicide was applied before sprouts, in phases 2-3 and 5-6 leaves of corn at rates of 4.0 (recommended) and 8.0 l/ha (double of the recommended). Herbicide working solutions were applied by hand-operated boom sprayer designed by All-Russian Research Institute of Phytopathology with working solution application rate of 200 l/ha. The area of experimental plots was 22.5 m^2, repeated four times, and the location was randomized.

In the phases of 10-12 leaves and milk ripeness of the cobs the height of plants was measured and the green mass was counted. For this purpose, 10 plants most typical for each plot were selected. Corn cobs were harvested manually in the phase of waxing ripeness of grain. After drying, they were analyzed (5 pieces from each plot) according to N.A. Maysuryan's method [18]. The remaining cobs were threshed on a stationary threshing machine. To quantify the nature of the direct response of cultivated plants to Lumax herbicide a tolerance coefficient (T) was used, which was calculated according to the formula

$$T = \frac{Yh}{Yc},$$

where Yc is the yield in the weed-free control, expressed in tons per hectare; Yh is the grain yield in the weed-free background with herbicide application, expressed in tons per hectare. Tolerance of corn plants to Lumax herbicide was evaluated by analyzing the results of the experiments laid on the crops infested to a greater or lesser degree. For this purpose, the method of weed harmfulness assessment by

V.S. Zuza[1] was used. Such an assessment involves the calculation of weed harmfulness coefficient Kw, which shows the amount of yield shortfall caused by 1 ton of weed mass. Calculation of the yield shortage at the end of the crop vegetation is carried out by the formula

$$Kw = \frac{\Delta Y}{\Delta W},$$

where ΔY is the difference in yield in the control and the variant where the herbicide was studied, expressed in tons per hectare; ΔW is the difference in the ratio of the weed mass, expressed in tons per hectare. All studies and data processing were performed according to the generally accepted methods [2-4].

RESULTS AND DISCUSSION

In the phase of 10-12 leaves of corn in the control variant, plants grew with an average height of 125 cm and vegetative mass of 357 g (see Table 1). In the variants with application of Lumax herbicide before sprouting and at the phase of 2-3 leaves, the plants were 1-5 cm higher and increased aboveground weight by 3-25 g more than in the control. When using the herbicide in a later phase of development (5-6 leaves), Lumax had a significant phytotoxic effect on the crop. Plants were registered 13-14 cm lower and their aboveground weight was 57-61 g less than in the control.

When recording in the phase of milky cob ripeness, Lumax herbicide continued to negatively affect plants of the crop (height 208 cm, weight 648-670 g) when used in the phase of 5-6 leaves in both rates of consumption. On the herbicide-free version, corn plants reached an average height of 214 cm and built up 702 g of vegetative mass.

Phytotoxic effect of Lumax herbicide (4.0 and 8.0 l/ ha), manifested during the growing season when used in the late phase of 5-6 leaves, had an impact on corn grain yield. In 2 years of research on these variants less grain by 0.40-0.52 t/ha than in the control was received (see Table 2). It should be noted that reliably less of it was collected in 2021 (5.81-6.13 t/ha, the control 6.85 t/ha). Climatic conditions of this year had a significant impact, as mentioned above.

Табл. 1. Влияние гербицида Люмакс на растения кукурузы (среднее за 2020, 2021 гг.)

Table 1. Influence of Lumax herbicide on corn plants (average for 2020 and 2021)

Experiment option	Dosage, l/ha	Treatment time	10-12 leaf phase				Corncob milky stage			
			Single plant height, cm	Single plant herbage, g	Change (+/-) from the control		Single plant height, cm	Single plant herbage, g	Change (+/-) from the control	
					height, cm	herbage, g			height, cm	herbage, g
Control	–	–	125	357	–	–	214	702	–	–
Lumax	4,0	Before sprouting	126	354	+1	–3	214	670	0	–32
Lumax	8,0		130	374	+5	+17	218	722	+4	+20
Lumax	4,0	2–3 leaf phase	126	358	+1	+1	215	678	+1	–24
Lumax	8,0		128	366	+3	+9	216	698	+2	–4
Lumax	4,0	5–6 leaf phase	112	300	–13	–57	208	670	–6	32
Lumax	8,0		111	296	–14	–61	208	648	–6	–54
LSD_{05}			6	31			7	58		

[1]Zuza V.S. Regression analysis in the study of relationships of cultivated plants and weeds. Agricultural Biology. 1974. No. 6. Pp. 838-843.

[2]Spiridonov Yu.Ya., Larina G.E., Shestakov V.G. Methodological guidelines for the study of herbicides used in crop production. Moscow: Pechatny Gorod, 2009. 252 p.

[3]Dospekhov B.A. Methodology of Field Experiment. Moscow: Kolos, 1979. 416 p.

[4]Koronevsky V.A. To the method of statistical data processing of long-term field experiments. Farming. 1985. No. 1. Pp. 56-57.

Табл. 2. Влияние гербицида Люмакс на урожайность зерна кукурузы и элементы ее структуры (среднее за 2020, 2021 гг.)

Table 2. Influence of Lumax herbicide on the yield of corn grain and elements of its structure (average for 2020 and 2021)

Experiment option	Dosage, l/ha	Treatment time	Corncob length, cm	Number of grains per cob, pcs.	Weight, g			Grain yield, t/ha	Tolerance coefficient
					corncob	grain per corncob	1000 grains		
Control	–	–	17,9	536	177	150	274	7,38	–
Lumax	4,0	Before sprouting	17,7	534	168	147	271	7,28	99
Lumax	8,0		17,8	544	174	152	280	7,52	102
Lumax	4,0	2–3 leaf phase	17,4	518	158	138	271	7,09	96
Lumax	8,0		17,5	524	165	144	272	7,26	98
Lumax	4,0	5–6 leaf phase	17,4	516	157	138	268	6,92	94
Lumax	8,0		17,1	494	151	132	265	6,86	93
LSD_{05}			0,5	29	11	10	1,6	0,56	

Laboratory analysis of corn cobs confirmed the yield data. Thus, the length of the cob, the number of grains in it, the weight of the cob and the weight of 1000 grains from the cob were reliably 0,5-0,8 cm, 42 pieces, 20-26 g, 12-18 g and 6-9 g less than the control in the variants of Lumax application during the phase of 5-6 leaves. When applying herbicide in the pre-emergence period at twice the recommended rate of consumption, the above indicators (exceptions: length and weight of the cob) were respectively 8 pcs, 2 and 6 g more, which confirms the resulting yield increase of 0.14 t/ha in this variant.

Calculation of the tolerance coefficient showed that in the variants with Lumax herbicide before sprouting and in the phase of 2-3 leaves of corn the difference in grain yield was within 2-4% in one direction or the other, and when treated in the later phase of crop development (5-6 leaves) the difference reached 6-7% in the downward direction. We can consider that in the first case corn was indifferent to Lumax, and in the second case we can indicate a significant phytotoxic effect on corn.

When conducting experiments on weedy background for 2 years of research on the control (without herbicides) variant 1.12 t/ha of corn grain was received (see Table 3).

There were weeds with a total aboveground mass of 28.1 tons/ha on this plot. Calculation of the coefficient of harmfulness showed that if corn responded equally to all three terms of herbicide application, the increase in yield from them would be proportional to the reduction in the weed mass, then the values of Kw in all three cases would be about the same. However, the actual values of the coefficients are different, so we can assume that corn is more tolerant when Lumax is applied in the phase of 2-3 leaves and less tolerant when it is used in the later phase of development.

Табл. 3. Расчет коэффициентов вредоносности сорняков

Table 3. Calculation of weed harmfulness coefficients

Option	B, t/ha	Y, t/ha	D	D	WHC
Control (without herbicides)	28,1	1,12	–	–	–
Control (manual weeding)	0	7,38	28,1	–6,26	–0,223
Lumax 4,0 l/ha					
before sprouting	12,4	4,46	15,7	–3,34	–0,213
2–3 leaf phase	12,6	4,61	15,5	–3,49	–0,225
5–6 leaf phase	14,1	3,71	14,0	–2,59	–0,185

Note. B – raw weed mass before harvesting; Y – corn yield; WHC – weed harmfulness coefficient.

CONCLUSIONS

1. Lumax herbicide can have a phytotoxic effect on plants and corn yields if the application regulations are not observed (overdose, application in late phases of development). The length of the cob, the number of grains in it, the weight of the cob and grains from it, as well as the weight of 1000 grains decreases.

2. Corn is more tolerant to Lumax herbicide when used during the 2-3 leaf development phase and less tolerant when used in later development phases.

СПИСОК ЛИТЕРАТУРЫ

1. *Петрова М.О., Черменская Т.Д., Долженко В.И.* Развитие исследований в аналитической лаборатории ВИЗР по оценке остаточных количеств пестицидов // Вестник защиты растений. 2020. Т. 103. № 2. С. 87–93. DOI: 10.31993/2308-6459-2020-103-2-13571.
2. *Соколов М.С., Санин С.С., Долженко В.И., Спиридонов Ю.Я., Глинушкин А.П., Каракотов С.Д., Надыкта В.Д.* Концепция фундаментально-прикладных исследований защиты растений и урожая // Агрохимия. 2017. № 4. С. 3–9.
3. *Долженко В.И., Петунова А.А., Маханькова Т.А.* Биолого-токсикологические требования к ассортименту гербицидов // Защита и карантин растений. 2001. № 5. С. 14.
4. *Данилова А.А.* Доступный способ регулирования скорости детоксикации пестицидов в зерновых агроценозах Западной Сибири // Достижения науки и техники АПК. 2016. Т. 30. № 4. С. 33–35.
5. *Дворянкин Е.А.* Продуктивность сахарной свеклы, поврежденной гербицидами гормоноподобного действия в сублетальных и изрежи-вающих посев дозах // Агрохимия. 2021. № 1. С. 49–54. DOI: 10.31857/S0002188121010051.
6. *Маханькова Т.А., Голубев А.С.* Гербициды для кукурузы // Защита и карантин растений. 2018. № 2. С. 37–64.
7. *Колесник С.А., Сташкевич А.В., Кислушко П.М.* Формирование ассортимента гербицидов для защиты посевов кукурузы в Беларуси // Защита и карантин растений. 2021. № 1. С. 18–21.
8. *Захаренко В.А.* Перспективы применения химических средств защиты растений в сельском хозяйстве (по материалам VII Международной конференции «Пестициды-16») // Агрохимия. 2017. № 4. С. 10–15.
9. *Кузнецова С.В., Губа Е.И.* Гербициды для раннеспелых гибридов кукурузы // Защита и карантин растений. 2017. № 7. С. 48–50.
10. *Багринцева В.Н.* Защита кукурузы от сорняков в товарных и семеноводческих посевах // Кукуруза и сорго. 2012. № 1. С. 27–28.
11. *Багринцева В.Н., Кузнецова С.В., Губа Е.И.* Послевсходовые гербициды с почвенным действием для кукурузы // Кукуруза и сорго. 2015. №1. С. 22–26.
12. *Багринцева В.Н., Губа Е.И., Кузнецова С.В.* Эффективность гербицида Майстер Пауэр в зависимости от сроков применения // Защита и карантин растений. 2020. № 3. С. 10–12.
13. *Солнцева О.И., Прудников А.Д.* Действие гербицидов на химический состав корма из кукурузы // Агрохимический вестник. 2019. № 2. С. 65–67. DOI: 10.24411/0235-2516-2019-10031.
14. *Кузнецова С.В., Багринцева В.Н.* Эффективность применения нового гербицида Крейцер // Агрохимия. 2021. № 10. С. 36-44. DOI: 10.31857/S0002188121100100.
15. *Голубев С.А., Маханькова Т.А., Комарова А.С.* Эффективность и безопасность применения гербицида Кельвин Плюс в посевах кукурузы в разных фазах развития культуры // Агрохимия. 2021. № 3. С. 38–44. DOI: 10.31875/S000218121030 08X.
16. *Костюк А.В., Лукачёва Н.Г.* Эффективность применения гербицидов в посевах кукурузы и толерантность культуры к ним // Сибирский вестник сельскохозяйственной науки. 2018. Т. 48. № 1. С. 38–43. DOI: 10.26898/0370-8799-2018-5.
17. *Костюк А.В., Лукачёва Н.Г.* Оценка эффективности и фитотоксичности гербицида Аденго в посевах кукурузы // Сибирский вестник сельскохозяйственной науки. 2020. Т. 50. № 1. С. 40–47. DOI: 10.26898/0370-8799-2020-1-5.
18. *Майсурян Н.А.* Растениеводство: монография. М., 1960. 383 с.

REFERENCES

1. Petrova M.O., Chermenskaya T.D., Dolzhenko V.I. Development of the research to assess residual pesticides in the analytical laboratory of VIZR. *Vestnik zaschity rastenii = Plant protection News*, 2020, vol. 103, no.2, pp. 87–93. (In Russian). DOI: 10.31993/2308-6459-2020-103-2-13571.
2. Sokolov M.S., Sanin S.S., Dolzhenko V.I., Spiri-

donov Yu.Ya., Glinushkin A.P., Karakotov S.D., Nadykta V.D. The concept of fundamental-applied studies of plant and yield protection. *Agrokhimiya = Agricultural chemistry*, 2017, no. 4, pp. 3–9. (In Russian).
3. Dolzhenko V.I., Petunova A.A., Makhan'kova T.A. Biological and toxicological requirements for the range of herbicides. *Zashchita i quarantine rastenii = Board of Plant Protection and Quarantine*. 2001, no. 5, pp. 14. (In Russian).
4. Danilova A.A. Accessible method of regulation of pesticide detoxication rate in cereal agrocenosis of Western Sibiria. *Dostizheniy nayki i tehniki APK = Achievements of Science and Technology of AIC.* 2016, vol. 30, no. 4, pp. 33–35. (In Russian).
5. Dvoryankin E.A. Productivity of beet damaged by hormone – like herbicides in subletal and thinning doses. *Agrokhimiya = Agricultural chemistry.* 2021, no. 1 pp. 49–54. (In Russian). DOI: 10.31857/S0002188121010051.
6. Makhan'kova T.A., Golyubev A.S. Herbicides for corn. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine.* 2018, no. 2, pp. 37–64. (In Russian).
7. Kolesnik S.A., Stashkevich A.V., Kislyshko P.M. Formation of range of herbicides for the protection of corn in Belarus. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine.* 2021, no 1, pp. 18–21. (In Russian).
8. Zakharenko V.A. The prospects of application of chemical means of plants protection in Agriculture (on materials of VII international conference «Pesticides-16», *Agrokhimiya = Agricultural chemistry*. 2017, no. 4, pp. 10–15. (In Russian).
9. Kuznetsova S.V., Guba E.I. Herbicides for early and mid-ripening corn hybrids. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine.* 2017, no. 7, pp. 48–50. (In Russian).
10. Bagrintseva V.N. Maize protection against weeds in commodity and seed-growing crops. *Kukuruza i sorgo = Corn and Sorghum.* 2012, no. 1, pp. 27–28. (In Russian).
11. Bagrintseva V.N., Kuznetsova S.V., Guba E.I. Postemergence herbicides with soil action for corn. *Kukuruza i sorgo = Corn and Sorghum.* 2015, no. 1, pp. 22–26. (In Russian).
12. Bagrintseva V.N., Guba E.I., Kuznetsova S.V. The effectiveness of herbicide Maister Power depending on the timing of application. *Zashchita i karantin rastenii = Board of Plant Protection and Quarantine.* 2020, no. 3, pp. 10–12. (In Russian).
13. Solntseva O.I., Prudnikov A.D. Influence of herbicides on chemical compound of forage from corn. *Agrokhimicheskii vestnik = Agrochemical Herald.* 2019, no. 2, pp. 65–67. (In Russian). DOI: 10.24411/0235-2516-2019-10031.
14. Kuznetsova S.V., Bagrintseva V.N. Effectiveness of the new herbicide Kreutzer. *Agrokhimiya = Agricultural Chemistry.* 2021, no. 10, pp. 36–44. (In Russian). DOI: 10.31857/S0002188121100100.
15. Golubev A.S., Makhan'kova T.A., Komarova A.S. Efficiency and safety of application of herbicide Kelvin Plus an corn at different crop stage. *Agrokhimiya = Agricultural Chemistry.* 2021, no. 13, pp. 38–44. (In Russian). DOI: 10.31857/S000218812103008X.
16. Kostyuk A.V., Lukacheva N.G. Efficiency of herbicide in maize sowing and culture tolerance to them. *Sibirskii vestnik sel'skokhozyaystvennoy nayki = Sibirian Herald of Agricultural Science.* 2018, vol. 48, no. 1, pp. 38–43. (In Russian). DOI: 10.26898/0370-8799-2018-5.
17. Kostyuk A.V., Lukacheva N.G. Estimation of efficiency and phytotoxicity of Adengo herbicide in corn crops. *Sibirskii vestnik sel'skokhozyaystvennoy nayki = Sibirian Herald of Agricultural Science*. 2020, vol. 50, no. 1, pp. 40–47. (In Russian). DOI: 10.26898/0370-8794-2020-1-5.
18. Maisuryan N.A. *Plant growing.* Moscow, 1960. 383 p. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Костюк А.В.,** кандидат сельскохозяйственных наук, ведущий научный сотрудник; **адрес для переписки:** Россия, 692684, Приморский край, Ханкайский район, с. Камень-Рыболов, ул. Мира, 42-а; e-mail: dalniizr@mail.ru

Ляшенко Е.В., младший научный сотрудник

AUTHOR INFORMATION

(✉) **Alexander V. Kostyuk,** Candidate of Science in Agriculture, Lead Researcher; **address:** 42-a, Mira St., Kamen-Rybolov, Khankasky district, Primorsky Territory, 692684, Russia; e-mail: dalniizr@mail.ru

Elena V. Lyashenko, Junior Researcher

Дата поступления статьи / Received by the editors 24.01.2022
Дата принятия к публикации / Accepted for publication 13.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-5
УДК: 633.13.632.4
Тип статьи: оригинальная
Type of article: original

ФИТОПАТОГЕННЫЕ МИКРОМИЦЕТЫ ОВСА В УСЛОВИЯХ ИРКУТСКОЙ ОБЛАСТИ

(✉) **Разина А.А., Дятлова О.Г.**
Иркутский научно-исследовательский институт сельского хозяйства
Иркутская область, с. Пивовариха, Россия
(✉) e-mail: gnu_iniish_nauka@mail.ru

Представлены результаты фитопатологического обследования партий районированных сортов овса Ровесник и Егорыч урожаев 2015, 2016 гг. и 2020, 2021 гг., выращенных в разных районах Иркутской области. Зараженность микромицетами определяли методом влажной камеры по ГОСТ 12044–93. Погодные условия в годы выращивания обследуемых партий овса были теплыми и характеризовались отклонением увлажнения в период вегетации от нормы, что приводило к ослаблению растений и к усилению развития фитопатогенных микромицетов. Установлена высокая повсеместная встречаемость грибов из рода *Alternaria*. Зараженность грибами из рода *Alternaria* овса сорта Ровесник, выращенного в 2015 г., составила от 20 до 36%, в 2016 г. – от 44 до 83%. Сорт Егорыч в 2016 г. заражен от 43 до 91%. В партиях урожая 2020 г. и 2021 г. независимо от сорта зараженность составила от 70 до 100% и от 60 до 98% соответственно. *Bipolaris* spp. отмечен во всех анализируемых партиях овса сорта Ровесник в урожае 2015, 2016 гг. при варьировании зараженности 3–12 и 4–37% соответственно. Сорт Егорыч урожая 2016 г. имел зараженность от 3 до 87%. В урожае 2020 и 2021 гг. выявлены единичные партии, свободные от *Bipolaris* spp., но большинство из них независимо от сорта имели степень заражения 7–40 и 3–45% соответственно в 2020 г. и в 2021 г. Встречаемость фитопатогенов из рода *Fusarium* spp. не зависела от сорта, но сильно отличалась по годам. В зерне большинства партий урожая 2015, 2016 гг. зараженность микромицетами *Fusarium* spp. была в интервале 1–24%, а в урожае 2020, 2021 гг. преобладали партии с очень высоким заражением этим возбудителем (23–93, 20–67% соответственно). Единичные партии были свободны от *Fusarium* spp.

Ключевые слова: овес, сорта, микромицеты, фитопатогены

PHYTOPATHOGENIC MICROMYCETES OF OATS UNDER THE CONDITIONS OF THE IRKUTSK REGION

(✉) **Razina A.A., Dyatlova O.G.**
Irkutsk Research Institute of Agriculture
Pivovarikha, Irkutsk region, Russia
(✉) e-mail: gnu_iniish_nauka@mail.ru

The results of phytopathological examination of grain batches of oat zoned varieties Rovesnik and Egorych grown in different areas of the Irkutsk region and harvested in 2015-2016 and in 2020-2021 have been presented. Infestation with micromycetes was determined by the wet chamber method according to GOST 12044-93. The weather conditions during the growing years of the examined oat batches were warm and characterized by a deviation of moisture during the growing season from the norm which led to plants weakening and the reinforced development of phytopathogenic micromycetes. A high ubiquitous occurrence of fungi from the genus *Alternaria* has been established. In 2015 the infestation of oat cultivar with Rovesnik fungi from the genus *Alternaria* ranged from 20 to 36%, and that grown in 2016 – from 44 to 83%. The variety Egorych in 2016 was infested from 43 to 91%. In the batches harvested in 2020 and 2021, irrespective to a cultivar, the infestation was from 70 to 100% and from 60 to 98%, correspondingly. *Bipolaris spp*. was observed in all the analyzed batches of oat variety Rovesnik in the harvests of 2015 and 2016 with a varying infestation range of 3-12% and 4-37%, respectively. The cultivar Egorych harvested in 2016 had the infestation level from 3 to 87%. In the harvests of 2020 and 2021, single batches free from *Bipolaris spp.* were found, but most of them had a degree of infestation, regardless of a variety, of 7-40% and 3-45%,

respectively, in 2020 and 2021. The occurrence of phytopathogens of the genus *Fusarium* spp. did not depend on the variety, but it differed greatly in years. In the grain of most batches harvested in 2015-2016, the infestation with micromycetes *Fusarium spp.* was within the range of 1-24%, and in the harvest of 2020-2021 the batches with very high infestation with this pathogen prevailed – 23-93% and 20-67%, respectively. Single batches were free of *Fusarium* spp.

Keywords: oats, cultivars, micromycetes, phytopathogens

Для цитирования: *Разина А.А., Дятлова О.Г.* Фитопатогенные микромицеты овса в условиях Иркутской области // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 39–45. https://doi.org/10.26898/0370-8799-2022-2-5. EDN GWLEYQ.

For citation: Razina A.A., Dyatlova O.G. Phytopathogenic micromycetes of oats under the conditions of the Irkutsk region. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 2, pp. 39–45. https://doi.org/10.26898/0370-8799-2022-2-5. EDN GWLEYQ.

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

INTRODUCTION

Oats is the most important food and forage crop in Russia. The biological potential of oat productivity is limited by different types of rust and smut, root rot, Helminthosporium leaf blotch, and the representatives of genera *Fusarium* and *Alternaria* dominate in grain mycobiota.

Many studies in different regions of our country were devoted to solving the problem of oat resistance to a number of pathogens, as a result of which the mechanisms of this crop resistance to phytopathogens were revealed [1], varieties resistant to crown and stem rust, loose and stinking smut, root rot were created [2], oat samples resistant and highly resistant to Siberian population of the Helminthosporium leaf blotch pathogen Drechslera avenae (Eidam.) Ito et Kuribay [3]. The effect of toxic metabolites of *Fusarium* fungi on the processes of morphogenesis and plant regeneration in the culture of immature embryos of spring oats was studied [4], and the efficiency of using the biomethod to protect oats from phytopathogens was studied [5].

Fusarium, *Alternaria*, *Penicillium* and *Aspergillus* fungi are the main producers of mycotoxins of economic importance. In addition to the reduced productivity of oats and other cereal crops due to the defeat of various pathogens, the infection of crops with toxigenic fungi of the *Fusarium*, *Alternaria*, *Penicillium* and *Aspergillus* genera and the accumulation of mycotoxins dangerous for human and animal health in plant products are of great importance all over the world [6-8].

In Russia, the most common mycotoxins for food oat grain are *Alternaria* toxins, T-2 and HT-2, NEOS, CIT, and DON [9, 10]. The influence of biochemical composition and some morphological characters of oat grains of different varieties on their contamination with micromycetes of genera *Alternaria* and *Fusarium* and accumulation of toxins was shown [11, 12]. Presowing seed dressing is considered as a reasonable strategy to reduce the risk of contamination of future crops with mycotoxins [13].

In the Irkutsk region, at present, the importance of oats is increasing not only as a forage crop, but also as a food crop both for domestic consumption in the region and for export. In the system of crop rotations of the region, the forecrops for wheat using oats as one of the components in the composition of annual grasses, in mixture with rape as a siderat are promising.

In this regard, the study of mycobiota of oat grain, which determines its contamination with mycotoxins, and determination of the possibility of using the grain for food and fodder purposes, is of great importance. Also, phytosanitary condition of oat seeds as a wheat forecrop in the composition of annual grasses and green manure in their absence shows the contamination of soil with root rot pathogens or contributes to the entry of the infection into the soil with contaminated seeds.

The purpose of the study was to identify the micromycete infestation of oat seeds grown in the Irkutsk region.

MATERIAL AND METHODS

The infestation of oat grain with micromycetes was determined by the wet chamber method[1]. The studies were carried out on 65 samples of released oat varieties Rovesnik and Egorych from different soil and climatic zones of the Irkutsk region with the yields of 2015, 2016, and 2020, 2021.

The agricultural enterprises of the Irkutsk region sow oats as the second or third crop after a valuable forecrop (fallow, peas, layer of perennial grasses, corn). Autumn plowing is traditional (mouldboard and non-mouldboard), and various types of non-mouldboard cultivation in autumn or spring (discing and cultivation) are also common. Farms with modern machinery (SM Kuzbass, Ob-4) carry out direct seeding of oats. Due to the difficult financial situation, farms practically do not disinfect oat seeds.

RESULTS AND DISCUSSION

Earlier, infestation of oat with the phytopathogenic micromycete *Bipolaris* spp. prevailed; at present, the structure of this crop microbiocenosis is gradually changing. In the literature, there are data on the change of phytopathogenic complex on spring wheat seeds - *Bipolaris sorokiniana* is not the predominant micromycete [14].

In our studies, all batches of oats subjected to phytopathological examination were mostly infected with a complex of micromycetes from genera *Alternaria* and *Fusarium*, and less from - *Bipolaris* sp.

Weather conditions in the years of cultivation of the examined batches of oats were warm and characterized by deviation of moisture during vegetation period from the norm, which led to weakening of plants and to strengthening of development of phytopathogenic micromycetes, mainly toxin-producing *Alternaria* spp. and *Fusarium* spp. and their accumulation on the grain (see Tables 1, 2).

High ubiquitous occurrence of fungi of the genus *Alternaria* was established. The degree of their infestation varied depending on the year of harvest. Thus, in batches of the oat variety Rovesnik grown in 2015, which was characterized as dry according to the HTC, the infection with fungi of this genus was from 20 to 36% (average - 26%). In 2016, the HTC of a wet crop, grain of the variety Rovesnik was infested from 44 to 83% (average 61%), and of the variety Egorych from 43 to 91% (average 61%). In the lots of harvests 2020 and 2021 - slightly arid and humid in different regions, regardless of the variety, the interval of contamination was, respectively, from 70 to 100% (average 78-92%) and from 60 to 98% (average 83-96%). Slightly arid and humid conditions of the vegetation periods contribute to high infection of grain by fungi of Alternaria genus 72-96%.

Bipolaris spp. was found in all analyzed batches of the oat variety Rovesnik in the 2015 and 2016 harvests, with varying infestations of 3-12, 4-37%, respectively. Egorych variety of the 2016 crop had infestation ranging from 3 to 87%. Single lots free of *Bipolaris* spp. were identified in the 2020 and 2021 harvests, but most had degrees of infestation regardless of the variety 7-40 and 3-45% in 2020 and 2021, respectively. Batch infestation with *Bipolaris* spp. also varied by district. In the variety Rovesnik, the lowest (up to 10%) in 2015 it was recorded in Kuytunsky district, in 2020 in Zalarinsky and Taishetsky districts, in 2021 in Alarsky, Bokhansky and Zalarinsky districts. Egorych variety had the least infestation in 2020 in Taishetsky district, in 2021 in Alarinsky and Bayandaevsky districts. The effect of hydrothermal conditions on the degree of *Bipolaris* spp. infestation was not found, so, in the variety Egorych with HTC 1.65 the infestation was 4%, and 1.27 - 30%, in the variety Rovesnik with HTC 1.62 the infestation was 20%, 1.65 - 4%.

The occurrence of phytopathogens of the genus *Fusarium* spp. did not depend on the vari-

[1]GOST 12044-93 Seeds of crops. Methods of determination of disease infestation. Minsk: Interstate Council for Standardization, Metrology and Certification, 33 p.

Табл. 1. Результаты фитопатологического анализа зерна овса сорта Ровесник
Table 1. Results of phytopathological analysis of Rovesnik cultivar oat grain

Variety, region, number of batches	Harvest year	HTC	Micromycetes, %			General infestation, %	Germination rate, %
			Alternaria spp.	*Bipolaris* spp.	*Fusarium* spp.		
Rovesnik, Kuytunsky, 6 batches	2015	0,99	26	8	20	49	90
Rovesnik, Zalarinsky, 8 batches	2016	1,66	61	19	31	81	76
Rovesnik (average)	2020	–	85	17	54	100	69
Including:							
Alarsky, 2 batches	2020	1,17	78	12	91	100	51
Bayandaevsky, 2 batches	2020	1,62	89	20	53	100	66
Bokhansky, 1 batch	2020	1,27	88	20	0	100	71
Zalarinsky, 2 batches	2020	1,20	80	5	55	100	57
Taishetsky, 2 batches	2020	1,65	92	4	65	100	83
Ust-Udinsky, 2 batches	2020	1,19	87	40	63	100	88
Rovesnik (average)	2021	–	92	16	28	100	68
Including:							
Alarsky, 2 batches	2021	1,39	94	8	23	100	88
Bayandaevsky, 2 batches	2021	1,70	90	45	26	100	57
Bokhansky, 3 batches	2021	1,35	92	7	19	100	68
Zalarinsky, 2 batches	2021	1,53	93	3	46	100	60

Табл. 2. Результаты фитопатологического анализа зерна овса сорта Егорыч
Table 2. Results of phytopathological analysis of Egorych cultivar oat grain

Variety, region, number of batches	Harvest year	HTC	Micromycetes, %			General infestation, %	Germination rate, %
			Alternaria spp.	*Bipolaris* spp.	*Fusarium* spp.		
Egorych, Zalarinsky, 9 batches	2016	1,66	61	28	20	82	86
Egorych (average)	2020		79	15	36	100	72
Including:							
Alarsky, 2 batches	2020	1,17	82	13	45	100	63
Bayandaevsky, 2 batches	2020	1,62	81	15	42	100	75
Bokhansky, 2 batches	2020	1,27	78	30	23	100	63
Zalarinsky, 2 batches	2020	1,20	72	11	43	100	62
Taishetsky, 2 batches	2020	1,65	90	4	35	100	80
Ust-Udinsky, 3 batches	2020	1,19	74	20	32	100	86
Egorych (average)	2021	–	90	10	27	100	57
Including:							
Alarsky, 2 batches	2021	1,39	85	8	25	100	45
Bayandaevsky, 3 batches	2021	1,70	83	7	16	96	50
Bokhansky, 3 batches	2021	1,35	96	10	37	100	65
Zalarinsky, 3 batches	2021	1,53	96	16	30	100	68

ety, but differed greatly from year to year. In the grain of most lots of the 2015, 2016 harvests, *Fusarium* spp. micromycetes infestation was in the range 1-24% (average 20-31%), while in the 2020, 2021 harvests, the lots with very high infestation with this pathogen dominated - 23-93% (average 0-91%), 20-67% (average 16-46%) respectively. Single lots were free of *Fusarium* spp. Grains of both analyzed oat varieties were most heavily infested in 2020 in all studied areas with HTC from 1.17 to 1.65, especially the variety Rovesnik - the average infestation of batches of this variety was 18% higher compared to the variety Egorych.

The wide ranges of micromycete infestation within the considered years, districts, and varieties suggest that the degree of oat batch infestation depends not only on these factors, but also on the farming practices used in the cultivation of the crop in a particular farm. Micromycetes of infected oat seeds can contribute to soil pathogenicity and negatively influence the phytosanitary situation in grain crop rotations. Currently, they are used in the Irkutsk region in grain and livestock enterprises with stabling animals, which requires the use of concentrated grain fodder, forcing farms to reduce fallow and tilled crops.

From the point of view of safety of grain use for food and fodder purposes, it is necessary to pay attention to the high contamination of oat grain in the region with toxin-producing fungi of genera *Alternaria* and *Fusarium*. The negative effect of high infestation with phytopathogenic micromycetes manifested itself in the reduction of laboratory germination of oats, which in the vast majority of batches did not exceed 87% and could not meet the quality of the Russian standard GOST R 52325-2005 (see Tables 1 and 2)[2].

In order to obtain a high yield of grain free of mycotoxins and to form a favorable situation in grain agrocenoses, when cultivating oats, preference should be given to agricultural practices that reduce the accumulation and spread of phytopathogenic micromycetes and consider the phytosanitary status of seeds. Seed batches with high infestation require obligatory presowing dressing with fungicides approved for use in the Russian Federation.

CONCLUSIONS

1. Phytopathogenic micromycetes of genera *Alternaria* and *Fusarium* are predominant in grain infestation of oat batches grown in the Irkutsk region in 2015, 2016 and 2020, 2021. *Bipolaris* spp. occurs less frequently, but in the overwhelming number of the examined batches exceeds the threshold of pest infestation of seeds.

2. Agricultural producers of the Irkutsk region should pay attention to the high contamination of oat grain in the region with toxin-producing fungi of genera *Alternaria* and *Fusarium* in order to produce safe food products.

3. Micromycetes of infected oat seeds may contribute to soil pathogenicity and play a negative role in the formation of the phytosanitary situation in grain crop rotations, which are currently widely used in the Irkutsk Region.

СПИСОК ЛИТЕРАТУРЫ

1. *Исачкова О.А.* Устойчивость голозерного овса к семенной инфекции // Сибирский вестник сельскохозяйственной науки. 2018. № 2. С. 11–16. DOI: 10.26898/0370-8799-2018-2-2.
2. *Баталова Г.А.* Селекция зерновых культур на иммунитет на Северо-Востоке Европейской территории России // Зерновое хозяйство России. 2017. № 3. С. 8–11.
3. *Нешумаева Н.А., Голубев С.С.* Оценка устойчивости овса к сибирской популяции возбудителя красно-бурой пятнистости Drechslera avenae // Достижения науки и техники АПК. 2018. № 5. С. 48–51.
4. *Зобова Н.В., Луговцева С.Ю., Нешумаева Н.А.* Исследование влияния метаболитов микомицетов рода *Fusarium* на каллусную культуру овса // Достижения науки и техники АПК. 2019. № 7. С. 24–28.
5. *Власов А.Г., Купцов В.Н., Халецкий С.П., Коломиец Э.И.* Применение биопестицида Бактавен для защиты посевов овса от болезней // Вестник защиты растений. 2017. № 2. С. 40–45.

[2]Seeds of agricultural plants. Varietal and sowing characteristics. General and technical conditions. Moscow: Standartinform, 2009. 23 p.

6. *Левитин М.М., Джавахия Г.Г.* Токсикогенные грибы и проблемы продовольственной безопасности (обзор) // Достижения науки и техники АПК. 2020. № 12. С. 5–11.
7. *Drakopoulos D., Kagi A., Alejandro G., Six J., Jenny E., Forrer H-R., Musa T., Meca G., Vogelgsang S.* Prevention of Fusarium head blight infection and mycotoxins in wheat with cut-and-carry biofumigation and botanicals. *Field Crops Research*, 2020, no. 246, P. 107681.
8. *Кононенко Г.П., Зотова А.Е., Буркин А.А.* Опыт микотоксикологического обследования зернофуражных культур // Сельскохозяйственная биология. 2021. № 5. С. 958–967. DOI: 10.15389/agrobiology.2021.5.958rus.
9. *Киселева М.Г., Седова И.Б., Чалый З.А., Захарова Л.П., Аристархова Т.Б., Тутельян В.А.* Анализ продовольственного зерна в Российской Федерации на загрязненность широким спектром микотоксинов (на примере урожая 2018 года) // Сельскохозяйственная биология. 2021. № 3. С. 559–577. DOI: 10.15389/agrobiology.2021.3.559rus.
10. *Орина А.С., Гаврилова О.П., Гагкаева Т.Ю., Гогина Н.Н.* Контаминация зерна в Западной Сибири грибами *Alternaria* и их микотоксинами // Вестник защиты растений. 2021. № 3. С. 153–162.
11. *Лоскутов И.Г., Шеленга Т.В., Конарев А.В., Хорева В.И., Шварда А.Л., Блинова Е.В., Гнутиков А.А.* Биохимические аспекты взаимоотношений грибов и растений на примере фузариоза овса // Сельскохозяйственная биология. 2019. № 3. С. 575–588.
12. *Орина А.С., Гаврилова О.П., Гагкаева Т.Ю., Лоскутов И.Г.* Симбиотические взаимоотношения грибов *Fusarium* и *Alternaria,* колонизирующих зерно овса // Сельскохозяйственная биология. 2017. № 5. С. 986–994.
13. *Sarrocco S., Vannacci G.* Preharvest application of beneficial fungi as a strategy to prevent postharvest mycotoxin contamination: A review. *Crop Protection*, 2018, no. 110, pp. 160–170.
14. *Кекало А.Ю., Заргарян Н.Ю., Филиппов А.С., Немченко В.В.* Эффективность применения фунгицидов для защиты яровой пшеницы от корневых гнилей // Сибирский вестник сельскохозяйственной науки. 2019. № 3. С. 24–30. DOI: 10.26898/0370-8799-2019-3-3.

REFERENCES

1. Isachkova O.A. Resistance of hulless oats to seed infection. *Sibirskij vestnik sel'skokhozyaistvennoy nauki = Siberian Herald of Agricultural Science,* 2018, no. 2, pp. 11–16. (In Russian). DOI: 10.26898/0370-8799-2018-2-2.
2. Batalova G.A. Grain crop breeding for immunity in the north-east of the European territory of Russia. *Zernovoe khozyaistvo Rossii = Grain economy of Russia,* 2017, no. 3, pp. 8–11. (In Russian).
3. Neshumaeva N.A., Golubev S.S. Evaluation of oat resistance to Siberian population of a pathogenic agent of leaf stripe DRECHSLERA AVENAE. *Dostizhenija nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2018, no. 5, pp. 48–51. (In Russian).
4. Zobova N.V., Lugovtsova S.Yu., Neshumaeva N.A. Study of the influence of mycomycetes' metabolites of fusarium genus on callus oat culture. *Dostizhenija nauki i tekhniki APK = Achievements of Science and Technology of AIC*, 2019, no. 7, pp. 24–28. (In Russian).
5. Vlasov A.G., Kuptsov V.N., Khaletsky S.P., Kolomiets E.I. Application of Bactaven biopesticide in oat crop protection against diseases. *Vestnik zaschity rastenij = Plant Protection News,* 2017, no. 2, pp. 40–45. (In Russian).
6. Levitin M.M., Dzhavakhiya V.G. Toxigenic fungi and food security issues (review). *Dostizhenija nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2020, no. 12, pp. 5–11. (In Russian).
7. Drakopoulos D., Kägi A., Alejandro G., Six J., Jenny E., Forrer H-R., Musa T., Meca G., Vogelgsang S. Prevention of Fusarium head blight infection and mycotoxins in wheat with cut-and-carry biofumigation and botanicals. *Field Crops Research*, 2020, no. 246, p. 107681.
8. Kononenko G.P., Zotova E.V., Burkin A.A. Advances in mycotoxicological research of forage grain crops. *Sel'skokhozyaistvennaya biologija = Agricultural Biology,* 2021, no. 5, pp. 958–967. (In Russian). DOI: 10.15389/agrobiology.2021.5.958rus.
9. Kiseleva M.G., Sedova I.B., Chalyy Z.A., Zakharova L.P., Aristarkhova T.V., Tutelyan V.A. Multimycotoxin screening of food grain produced in Russia in 2018, *Sel'skokhozyaistvennaya biologija = Agricultural Biology,* 2021, no. 3,

pp. 559–577. (In Russian). DOI: 10.15389/agrobiology.2021.3.559rus.
10. Orina A.S., Gavrilova O.P., Gagkaeva T.Yu., Gogina N.N. Contamination of grain in West Siberia by *Alternaria* fungi and their mycotoxins. *Vestnik zaschity rastenij = Plant Protection News,* 2021, no. 3, pp. 153–162. (In Russian).
11. Loskutov I.G., Shelenga T.V., Konarev A.V., Horeva V.I., Shvarda A.L., Blinova E.V., Gnutikov A.A. Biochemical aspects of interactions between fungi and plants: a case study of *Fusarium* in oats. *Sel'skokhozyaistvennaya biologija = Agricultural Biology*, 2019, no. 3, pp. 575–588. (In Russian).
12. Orina A.S., Gavrilova O.P., Gagkaeva T. Yu., Loskutov I.G. Symbiotic relationships between aggressive *Fusarium* and *Alternaria* fungi colonizing oat grain. *Sel'skokhozyaistvennaya biologija = Agricultural Biology*, 2017, no. 5, pp. 986–994. (In Russian).
13. Sarrocco S., Vannacci G. Preharvest application of beneficial fungi as a strategy to prevent postharvest mycotoxin contamination: A review. *Crop Protection*, 2018, no. 110, pp. 160–170.
14. Kekalo A.Yu., Zargaryan N.Yu., Filippov A.S., Nemchenko V.V. Efficiency of application of fungicides for spring wheat protection against root rots. *Sibirskij vestnik sel'skokhozyaistvennoy nauki = Siberian Herald of Agricultural Science,* 2019, no. 3, pp. 24–30. (In Russian). DOI: 10.26898/0370-8799-2019-3-3.

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Разина А.А.,** кандидат биологических наук, доцент, старший научный сотрудник**; адрес для переписки:** 664511, Иркутская область, Иркутский район, с. Пивовариха, ул. Дачная, 14; e-mail: gnu_iniish_nauka@mail.ru

Дятлова О.Г., научный сотрудник

AUTHOR INFORMATION

(✉) **Alfia A. Razina,** Candidate of Science in Biology, Associate Professor, Senior Researcher; **address:** 14, Dachnaya St., Pivovarikha, Irkutsk district, Irkutsk region, 664511; e-mail: gnu_iniish_nauka@mail.ru

Olga G. Dyatlova, Researcher

Дата поступления статьи / Received by the editors 20.01.2021
Дата принятия к публикации / Accepted for publication 05.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-6
УДК: 636.5.084
Тип статьи: оригинальная
Type of article: original

БЕЛКОВО-ВИТАМИННАЯ МУКА ИЗ ПШЕНИЧНЫХ ОТРУБЕЙ, ОБОГАЩЕННАЯ ФИТАЗОЙ В РАЦИОНЕ ПЕРЕПЕЛОВ

[1] (✉) Рогачёв В.А., [1]Мерзлякова О.Г., [2]Лукьянчикова Н.Л., [1]Магер С.Н.

[1]Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
[2]Сибирский филиал Федерального научного центра пищевых систем им. В.М. Горбатова Российской академии наук
Новосибирск, Россия
(✉) e-mail: helmmet@mail.ru

Представлены результаты эксперимента по использованию в рационе выращиваемых перепелов фракционированной белково-витаминной муки из пшеничных отрубей (в чистом виде и в смеси с ферментным препаратом, выпускаемым под торговой маркой Фитбест) с размером частиц 140 мкм. Опыт продолжительностью 60 дней проведен по общепринятой методике на перепелах японской породы. Для эксперимента три аналогичные группы по 80 гол. (одна контрольная и две опытные) сформированы в суточном возрасте птиц. Все группы получали основной рацион, приготовленный с учетом возраста и физиологических особенностей перепелов. В рационе молодняка 1-й и 2-й опытных групп часть пшеницы (7%) комбикорма заменили пшеничной белково-витаминной мукой (размер частиц 140 мкм). При этом перепелам 2-й опытной группы скармливали белково-витаминную муку с ферментным препаратом Фитбест Р5000 GT, предназначенным для повышения биодоступности фосфора, минеральных элементов и аминокислот из компонентов кормов для сельскохозяйственной птицы и свиней. Птицу содержали в клеточной батарее при соблюдении требуемых условий микроклимата. Изучено влияние скармливания экспериментальных добавок на сохранность поголовья цыплят, интенсивность их роста, мясную продуктивность, химический и аминокислотный состав мяса (фарша), гематологические показатели. Введение в комбикорм перепелов белково-витаминной муки из пшеничных отрубей в чистом виде и с ферментным препаратом Фидбест Р5000 GT повысило сохранность птицы на 3,01%, среднесуточный прирост живой массы на 3,09 и 3,44% при практически равных затратах кормов на единицу продукции. В мясе птицы, потреблявшей в составе комбикорма муку из пшеничных отрубей с препаратом, содержащим фитазу, содержание жира, кальция и фосфора увеличилось соответственно в 1,17; 1,13 и 1,17 раза. Концентрация кальция и фосфора в мясе перепелов, получавших муку без ферментного препарата, была ниже, чем у аналогов, потреблявших муку с фитазой в 1,2 и 1,1 раза. Биохимические показатели крови всех подопытных цыплят оставались в пределах физиологической нормы.

Ключевые слова: перепела, комбикорм, белково-витаминная мука, ферментный препарат, сохранность, живая масса

PROTEIN-VITAMIN FLOUR FROM WHEAT BRAN ENRICHED WITH PHYTASE IN THE DIET OF QUAILS

(✉) **[1]Rogachev V.A., [1]Merzlyakova O.G., [2]Lukyanchikova N.L., [1]Mager S.N.**
[1]Siberian Federal Scientific Center of Agro-BioTechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia
[2]Siberian branch of Federal State Budgetary Scientific Institution Federal Scientific Center for Food Systems named after V.M. Gorbatov RAS
Novosibirsk, Russia
(✉) e-mail: helmmet@mail.ru

The results of the experiment on the use of fractionated protein-vitamin wheat bran flour (pure and mixed with enzyme preparation produced under Feedbest® trade mark) with particle size 140 microns in the ration of growing quails are presented. The experiment lasting 60 days was conducted according to the generally accepted methodology on quails of the Japanese breed. For the experiment, three similar groups of 80 birds each (one control and two experimental) were formed at one day of age. All groups received a basic diet prepared taking into account the age and physiological characteristics of quails. In the diet of young animals of the 1st and 2nd experimental groups a part of wheat (7%) mixed fodder was replaced by wheat protein-vitamin flour (particle size 140 microns). The quails of the 2nd experimental group were fed protein-vitamin meal with the enzyme preparation Feedbest® P5000 GT designed to increase the bioavailability of phosphorus, mineral elements and amino acids from components of feed for poultry and pigs. The birds were kept in a cage battery under the required microclimate conditions. The effect of feeding experimental additives on the safety of chickens, the intensity of their growth, meat productivity, chemical and amino acid composition of meat (minced meat), hematological parameters was studied. Introduction of protein-vitamin wheat bran meal pure and enzyme preparation Feedbest® P5000 GT into quail mixed fodder increased bird survival by 3.01%, average daily gain of live weight by 3.09 and 3.44% with almost equal feed expenses per unit production. The fat, calcium and phosphorus content in the meat of poultry fed with wheat bran flour containing phytase increased by 1.17, 1.13 and 1.17 times, respectively. The concentration of calcium and phosphorus in the meat of quail that received flour without enzyme preparation was 1.2 and 1.1 times lower than that of their counterparts that consumed flour with phytase. Biochemical blood parameters of all the experimental chickens remained within the physiological norm.

Keywords: quail, compound feed, protein-vitamin flour, enzyme preparation, livability, live weight

Для цитирования: *Рогачёв 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. https://doi.org/10.26898/0370-8799-2022-2-6. EDN IXOMCC.

For citation: 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. https://doi.org/10.26898/0370-8799-2022-2-6. EDN IXOMCC.

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

INTRODUCTION

Optimization of poultry feeding presupposes a balance of diets in terms of essential nutrients [1]. Consequently, developments aimed at improving the efficiency of grain raw materials in mixed fodders are of particular importance. During variety milling of wheat and rye grains the shells, aleurone layer and germ, morphological parts containing biologically valuable components are separated from the kernel [1,2] [2-4]. In the Siberian branch of the Federal Scientific Center of Food Systems named after M.M. Gorbatov of the Russian Academy of Sciences works are carried out to substantiate the possibility of producing biologically active forage high-protein and protein-vitamin additives from the products of flour-milling production (bran). The fractions obtained by milling bran and separating them on sieves differ in their biochemical composition. High-protein flour is a very fine fraction (50-60 microns) of milling. The fine fraction (140 μm) contains more protein and vitamins, but less crude fiber compared to the coarse fraction (400-800 μm). The amino acid composition of the protein of the obtained fractions significantly differs from the composition of wheat endosperm proteins and is characterized by a more balanced amino acid composition [5]. The content of dietary fiber in wheat bran can reach more than 50%. They are represented mainly by non-starch polysaccharides: arabinoxylans, β-glucans, fructans, cellulose [6]. In our previous studies, it was found that the use in the diet of laying quail of fractionated wheat bran flour with a particle size of 140 microns instead of 7% wheat feed is the most effective [7]. This fine fraction of flour contains more protein and almost 2 times less crude fiber than the large fractions (400-800 microns), because it is enriched with elements of the aleurone layer and germ, the concentration of protein in which reaches 35%, and cellulose and lignin are practically absent. The aleurone layer is also characterized by a higher content of soluble fibers compared to the outer shells of the grain [8]. The predominance of elements of the aleurone layer and germ in the fine fraction of the flour is explained by their more fragile structure compared to the outer shells of the grain; they are easier to dry grind and form a fine powder. The main form of phosphate storage in grains, legumes and nuts is phytic acid. Up to 80% of all phosphorus in seeds can be complexed with this natural compound. Almost 90% of phytic acid in cereals is localized in the aleurone layer, some amount (10%) is in the seed bud [9]. Phytic acid is considered an antialimentary factor because of its ability to firmly bind iron, calcium, zinc and magnesium ions to form phytate-mineral complexes whose solubility and digestibility are reduced. In wheat bran, the concentration of phytic acid is 3116-5839 mg/100 g [10]. During grain germination, phytic acid is decomposed by endogenous phytases, resulting in increased bioavailability of phosphorus and 2-valent ions. The addition of preparations containing phytase to bran should contribute to the enzymatic degradation of phytate and, as a consequence, increase the bioavailability of minerals. Therefore, studies on the effect of phytase introduced into the feed additive of fractionated protein-vitamin flour of wheat bran on the productivity and physiological condition of poultry are relevant.

The aim of the research was to evaluate the efficiency of using the protein-vitamin fraction of wheat bran (grinding degree 140 microns) enriched with a new generation enzyme preparation Fitbest® P5000 GT in diets of quails grown up to 60 days of age.

The research objectives are to determine the effect of the studied feed additive on the safety and growth rate of quail chickens, their meat productivity, chemical and amino acid composition of meat, and biochemical blood parameters.

[1]Sivilgaev A.V., Skryabin V.A., Reimer V.A. Production and application of activated high-protein additives from grain raw materials. Proceedings of the II International Conference "Food, Ecology, Quality". Krasnoobsk, 2002. P. 216.

[2]Machikhin L.I., Skryabin V.A. Production of protein-vitamin products from secondary grain raw materials. Food. Ecology. Quality. Proceedings of the V International Scientific and Practical Conference / RASKhN. Siberian Branch. SSI SibNIPTIP. Novosibirsk. 2008. Pp. 144-146.

MATERIAL AND METHODS

The experiment with duration of 60 days was carried out according to the standard methodology in 2021 on the quail farm of the physiological cage of the Siberian Research and Technological Design Institute of Animal Husbandry of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences (SRTDIAH SFSCA RAS) on Japanese quails formed at the age of one day into three similar groups (one control and two experimental) with 80 birds in each[3] (see Table 1).

Poultry housing conditions and microclimate in the cage battery complied with zootechnical requirements. All experimental birds were fed the same basic diet (mixed fodder), prepared taking into account the age and physiological characteristics of the quails. Intergroup differences were as follows: the birds of the control group received only the basic diet (BD), the quails of the 1st and 2nd experimental groups consumed BD, in which part of the wheat (7%) was replaced by a protein-vitamin fraction of wheat bran with a grinding degree of 140 microns. Quails of the 2nd experimental group received the protein-vitamin fraction of wheat bran to which the enzyme preparation Fitbest® P5000 GT, designed to increase the bioavailability of phosphorus, mineral elements and amino acids from components of feed for poultry and pigs, was introduced. Heat stable preparation of new generation Fitbest® P5000 GT ensures release of more than a half of P and amino nitrogen bound in protein matrix with phytin, chelated minerals (Ca, Mg, Zn, Cu, Fe, etc), eliminates anti malnutrition factors, increases availability of nutrients and energy in feed. Dosage of enzyme preparation (300 g/t feed) corresponds to the norm for broiler chickens, recommended in the instructions for its use. Protein-vitamin flour with particle size of 140 microns used in the experiment was produced at the experimental bench of the Siberian branch of the Federal Research Center of Food Systems named after M. Gorbatov RAS by grinding wheat bran on a finger-type mill and further fractionation on sieves. The output of the required fraction is 50% of the initial mass of wheat bran.

Табл. 1. Схема опыта
Table 1. Experiment scheme

Group	Number, heads	Feeding conditions
Control	80	BD (basic diet – mixed fodder)
Experimental:		
1st	80	BD, containing 7% of the protein-vitamin fraction of wheat bran (140 microns grinding)
2nd	80	BD, containing 7% of protein-vitamin fraction of wheat bran (140 microns grinding) with enzyme preparation Fidbest® P5000 GT (dosage 300 g/t)

The diets were prepared in accordance with the norms of the All-Russian Research Technological Institute of Poultry Breeding of the Russian Academy of Sciences[4] [1]. The mixed fodder fed according to the eating capacity contained the recommended amount of metabolizable energy and basic nutrients. For the first 5 days, the chicks were fed boiled quail eggs in addition to the mixed fodder in order to improve their adaptation to the external environment. Feed intake was monitored daily by weighing the given feed and its residues. The behavior and health status of the quails was monitored daily. Control weighings of the birds were performed at starter, at 30 days of age, and at 2 months of age at the end of the rearing period. At 60 days of age, quail cockerels were slaughtered, selected according to the average live weight of the group (three heads from each group) (see footnote 3). The chemical composition of mixed fodder, wheat bran meal, and quail meat was studied in the biochemical labo-

[3]Methodology of scientific and industrial research on the feeding of poultry. Edited by V.I. Fisinin and Sh.A. Imangulov. Sergiev Posad, 2000. 33 p.

[4]Recommendations on feeding of farm poultry. Edited by V.I. Fisinin and Sh.A. Imangulov, I.A. Egorov, T.M. Okolelova. Sergiev Posad, 2003. 142 p.

ratory of the SRTDIAH SFSCA RAS according to generally accepted methods of zootechnical analysis. Biochemical composition of poultry blood was determined in the biotechnology laboratory of the Institute of Experimental Veterinary Science of Siberia and the Far East SFSCA RAS. The digital material obtained in the experiment was processed by the method of variation statistics on a personal computer using Microsoft Office Excel software.

Табл. 2. Структура и питательность комбикормов для перепелов

Table 2. Structure and nutritional value of mixed fodder for quails

Component	Age, days	
	0–30	31–60 and older
Structure, %		
Feed wheat	60,0	57,0
Full fat soybeans	10,0	10,0
Sunflower seed cake	10,0	10,0
Fish meal	5,0	–
Meat and bone meal	5,0	10,0
Fodder yeast	5,0	5,0
Premix	1,0	1,0
Tricalcium phosphate	2,0	2,0
Fodder chalk	2,0	2,0
Shell	–	3,0
100 g of mixed fodder contains		
Exchange energy, MJ		
crude nutrients	1,28	1,32
digestible nutrients	1,10	1,11
Crude protein, %	26,40	20,88
Digestible protein, %	15,45	14,60
Crude fat, %	3,71	3,83
Crude fiber, %	7,29	3,97
Nitrogen-free extractive substance, %	41,28	45,49
Crude ash, %	1,31	1,21
Calcium, %	1,46	1,84
Phosphorus, %	0,86	1,01

RESULTS AND DISCUSSION

Quail fodder was prepared taking into account their age and in accordance with the basic requirements for this type of birds: balance, high caloric value, and the required degree of milling (see Table 2). The mixed fodder was fed according to the eatability.

In terms of energy nutrition, pure and enriched with enzyme preparation Fitbest® P5000 GT fractionated protein-vitamin wheat bran flour were practically equal (difference in ME concentration of 0.78%). No significant differences between them in crude protein content (0.35% difference) and amino acid index (amino acid balance) (2.06% difference) were also noted (see Table 3).

In 1 kg of fractionated protein-vitamin wheat bran flour with a grinding degree of 140

Табл. 3. Питательность и химический состав фракционированной белково-витаминной муки пшеничных отрубей (степень помола 140 мкм)

Table 3. Nutritional value and chemical composition of fractionated protein-vitamin wheat bran flour (degree of grinding 140 microns)

Indicator	Fractionated protein-vitamin wheat bran flour	
	pure	with enzyme preparation Feedbest® P5000 GT
Exchange energy, MJ/kg	14,17	14,06
Chemical composition, %		
Crude protein	14,68	15,03
Crude fat	3,86	3,97
Crude fiber	3,80	3,09
Nitrogen-free extractive substance	60,7	57,51
Crude ash	2,86	2,98
Calcium	0,500	0,546
Phosphorus	0,252	0,246
Essential amino acids sum	4,297	3,686
Dispensable amino acids sum	8,035	7,038
Amino acids total	12,332	10,724
Amino acid index	0,535	0,524

microns the content of vitamin B1 was 7.6 mg, vitamin B3 - 3.8 mg vitamin B5 - 72.3 mg, vitamin E - 31.0 mg, which is more than in the original wheat bran by 2.17; 1.52; 1.64 and 1.24 times respectively.

The use of protein-vitamin wheat bran flour of 140 microns grinding degree in pure form and enriched with enzyme preparation Fidbest® P5000 GT in quail diets was found to have a positive effect on the safety and growth rate of birds (see Table 4).

The survival of chickens in the 1st and 2nd experimental groups increased by 3,01% relative to the control, the average daily gain of live weight (for 60 days of experience) by 3,09 and 3,44% (p>0,05) with almost equal feed consumption per unit (the maximum intergroup difference between the control and the 2nd experimental group was 1,75%). Feed consumption by poultry of the 1st and 2nd experimental groups increased insignificantly by 3.55 and 5.0% in comparison with the control counterparts.

The results of the control slaughter of quail chickens showed that the weight of the pan-ready carcass in the 1st and 2nd experimental groups was 1.44 and 3.36% higher than in the control (p> 0.05) (see Table 5). Intergroup differences in slaughter yield were insignificant (maximum 1.92%).

Inclusion of wheat bran protein-vitamin flour in the diet affected the chemical composition of meat (minced meat) of quail chickens (see Table 6). The first experimental group exceeded the control group in meat dry matter content by 1.75% (p> 0.05), fat by 1.18 times, but was inferior to it in calcium concentration by 1.06 times (p> 0.05). The meat of poultry of the 2nd ex-

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	
		1st	2nd
Safety, %	94,00	97,01	97,01
Live weight, g:			
in the beginning of the experiment	8,50 ± 0,07	8,50 ± 0,09	8,73 ± 0,07
at the age of 30 days	79,81 ± 2,42	90,32 ± 2,42	85,31 ± 2,08
at the age of 60 days	183,37 ± 2,53	188,73 ± 2,55	189,26 ± 2,04
Live weight gain in 60 days, g:			
absolute	174,87 ± 2,39	180,23 ± 2,44	180,53 ± 2,38
daily average	2,91 ± 0,03	3,0 ± 0,04	3,01 ± 0,03
Feed consumption in 60 days, kg	1,100	1,139	1,155
Feed expenses per 1 kg of growth, kg	6,29	6,32	6,40

Табл. 5. Результаты контрольного убоя подопытной птицы
Table 5. Results of control slaughter of experimental poultry

Indicator	Group		
	control	experimental	
		1st	2nd
Pre-slaughter live weight, g	180,12 ± 0,77	185,43 ± 0,68	184,29 ± 0,59
Gutted carcass weight, g	139,0 ± 0,84	141,00 ± 0,63	143,67 ± 0,99
Slaughter yield, %	77,17 ± 0,43	76,04 ± 0,95	77,96 ± 0,53

perimental group fed wheat bran with enzyme preparation contained 0,87% more dry matter, 1,17 times more fat ($p < 0,01$), 1,13 times more calcium and 1,17 times more phosphorus ($p < 0,05$) than the control. The concentration of calcium and phosphorus in the meat of quails fed with flour without enzyme preparation was 1.2 and 1.1 times lower than that of counterparts consuming flour with phytase.

No significant intergroup differences in the balance of meat amino acids were observed. The amino acid index of meat of quail of control counterparts, the 1st and 2nd experimental groups was almost the same (within 0.92-0.97).

Hematological studies indicate that all experimental quails were clinically healthy (see Table 7). No significant intergroup differences in biochemical blood parameters of the birds were observed.

Табл. 6. Химический и аминокислотный состав мяса (фарша) цыплят перепелов, %
Table 6. Chemical and amino acid composition of meat (minced meat) of quail chickens, %

Indicator	Group		
	control	experimental	
		1st	2nd
Dry matter	29,27 ± 0,17	31,02 ± 0,09	30,14 ± 0,20
Proteic substance	19,67 ± 0,27	20,32 ± 0,11	19,58 ± 0,22
Fat	6,00 ± 0,19	7,07 ± 0,10	7,00 ± 0,10
Ash	3,60 ± 0,08	3,63 ± 0,05	3,56 ± 0,04
Calcium	1,329 ± 0,004	1,250 ± 0,005	1,504 ± 0,004
Phosphorus	0,800 ± 0,005	0,846 ± 0,006	0,933 ± 0,005
Amino acids:			
Essential amino acids sum (arginine, valine, histidine, lysine, leucine, isoleucine, tryptophan, threonine, tyrosine, phenylalanine)	7,81	7,76	7,72
Dispensable amino acids sum (proline, serine, alanine, glycine, glutamine, asparagine, cystine)	8,46	7,99	7,92
Amino acid index	0,92	0,97	0,97

Табл. 7. Биохимические показатели крови цыплят перепелов
Table 7. Biochemical blood parameters of quail chickens

Indicator	Group		
	control	experimental	
		1st	2nd
Total protein, g/l	38,15 ± 1,54	38,50 ± 0,75	39,12 ± 1,60
Albumin, g/l	21,08 ± 1,22	20,81 ± 0,74	21,69 ± 0,83
Globulin, g/l	17,07 ± 0,43	17,69 ± 0,35	17,43 ± 0,76
SGOT, units/l	280,77 ± 27,18	278,32 ± 19,18	293,03 ± 35,10
SGPT, units/l	15,67 ± 3,16	14,73 ± 1,58	14,73 ± 3,68
Calcium, mmol/l	2,41 ± 0,07	2,47 ± 0,09	2,57 ± 0,07
Phosphorus, mmol/l	2,32 ± 0,13	3,15 ± 0,51	3,19 ± 0,47
Glucose, mmol/l	4,54 ± 0,27	5,02 ± 0,31	4,70 ± 0,21

CONCLUSIONS

1. The use of protein-vitamin wheat bran flour of 140 μm grinding degree in pure form and with enzyme preparation Fitbest® P5000 GT (instead of 7% wheat mixed feed) in quail diets had a positive effect on the livestock breeding indicators. The survival rate of chickens in the experimental groups increased by 3.01% relative to the control; average daily gain of live weight increased by 3.09 and 3.44% ($p < 0,05$) with practically the same amount of feed per unit. Intergroup differences in slaughter yield are insignificant (maximum 1.92%).

2. The meat of quails fed with protein-vitamin wheat bran meal containing Fitbest® P5000 GT containing phytase had 1.17; 1.13 and 1.17 times more fat, calcium and phosphorus, respectively, in comparison with the control ($p < 0.05$). The concentration of calcium and phosphorus in the meat of quails fed with flour without enzyme preparation was 1.2 and 1.1 times lower than that of counterparts consuming flour with phytase. Biochemical blood parameters of all experimental chickens remained within the physiological norm.

СПИСОК ЛИТЕРАТУРЫ

1. *Фисинин В.И., Егоров И.А., Околелова Т.М., Имангулов Ш.А.* Кормление сельскохозяйственной птицы: монография. Сергиев Посад, 2003. 375 с.
2. *Вишняков А., Власов В., Тоньшина Т., Новицкий О., Панин И.* Мука зародышей пшеницы в комбикормах // Комбикорма. 2003. № 4. С. 41–42.
3. *Казаков Е.Д., Кретович В.Л.* Биохимия зерна и продуктов его переработки: монография. М.: Агропромиздат, 1989. 368 с.
4. *Якунина Н., Мальцева Н., Ядришенская О., Невинный В.* Кормовая добавка из зародышей пшеницы // Комбикорма. 2004. № 4. С. 37–38.
5. *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.
6. *Лукьянчикова Н.Л., Скрябин В.А., Табанюхов К.А.* Особенности состава отрубей пшеницы и ржи и их роль в профилактике хронических заболеваний человека. Обзор // Инновации и продовольственная безопасность. 2020. № 4 (30). С. 41–58.
7. *Рогачёв В.А., Мерзлякова О.Г., Чегодаев В.Г., Лукьянчикова Н.Л.* Фракционированная белково-витаминная мука из пшеничных отрубей в рационах несушек перепелов // Кормление сельскохозяйственных животных и кормопроизводство. 2021. № 11 (196). С. 40–48.
8. *Hemery Y., Rouau X., Lullien-Pellerin V., Barron C., Abecossis J.* Dry processes to develop wheat fractions and products with enhanced nutritional quality // Journal of Cereal Science. 2007. N 46. P. 327–347.
9. *Dost K., Tokul O.* Determination of phytic acid in wheat and wheat products by reverse phase high performance liquid chromatography // Analytica Chimica Acta. 2006. N 558. P. 22–27.
10. *Bilgicli N., Ibanoglu. S.* Effect of wheat germ and wheat bran on the fermentation activity, phytic acid content and colour of tarhana // Journal of Food Engineering. 2007. N 78. P. 681–686.

REFERENCES

1. Fisinin V.I., Egorov I.A., Okolelova T.M., Imangulov S.A. *Feeding of poultry*. Sergiev Posad, 2003, 375 p. (In Russian).
2. Vishnyakov A., Vlasov V., Tonshina T., Novitsky O., Panin I. Flour of wheat germ in compound feeds. *Kombikorma = Compound feeds*, 2003, no. 4., pp. 41–42. (In Russian).
3. Kazakov E.D., Kretovich V.L. *Biochemistry of grain and products of its processing.* Moscow, Agropromizdat Publ., 1989, 368 p. (In Russian).
4. Yakunin, N., Maltsev N., Adriansky O., Nevinny V. Feed additive of wheat germ. *Kombikorma = Compound feeds*, 2004, no. 4, pp. 37–38. (In Russian).
5. Skryabin V.A., Sabayev 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' = Innovation and food safety,* 2019, no. 3 (25), pp. 105–111. (In Russian).
6. Lukyanchikova N.L., Skryabin V.A., Tabanyukhov K.A. Peculiarities of the composition of wheat and rye bran and their role in the prevention of chronic diseases. Review. *Innovatsii i prodovol'stvennaya bezopasnost' = Innovations and food safety,* 2020, no. 4 (30), pp. 41–58. (In Russian).

7. Rogachev V.A., Merzlyakova O.G., Chegodaev V.G., Lukyanchikova N.L. Fractionated protein and vitamin flour from wheat bran in the diets of laying quails. *Kormlenie sel'skokhozyaistvennykh zhivotnykh i kormoproizvodstvo = Feeding of farm animals and feed production,* 2021, no.11 (196), pp. 40–48. (In Russian).
8. Hemeri Yu., Ruau H., Lullien-Pellerin V., Barron S., Abekossis J. Dry processes for obtaining wheat fractions and products with increased nutritional quality. *Journal of Grain Sciences,* 2007, no. 46, pp. 327–347.
9. Dost K., Tokul O. Determination of phytic acid in wheat and wheat products by high-performance liquid chromatography with a reverse phase. *Analytica Chimica Acta,* 2006, no. 558, pp. 22–27.
10. Have Bilgili N., Ibanoglu. S. Effect of wheat germ and wheat bran on the activity of fermentation, the contents of phytic acid and color Tarkhany. *Journal of food engineering,* 2007, no. 78, pp. 681–686.

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Рогачёв В.А.,** доктор сельскохозяйственных наук, заведующий лабораторией; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, а/ я 463, СФНЦА РАН; e-mail: helmmet@mail.ru

Мерзлякова О.Г., старший научный сотрудник

Лукьянчикова Н.Л., кандидат биологических наук, старший научный сотрудник

Магер С.Н., доктор биологических наук, руководитель структурного подразделения СибНИПТИЖ СФНЦА РАН

AUTHOR INFORMATION

(✉) **Victor A. Rogachev,** Doctor of Science in Agriculture, Laboratory Head; **address:** PO Box 463, SFSCA RAS, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: helmmet@mail.ru

Olga G. Merzlyakova, Senior Researcher

Nina L. Lukyanchikova, Candidate of Science in Biology, Senior Researcher

Sergey N. Mager, Doctor of Science in Biology, Business Unit Supervisor at Siberian Research Institute of Animal Husbandry SFSCA RAS

Дата поступления статьи / Received by the editors 22.12.2021
Дата принятия к публикации / Accepted for publication 17.03.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-7
УДК: 619:616.775.26
Тип статьи: оригинальная
Type of article: original

ВЛИЯНИЕ НАНОЧАСТИЦ СЕРЕБРА НА АНТИБИОТИКОРЕЗИСТЕНТНОСТЬ МИКРООРГАНИЗМОВ ПРИ ЛЕЧЕНИИ ЭНДОМЕТРИТА КОРОВ

Нефедова Е.В., (✉) **Шкиль Н.Н.**
Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: nicola07@mail.ru

Главный этиологический фактор возникновения эндометритов – патогенная и условно-патогенная микрофлора, проникающая в матку в послеродовой период, во время течки, искусственного осеменения загрязненной спермой. Проведено исследование с целью изучения изменения антибактериальной чувствительности микроорганизмов при терапии послеродового гнойно-катарального эндометрита коров препаратом, содержащим наночастицы серебра. Для изучения роли условно-патогенной микрофлоры в этиологии послеродовых гнойно-катаральных эндометритов проведено клиническое исследование 150 коров в условиях хозяйства Новосибирской области в период массового отела. Животных по принципу аналогов разделили на опытную и контрольную группы. Контрольной группе вводили рыбий жир внутриматочно в дозе 150 мл с окситетрациклином гидрохлоридом в дозе 40 мг/кг живой массы, 1 раз в 48 ч и утеротон внутримышечно в дозе 10 мл, однократно 1 раз в 48 ч. Опытной группе вводили внутриматочно 10%-й водный раствор арговита в дозе 100 мл, 1 раз в 48 ч и утеротон внутримышечно 10 мл, однократно 1 раз в 48 ч. Установлено, что при лечении послеродового гнойно-катарального эндометрита коров препаратом арговит уменьшается средний срок лечения заболевания в 1,8 раза по сравнению препаратом в контрольной группе. При лечении послеродового гнойно-катарального эндометрита коров препаратом арговит установлен рост антибиотикочувствительности изолированной микрофлоры к 21 препарату (87,5%) – от 1,2 до 100%. В контрольной группе отмечено снижение антибиотикочувствительности выделенной микрофлоры к 18 (75%) препаратам – от 1,1 до 28,7%.

Ключевые слова: гнойно-катаральный эндометрит, наночастицы серебра, антибиотикорезистентность, микроорганизмы

EFFECT OF SILVER NANOPARTICLES ON ANTIBIOTIC RESISTANCE OF MICROORGANISMS IN THE TREATMENT OF ENDOMETRITIS IN COWS

Nefedova E.V., (✉) **Shkil N.N.**
Siberian Federal Scientific Center of Agro-BioTechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk Region, Russia
(✉) e-mail: nicola07@mail.ru

The main etiological factor in endometritis is pathogenic and opportunistic pathogenic microflora entering the uterus during the postpartum period, during estrus, artificial insemination with contaminated sperm. A study was carried out to investigate changes in antibacterial sensitivity of microorganisms during therapy after labor purulent-catarrhal endometritis of cows with a preparation containing silver nanoparticles. To study the role of opportunistic pathogenic microflora in the etiology of postpartum purulent-catarrhal endometritis a clinical study of 150 cows in a farm in the Novosibirsk region during mass calving was carried out. Animals were divided into experimental and control groups according to the analogy principle. The control group received fish oil intramuscularly in a dose of 150 ml with oxytetracycline hydrochloride in a dose of 40 mg/kg of live weight once every 48 hours and uteroton intramuscularly in a dose of 10 ml once every 48 hours. The experimental group received intrauterine injections of argovit 10% aqueous solution at a dose of 100 ml once every 48 h and uteroton intramuscularly at a dose of 10 ml once every 48 h. It was found that the treatment of postpartum purulent-catarrhal endometritis of cows with argovit decreased the average duration of treatment of the disease by 1.8 times compared to the preparation in the control group. When treating postpartum purulent-catarrhal endometritis of cows with argovit, an increase

in antibiotic sensitivity of the isolated microflora to 21 drugs (87.5%) from 1.2 to 100% was found. In the control group, there was a decrease in antibiotic sensitivity of the isolated microflora to 18 (75%) preparations from - 1.1 to 28.7%.

Keywords: clinical endometritis, silver nanoparticles, antibiotic resistance, microorganisms.

Для цитирования*: Нефедова Е.В., Шкиль Н.Н.* Влияние наночастиц серебра на антибиотикорезистентность микроорганизмов при лечении эндометрита коров // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 55–62. https://doi.org/10.26898/0370-8799-2022-2-7. EDN LAVGTZ.

For citation: Nefedova E.V., Shkil N.N. Effect of silver nanoparticles on antibiotic resistance of microorganisms in the treatment of endometritis in cows. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 2, pp. 55–62. https://doi.org/10.26898/0370-8799-2022-2-7. EDN LAVGTZ.

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

INTRODUCTION

The increase in the reproduction of herds is greatly slowed down by the spread of the breeding stock infertility, which is caused by gynecological pathologies. Inflammatory processes in the uterus take a chronic course due to untimely treatment of acute endometritis, as well as incomplete course of therapy. Endometritis, which reduces milk productivity, reproductive ability, and milk quality, leading to premature culling and failure to produce animal yield, is one of the most common gynecological diseases of cattle [1-5].

Endometritis of bacterial origin remains one of the most pressing problems of veterinary medicine. Due to the complexity of the etiology of this disease, it is currently impossible to develop a specific prevention and therapy, which entails uncontrolled use of broad-spectrum drugs. Their long-term uncontrolled use has led to global antibiotic resistance of microorganisms [6, 7]. This raises the need for the latest complex drugs. One of the promising areas of modern pharmacology is the creation of new drugs using nanotechnology products, which opens up the possibility of increasing their effectiveness [8, 9].

The purpose of the study was to investigate the change in antibacterial sensitivity of microorganisms during the therapy of postpartum purulent-catarrhal endometritis of cows with a preparation containing silver nanoparticles.

MATERIAL AND METHODS

To study the role of opportunistic microflora in the etiology of postpartum purulent-catarrhal endometritis a clinical study of 150 cows under farm conditions in the Novosibirsk region was carried out. Endometritis diagnostics, treatment, typing and antibiotic sensitivity determination of the isolated microorganisms were carried out according to the "Methodical instructions on diagnostics, therapy and prophylaxis of reproductive organs diseases of cows and heifers" (2005). The material for examination was vaginal mucus secretion before and after treatment. The vaginal secretion was collected with a sterile cotton-gauze tampon after a thorough cleaning of the vulva and the root of the tail with a tampon moistened with 70% ethyl alcohol rectifying agent.

Bacteriological examination was performed by inoculating the vaginal mucus secretion on 5% blood agar, MPA with 1% glucose, and Endo medium. Staphylococci and streptococci were isolated using a selective supplement ("StaphStrepto Supplement", India). Identification of microflora isolated from sick cows was carried out taking into account cultural, morphological and biochemical properties of bacteria according to generally accepted methods (Bergey's Bacterial Identifier, 2000). Biochemical properties of bacteria were studied using a set of reagents - biochemical plates differentiating enterobacteriaceae (SPA Diagnostic Systems LLC, Nizhny Novgorod), streptococci

(Strepto-test 16 Erba Lachema s.r.o., the Czech Republic), staphylococci (Staphytest- 24 Erba Lachema s.r.o., the Czech Republic).

Microflora sensitivity was investigated by disco-diffusion method on Mueller-Hinton agar (Bio-Rad, USA) in accordance with the criteria of the European Committee for Antibiotic Susceptibility Testing (EUCAST, 2018). Multiple drug resistance was defined as resistance to three or more antibacterial agents.

Argovit drug is a complex of highly dispersed nanoparticles of cluster silver, polyvinylpyrrolidone and aqueous solution obtained by electrobeam method. It has a wide range of antimicrobial action against Gram-positive and Gram-negative, aerobic and anaerobic, spore-forming and asporogenic bacteria in the form of monocultures and microbial associations.

Fish oil (veterinary fat), derived from fish and marine mammals, is a source of vitamins and polyunsaturated fatty acids, 1 ml of which contains vitamins: E - 600 micrograms, A - 500 IU and D3 - 30 IU. It is used internally for prevention and treatment of vitamin A deficiency, rickets, chronic infections, sexual disorders in animals.

Oxytetracycline hydrochloride is an antibacterial drug of the tetracycline group that is effective against rickettsiae, gram-negative and gram-positive microbes.

Uterotone has a blocking effect on myometrial beta-adrenoreceptors, which contributes to the activity of endogenous oxytocin, resulting in increased uterine smooth muscle contractions.

Animals were divided into experimental and control groups according to the analogy principle. The control group (n = 75) received fish oil intrauterinely in a dose of 150 ml with oxytetracycline hydrochloride in a dose of 40 mg/kg live weight once every 48 hours and Uteroton intramuscularly in a dose of 10 ml, once every 48 hours. The experimental group received intrauterine injections of Argovit 10% aqueous solution in a dose of 100 ml once every 48 hours and Uteroton intramuscularly in a dose of 10 ml once every 48 hours.

RESULTS AND DISCUSSION

Microbiological studies of mucus from the cervical-vaginal canal of cows with postpartum endometritis revealed microorganisms of *Streptococcus* spp. in 24.1% of samples, *Staphylococcus* spp. - 22.5, *E. coli* 20.0, *S. enteritidis* 19.2, and *Pr. vulgaris* 14.2% of samples, respectively (see Table 1). Bacteriological studies of uterine and vaginal secretions of cows with postpartum purulent-catarrhal endometritis revealed the following associations of microorganisms: *Str. pyogenes* + *St. aureus* + *Pr. vulgaris* + *E. coli* (47.5%), *Str. pyogenes* + *E. coli* (19.2), *S. enteritidis* + *E. coli* + *Pr. vulgaris* (15.8), *St. aureus* + *E. coli* (10) and *Str. pyogenes* + *St. aureus* (7.5%).

Laboratory studies of microbial isolates showed high sensitivity to oxytetracycline, which justified its use as a control drug in the production trial of Argovit. The results of the study revealed significant therapeutic efficacy in the treatment of postpartum purulent catarrhal endometritis in cattle with silver-containing drug Argovit compared with an antibacterial agent. During therapy with Argovit the average period of treatment of cows was 7,8 ± 0,1 days,

Табл. 1. Микроорганизмы, выделенные из маточно-влагалищных выделений коров, больных послеродовым гнойно-катаральным эндометритом

Table 1. Microorganisms isolated from the uterine-vaginal secretions of cows with postpartum purulent-catarrhal endometritis

Microorganism	Number of isolates	%
Streptococcus pyogenes	29	24,1
Streptococcus aureus	27	22,5
Escherichia coli	24	20,0
Salmonella enteritidis	23	19,2
Proteus vulgaris	17	14,2
Str. pyogenes + *St. aureus* + *Pr. vulgaris* + *E. coli*	57	47,5
Str. pyogenes + *E. coli*	23	19,2
Salmonella + *E. coli* + *Pr. vulgaris*	19	15,8
St. aureus + *E. coli*	12	10,0
Str. pyogenes + *St. aureus*	9	7,5

which is 1,8 times shorter in comparison with the complex preparation (fish oil + oxytetracycline hydrochloride) in the control group, where the period of treatment was 14,1 ± 0,6 days.

After treatment of cows with postpartum purulent-catarrhal endometritis, the control group showed a decrease in antibiotic sensitivity of the isolated microflora to 18 (75%) drugs, from 1.1 to 28.7%. A slight increase to tylosin, lincomycin, polymyxin, erythromycin, gentamicin and carbenicillin was detected, from 3.7 to 24.8%. When cows were treated with Argovit, there was an increase in antibiotic sensitivity of isolated microflora to 21 drugs (87.5%), from 1.2 to 100%, with simultaneous decrease of sensitivity to doxycycline, enrofloxacin and oxytetracycline from 3.1 to 23.2% (see Table 2).

The obtained results of enhancing the bactericidal effect when AgNPs are used together with antibacterial drugs are confirmed in other studies as well. S. Z. Naqvi et al. [10] described the combined effect of concomitant use of antibacterial drugs and silver nanoparticles against multidrug-resistant bacteria. It was found that the synergistic effect of antibiotics (ciprofloxacin, imipenem, gentamicin, vancomycin, trimethoprim) and nanoparticles led to an increase in antibacterial activity by 0.2-7.0 (average 2.8) times. This confirms that nanoparticles can be effectively used in combination with antibiotics to increase their effectiveness against various pathogenic microbes. M.S.M. Mohamed et al. [11] described the antibacterial effect of combined use of AgNPs and vancomycin against *St.*

Табл. 2. Изменение уровня чувствительности выделенной микрофлоры к антибиотикам при лечении гнойно-катарального эндометрита (n = 40), %

Table 2. Change in the level of sensitivity of the isolated microflora to antibiotics in the treatment of purulent-catarrhal endometritis (n = 40), %

Antibiotic	Control group, n = 40		%	Experimental group		%
	Before treatment	After treatment		Before treatment	After treatment	
Amoxicillin	12,9 ± 0,9	11,3 ± 0,5	–12,4	15,2 ± 0,3	18,7 ± 0,1	+23
Ampicillin	15,3 ± 0,1	10,9 ± 0,4	–28,7	16,2 ± 0,5	17,1 ± 0,4	+5,5
Amikacin	14,3 ± 1,0	12,8 ± 0,2	–10,4	16,5 ± 0,2	16,7 ± 0,7	+1,2
Benzyl-penicillin	16,1 ± 0,3	15,3 ± 0,1	–4,9	16,1 ± 0,1	16,7 ± 0,4	+3,1
Gentamicin	15,3 ± 0,8	17,4 ± 0,2	+13,7	18,9 ± 0,4	21,4 ± 0,1	+13,2
Doxycycline	16,1 ± 0,1	14,3 ± 0,9	–11,2	16,3 ± 0,1	15,8 ± 0,5	–3,1
Carbenecillin	12,5 ± 0,7	15,6 ± 0,2	+24,8	20,1 ± 0,4	21,8 ± 0,4	+8,4
Norfloxacin	16,2 ± 1,1	12,3 ± 0,9	–24,1	16,3 ± 0,7	17,4 ± 0,1	+6,7
Neomycine	13,7 ± 0,5	12,6 ± 0,3	–8	16,9 ± 0,5	18,5 ± 0,2	+9,5
Polymyxin	12,1 ± 0,7	13,1 ± 0,4	+8,3	16,4 ± 0,7	17,5 ± 0,3	+6,7
Rifampicine	15,2 ± 0,2	14,1 ± 0,1	–7,2	–	15,6 ± 0,1	+100
Streptomycin	19,9 ± 0,1	15,6 ± 0,7	–21,6	17,4 ± 0,2	18,1 ± 0,1	+4
Enrofloxacin	19,3 ± 0,6	17,5 ± 0,1	–9,3	18,9 ± 0,7	16,3 ± 0,2	–13,7
Ciprofloxacin	18,1 ± 0,8	16,7 ± 0,5	–7,7	16,9 ± 0,3	19,2 ± 0,4	+13,6
Tetracyclin	18,3 ± 0,4	17,1 ± 0,7	–6,5	–	17,1 ± 0,6	+100
Oxytetracycline	22,1 ± 0,7	17,8 ± 0,5	–19,4	23,2 ± 0,5	17,8 ± 0,7	–23,2
Ofloxacin	17,3 ± 0,5	16,2 ± 0,1	–6,3	–	18,4 ± 0,6	+100
Lincomycin	17,6 ± 0,2	18,7 ± 0,4	+6,2	16,9 ± 0,5	18,1 ± 0,3	+7,1
Tylosin	13,7 ± 0,6	14,2 ± 0,1	+3,7	17,8 ± 0,4	18,5 ± 0,1	+3,9
Tobramycin	17,3 ± 0,2	17,1 ± 0,4	–1,1	17,6 ± 0,7	18,4 ± 0,7	+4,5
Laevomycetin	17,5 ± 0,1	16,2 ± 0,3	–7,4	–	15,6 ± 0,1	+100
Ceftiofur	16,7 ± 0,3	15,8 ± 0,6	–5,4	16,1 ± 0,8	16,7 ± 0,2	+3,7
Ofloxacin	17,8 ± 0,6	16,6 ± 0,1	–6,7	16,5± 0,5	16,8 ± 0,1	+1,8
Erythromycin	14,2 ± 0,4	15,7 ± 0,8	+10,5	18,3 ± 0,4	19,1 ± 0,7	+4,4

aureus, *Pseudomonas aeruginosa* and *Streptococcus pneumoniae*.

Synergistic effect of AgNPs in combination with erythromycin and levofloxacin against *St. aureus* was noted. Antimicrobial activity with antibiotics compared to pure silver nanoparticles increased by 1.16-1.32 times. This synergism may be relevant for the treatment of infections caused by multidrug-resistant bacteria [12].

The results of the studies confirm the synergistic antibacterial effect of the combined use of AgNPs and antibacterial agents, which was established by determining the antimicrobial activity of AgNPs and chlorhexidine gluconate against the five most common pathogenic bacteria of the human oral cavity. The average MIC value of AgNPs for *Streptococcus mutans* MTCC 497 was 60 ± 22.36 μg/ml, *Str. oralis* MTCC 2696 - 45 ± 11.18, *Lactobacillus asidorhylus* MTCC 10307 - 15 ± 5.59, *L. fermentum* - 90 ± 22.36, *Candida albicans* MTCC183- 2.82 ± 0.68 μg/ml respectively. For chlorhexidine gluconate, the mean MIC of *Str. mutans* MTCC 497 was 300 ± 111.80 μg/ml, *Str. oralis* MTCC 2696 was 150 ± 55.90, *L. acidophilus* MTCC 10307 was 450 ± 111.80, *L. fermentum* was 450 ± 111.80 and *C. albicans* MTCC 183 was 150 ± 55.90 μg/ml [13].

The results of the studies showed the intensity of bactericidal properties depending on the type of the studied preparation. Literature data confirm the evaluation of the antibacterial effect of using AgNPs and antibiotics against bacteria isolated from animals that show resistance to antibiotics by serial dilution method. The minimum inhibitory concentrations of both types of antimicrobials were determined, both individually and in combination. The fractional index of inhibitory concentration was calculated and used to classify the observed collective antibacterial activity as synergistic, additive (only the sum of the individual drug effects), indifferent (no effect), or antagonistic. Of the 40 tests performed, 7 were synergistic, 17 were additive, and 16 were indifferent. None of the combinations tested showed an antagonistic effect. Most synergistic effects were observed for combinations of AgNPs administered together with gentamicin, but the greatest increase in antibacterial activity was found for combination therapy together with penicillin G against *Actinobacillus pleuropneumoniae. A. pleuropneumoniae* and *Pasteurella multocida*, initially resistant to amoxicillin, gentamicin and colistin, were sensitive to these antibiotics when combined with AgNPs. A study shows that AgNPs have potential as adjuvants for the treatment of bacterial diseases in animals [14].

The analysis of the studies allows us to identify some regularities in the changes of antibacterial properties of the preparations when they are used mono- and in combination. The presence of pronounced antibacterial properties in the Argovit preparation containing AgNPs both in monovariant use and in combination with antibacterial preparations was noted. At the same time, the inclusion of AgNPs and DMSO has a pronounced synergistic effect and significantly reduces the antibiotic concentration at which the bactericidal effect is fixed. The highest sensitivity of both AgNPs and their combinations with antibiotics was found in the reference strain *E. Coli* ATCC 25922 strain compared to the *E. coli* isolate isolated from an animal with a clinical manifestation of an infectious disease. The combination of AgNPs and the antibiotics enrofloxacin, gentamicin, ceftimag, cipromag, oxytetracycline, and ampicillin showed the greatest increase in bactericidal activity against both *E. coli* ATCC 25922 and the *E. coli* isolate than the combination of AgNPs + antibiotic + DMSO, except for cloxacillin when studied with the *E. coli* isolate [9, 15].

Increasing the effectiveness of antimicrobial activity due to combinations of AgNPs and antibiotics will allow the use of antibiotics that have fallen out of use due to bacterial resistance problems, providing additional treatment options in the health, veterinary and agricultural sectors. The studies conducted confirm the results of I.A. Mamonova[1] on the ability of metal nanoparticles to restore the sensitivity of *E. coli*

[1]Mamonova I.A. Effect of transition metal nanoparticles on antibiotic-resistant strains of microorganisms: thesis abstract of the Can. Sci. in Biology. M., 2013. 21 p.

strains to some β-lactam antibiotics (ampicillin, amoxicillin) and aminoglycosides.

The results obtained open the prospect of further studies of AgNPs to evaluate the synergistic qualities of increasing the bactericidal properties of antibiotics against a wide range of infectious pathogens in the treatment of a wide range of pathologies.

CONCLUSION

When treating postpartum purulent-catarrhal endometritis of cows with the drug argovit, an increase in antibiotic sensitivity of the isolated microflora to 21 drugs (87.5%) from 1.2 to 100% was found. After treatment with the given preparation in cows suffering from postpartum purulent-catarrhal endometritis, the control group showed the decrease of antibiosensitivity of isolated microflora to 18 (75%) preparations from 1,1 to 28,7%. At the same time a slight increase to tylosin, lincomycin, polymyxin, erythromycin, gentamicin, and carbenicillin was observed, from 3.7 to 24.8%.

СПИСОК ЛИТЕРАТУРЫ

1. *Madoz L.V., Giuliodori M.J., Migliorisi A.L., Jaureguiberry M., Sota R.L.* Endometrial cytology, biopsy, and bacteriology for the diagnosis of subclinical endometritis in grazing dairy cows // Journal of Dairy Science. 2014. Vol. 97. N 1. P. 195–201.
2. *Wang J.* Comparison of vaginal microbial community structure in healthy and endometritis dairy cows by PCR-DGGE and real-time PCR // Anaerobe. 2016. Vol. 38. P. 1–6.
3. *Коба И.С., Решетка М.Б., Дубовиков М.С.* Распространение острых и хронических эндометритов у коров в сельскохозяйственных организациях Краснодарского края // Вестник Алтайского государственного аграрного университета. 2016. Т. 2. № 136. С. 103–106.
4. *Баймишев М.Х., Григорьев В.С.* К этиологии послеродовых осложнений у коров черно-пестрой породы // Известия Омского государственного аграрного университета. 2009. Т. 22. № 2. С. 267–269.
5. *Медведев Г.Ф., Гавриченко Н.* Причины, диагностика, лечение и профилактика метритного комплекса // Ветеринарное дело. 2013. № 10. С. 37–40.
6. *Валюшкин К.Д.* Ветеринарное акушерство, гинекология и биотехнология размножения: монография. М.: Колос, 2003. 495 с.
7. *Терентьева Н.Ю., Ермолаев В.А.* Роль микроорганизмов в этиологии акушерских заболеваний коров // Вестник Ульяновской государственной сельскохозяйственной академии. 2015. Т. 4. № 32. С. 147–155.
8. *D'Costa V.M., McGrann K.M., Hughes D.W.* Sampling the antibiotic resistome // Science. 2006. P. 374–377. DOI: 10.1126/science.1120800.
9. *Шкиль Н.Н., Нефедова Е.В.* Влияние антибиотиков и наночастиц серебра на изменение чувствительности *E. coli* к антибактериальным препаратам // Сибирский вестник сельскохозяйственной науки. 2020. Т. 50. № 2. С. 84–91.
10. *Naqvi S.Z., Kiran U., Ali M.I., Jamal A., Hameed A., Ahmed S., Ali N.* Combined efficacy of biologically synthesized silver nanoparticles and different antibiotics against multidrug-resistant bacteria // International Journal of Nanomedicine**.** 2013. Vol. 8. P. 3187–3195. DOI: 10.2147/IJN.S49284.
11. *Mohamed M.S.M., Mostafa H.M., Mohamed S.H.* Combination of silver nanoparticles and vancomycin to overcome antibiotic resistance in planktonic/biofilm cell from clinical and animal source // Microbial Drug Resistance. 2020. Nov. 26 (11). P. 1410–1420. DOI: 10.1089/mdr.2020.0089.
12. *Singh R., Wagh P., Wadhwani S., Gaidhani S., Kumbhar A., Bellare J., Ananda Chopade B.* Synthesis, optimization, and characterization of silver nanoparticles from Acinetobacter calcoaceticus and their enhanced antibacterial activity when combined with antibiotics // International Journal of Nanomedicine. 2013. Vol. 8. P. 4277–4290. DOI: 10.2147/IJN.S48913.
13. *Panpaliya N.P., Dahake P.T., Kale Y.J., Dadpe M.V., Kendre S.B.* In vitro evaluation of antimicrobial property of silver nanoparticles and chlorhexidine against five different oral pathogenic bacteria // Saudi Dental Journal. 2019. N 31 (1). P. 76–83. DOI: 10.1016/j.sdentj.2018.10.004.
14. *Smekalova M., Aragon V., Panacek A., Prucek R., Zboril R., Kvitek L.* Enhanced antibacterial effect of antibiotics in combination

with silver nanoparticles against animal pathogens // Journal of Veterinary. 2016. Vol. 209. P. 174–179. DOI: 10.1016/j.tvjl.2015.10.032.

15. *Shkil N.N., Nefyodova E.V., Shkil N.A., Nozdrin G.A., Lazareva M.V., Rasputina O.V., Ryumkina I.N.* Adjuvant properties of silver and dimethyl sulfoxide nanoparticles in studying antibacterial activity of antibiotics against *E. coli* // International journal of agriculture and biological science. 2020. Vol. 4. P. 119–126. DOI: 10.5281/zenodo.4286955.

REFERENCES

1. Madoz L.V., Giuliodori M.J., Migliorisi A.L. , Jaureguiberry M., Sota R.L. Endometrial cytology, biopsy, and bacteriology for the diagnosis of subclinical endometritis in grazing dairy cows. *Journal of Dairy Science*, 2014, vol. 97, no. 1, pp. 195–201.
2. Wang J. Comparison of vaginal microbial community structure in healthy and endometritis dairy cows by PCR-DGGE and real-time PCR. *Anaerobe*, 2016, vol. 38. pp. 1–6.
3. Koba I.S., Lattice M.B., Dubovikov M.S. The incidence of acute and chronic endometritis in cows in the farming enterprises of the Krasnodar Region. *Vestnik Altaiskogo gosudarstvennogo agrarnogo universiteta = Bulletin of Altai State Agricultural University*, 2016, vol. 2, no. 136, pp. 103–106. (In Russian).
4. Baymishev M.Kh., Grigoriev V.S. On the etiology of postnatal complications in black-flecked cows. *Izvestiya Omskogo gosudarstvennogo agrarnogo universiteta = Izvestia Orenburg State Agrarian University*, 2009, vol. 22, no. 2, pp. 267–269. (In Russian).
5. Medvedev G.F., Gavrichenko N. Causes, diagnosis, treatment and prevention of the metritis complex. *Veterinarnoe delo = Veterinary business*, 2013, no. 10, pp. 37–40. (In Russian).
6. Valyushkin K.D. *Veterinary obstetrics, gynecology and reproduction biotechnology*. Moscow, Kolos Publ., 2003, 495 p.
7. Terentyeva N.Yu., Ermolaev V.A. The role of microorganisms in the etiology of obstetric diseases in cows. *Vestnik Ul'yanovskoi gosudarstvennoi sel'skokhozyaistvennoi akademii = Vestnik of Ulyanovsk State Agricultural Academy*, 2015, vol. 4, no. 32, pp. 147–155. (In Russian).
8. D'Costa V.M., McGrann K.M., Hughes D.W. Sampling the antibiotic resistome. *Science*, 2006, pp. 374–377. DOI: 10.1126/science.1120800.
9. Shkil N.N., Nefedova E.V. Influence of antibiotics and silver nanoparticles on the change of sensitivity of E. coli to antibacterial drugs. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2020, vol. 50, no. 2, pp. 84–91. (In Russian).
10. Naqvi S.Z., Kiran U., Ali M.I., Jamal A., Hameed A., Ahmed S., Ali N. Combined efficacy of biologically synthesized silver nanoparticles and different antibiotics against multidrug-resistant bacteria. *International Journal of Nanomedicine*, 2013, vol. 8, pp. 3187–3195. DOI: 10.2147/IJN.S49284.
11. Mohamed M.S.M., Mostafa H.M., Mohamed S.H. Combination of silver nanoparticles and vancomycin to overcome antibiotic resistance in planktonic/biofilm cell from clinical and animal source. *Microbial Drug Resistance*. 2020, nov. 26 (11), pp. 1410-1420. DOI: 10.1089/mdr.2020.0089.
12. Singh R., Wagh P., Wadhwani S., Gaidhani S., Kumbhar A., Bellare J., Ananda Chopade B. Synthesis, optimization, and characterization of silver nanoparticles from Acinetobacter calcoaceticus and their enhanced antibacterial activity when combined with antibiotics. *International Journal of Nanomedicine*, 2013, vol. 8, pp. 4277–4290. DOI:10.2147/IJN.S48913.
13. Panpaliya N.P., Dahake P.T., Kale Y.J., Dadpe M.V., Kendre S.B. In vitro evaluation of antimicrobial property of silver nanoparticles and chlorhexidine against five different oral pathogenic bacteria. *Saudi Dental Journal*, 2019, no. 31 (1), pp. 76–83. DOI: 10.1016/j.sdentj.2018.10.004.
14. Smekalova M., Aragon V., Panacek A., Prucek R., Zboril R., Kvitek L. Enhanced antibacterial effect of antibiotics in combination with silver nanoparticles against animal pathogens. *Journal of Veterinary*, 2016, vol. 209, pp. 174–179. DOI: 10.1016/j.tvjl.2015.10.032.
15. Shkil N.N., Nefyodova E.V., Shkil N.A., Nozdrin G.A., Lazareva M.V., Rasputina O.V., Ryumkina I.N. Adjuvant properties of silver and dimethyl sulfoxide nanoparticles in studying antibacterial activity of antibiotics against E. coli**.** *International journal of agriculture and biological science*, 2020, vol. 4, pp. 119–126. DOI: 10.5281/zenodo.4286955.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Нефедова Е.В., кандидат ветеринарных наук, старший научный сотрудник

(✉) **Шкиль Н.Н.,** доктор ветеринарных наук, заведующий лабораторией; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: nicola07@mail.ru

AUTHOR INFORMATION

Ekaterina V. Nefedova, Candidate of Science in Veterinary Medicine, Senior Researcher

(✉) **Nikolai N. Shkil,** Doctor of Science in Veterinary Medicine, Laboratory Head; **address:** PO Box 463, SFSCA RAS, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: nicola07@mail.ru

Дата поступления статьи / Received by the editors 11.01.2022
Дата принятия к публикации / Accepted for publication 28.03.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-8
УДК: 664.859: 582.711.71
Тип статьи: оригинальная
Type of article: original

ИСПОЛЬЗОВАНИЕ ПЛОДОВ ШИПОВНИКА В ТЕХНОЛОГИИ ПИТЬЕВЫХ КИСЕЛЕЙ

Щербинин В.В., (✉) Голуб О.В., Чекрыга Г.П., Мотовилов О.К.
Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, Россия
(✉) e-mail: golubiza@rambler.ru

Представлены исследования по разработке рецептуры и технологии киселей питьевых, содержащих нативные биологически активные вещества за счет использования плодов шиповника. Проанализировано по пять вариантов новой продукции из свежих и сушеных плодов шиповника с добавлением сахара, картофельного крахмала, ксантановой камеди и лимонной кислоты. Установлено, что кисели питьевые, содержащие не менее 21,5% свежих или 5,37% сушеных плодов шиповника, были наиболее привлекательными. Использование механоакустического оборудования при изготовлении киселей приводит к физико-химическим изменениям сырья (частичной деструкции клеточных стенок, образованию новых красящих веществ и др.), что положительно влияет на формирование органолептической характеристики новой продукции, а также сокращает технологические операции производства и ингибирует микроорганизмы. Употребление 200 см^3 новой продукции обеспечивает организм человека не менее 62% от суточной потребности в аскорбиновой кислоте и не менее 66% – в β-каротине, а также пищевыми волокнами не менее 0,6 г и фенольными веществами – 11 мг. Установлен срок годности киселей питьевых шиповниковых – 12 мес в стеклянных банках при температуре 25° С и относительной влажности воздуха не выше 75% и в защищенном от прямых солнечных лучей месте. На основании проведенных исследований разработана нормативно-техническая документация на кисели питьевые шиповниковые.

Ключевые слова: шиповник, кисели питьевые, органолептические показатели, физико-химические показатели, биологически активные вещества, микробиологические показатели, срок годности

THE POSSIBILITIES OF USING ROSEHIP FRUITS IN THE POTABLE KISSELS TECHNOLOGY

Shcherbinin V.V., (✉) Golub O.V., Chekryga G.P., Motovilov O.K.
Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Novosibirsk region, Russia
(✉) e-mail: golubiza@rambler.ru

Research on the development of the recipe and technology of potable kissels containing native biologically active substances through the use of rosehip fruits is presented. Five variants of new products from fresh and dried rosehips with the addition of sugar, potato starch, xanthan gum and citric acid were analyzed. It was found that the potable kissels containing at least 21.5% fresh or 5.37% dried rosehip fruits were the most appealing. The use of mechanoacoustic equipment in the manufacture of kissels leads to physical and chemical changes in the raw materials (partial destruction of the cell walls, the formation of new coloring substances, etc.), which positively affects the formation of organoleptic characteristics of new products, as well as reduces the technological

operations of production and inhibits microorganisms. The consumption of 200 cm^3 of new products provides the human body with at least 62% of the daily requirement for ascorbic acid and at least 66% for β-carotene, as well as dietary fiber of at least 0.6 g and 11 mg of phenolic substances. The shelf life of rosehip potable kissels is 12 months in glass jars at 25 ° C and relative humidity of 75% or higher and in a place protected from direct sunlight. On the basis of this research, normative and technical documentation for potable rosehip kissels was developed.

Keywords: rosehip, potable kissels, organoleptic indicators, physico-chemical indicators, biologically active substances, microbiological indicators, shelf life

Для цитирования: *Щербинин В.В., Голуб О.В., Чекрыга Г.П., Мотовилов О.К.* Использование плодов шиповника в технологии питьевых киселей // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 63–72. https://doi.org/10.26898/0370-8799-2022-2-8. EDN LQOOID.

For citation: Shcherbinin V.V., Golub O.V., Chekryga G.P., Motovilov O.K. The possibilities of using rosehip fruits in the potable kissels technology. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 2, pp. 63–72. https://doi.org/10.26898/0370-8799-2022-2-8. EDN LQOOID.

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

INTRODUCTION

Specialists believe that rosehips are used in the creation of food products in a very small amount in spite of the fact that they contain valuable nutrients for the human body. The content of biologically active compounds providing physiological value of rosehips has a wide variability and depends on many factors (species, pomological variety, place of growth, time and harvesting conditions, etc.). [1-8].

Kissels, which belong to the original Russian cuisine, are currently being developed, studied, and produced either as food concentrates or as a sweet dish in the public catering system [9-14]. At the same time, there are virtually no works on the development and study of the characteristics of the quality of drinking kissels. In the system of the Federal Institute of Industrial Property, Federal Service for Intellectual Property, Patents and Trademarks only one patent of the Russian Federation № 2668338 for the method of production of collagen enriched drinking kissels for functional nutrition from fruits (actinidia, black chokeberry, honeysuckle, red ashberry) was registered. According to the "Unified Register of issued certificates of conformity and registered declarations of conformity", currently only six Russian companies in Moscow, St. Petersburg, Stavropol, Krasnoyarsk, Yekaterinburg and Rasskazov produce "drinking kissels". Rosehip kissels (according to the "Unified Register...") are produced in our country only as food concentrates by eight enterprises, which are located mainly in the Siberian Federal District (62.5%), and the rest in the Moscow, Chelyabinsk and Yaroslavl regions (12.5% each).

The purpose of the work is to conduct research on the possibility of making drinking kissels from rosehips.

Research objectives:

- develop the recipe and technology of drinking rosehip fruit kissels;
- determine the shelf life of rosehip drinking kissels.

MATERIAL AND METHODS

The experimental studies were carried out in the laboratories of the Siberian Federal Scientific Center of Agro-BioTechnologies of the Russian Academy of Sciences.

When conducting research we used materials that by their qualitative characteristics meet the requirements of the current normative documentation: rosehip fruit to form technical characteristics of drinking kissels, white sugar, potato starch, citric acid to form the original odor, structure and taste of ready-to-eat products, xanthan gum to reduce moisture

loss during thermal processing and subsequent storage, as well as stabilize the consistency of the finished product.

The study of chemical composition indicators (mass fraction of dry matter, sugars, proteins, fats, free organic acids, dietary fiber, ash, ascorbic acid, β-carotene), microbiological safety (content of yeast, bacteria of *Proteus, Staphylococcus aureus, Salmonella* genera, coli group (coliform bacteria)) and organoleptic evaluation of drinking rosehip kissels was carried out in accordance with the methods set forth in the current regulatory documents; the total amount of phenolic compounds in terms of gallic acid - spectrophotometric method with Folin-Ciocalteu reagent [15]. Processing of experimental data was carried out by methods of mathematical statistics (validity of the results $p \leq 0.05$) using MS Excel program.

RESULTS AND DISCUSSION

Studies on approbation of different variants of drinking rosehip kissels have been carried out. Table 1 shows the best variants of recipes.

Fluctuations in the "color" score ranged from 4.2 to 4.8 points (max = 5) and depended mainly on the amount of raw fruit used. The type of fruit raw material (fresh or dried) had little effect on this organoleptic characteristic (the color of the entire mass was a uniform red-brown) (see Fig. 1).

The indicator "smell and taste" was influenced by the fruit raw materials and sugar contained in the composition of kissels (variants 1-5), the other options (6-10) - fruit raw materials, sugar and citric acid. The evaluation of the experimental samples ranged from 4.4 to 5.0 points (max = 5). According to organoleptic characteristics "smell and taste" the best samples of kissel of variants 3 and 8 were recognized: harmonious, sweet and sour, rich, with a characteristic taste of rosehip, without extraneous smell and aftertaste. In the smell and taste of the samples of variants 1, 2, 6, 7 rosehip was strongly felt, in tones and aftertaste of variants 1 and 6 the presence of potato starch was noted. The taste of kissel samples of variants 4 and 5 was excessively sweet, 9 and 10 - excessively sour.

For the indicator "appearance and consistency" the experimental samples received from 3.4 to 4.8 points (max = 5). In terms of appearance, all samples were a homogeneous, kisselike mass without undissolved lumps. As the content of xanthan gum increased and the potato starch decreased, the mass thickened.

Табл. 1. Варианты рецептуры питьевых киселей шиповниковых, г/100 г
Table 1. Recipe variants of potable rosehip kissels, g/100 g

Recipe option	Rosehip	White Sugar	Potato starch	Xanthan gum	Citric acid
Fresh fruit					
1	22,5	5,5	2,2	0,00	–
2	22,0	6,0	2,0	0,15	–
3	21,5	6,5	1,8	0,30	–
4	21,0	7,0	1,6	0,45	–
5	20,5	7,5	1,4	0,60	–
Dried fruit					
6	5,47	5,5	2,2	0,00	0,15
7	5,42	6,0	2,0	0,15	0,17
8	5,37	6,5	1,8	0,30	0,19
9	5,32	7,0	1,6	0,45	0,21
10	5,27	7,5	1,4	0,60	0,23

Note. Water is applied to the required volume - 100 cm^3.

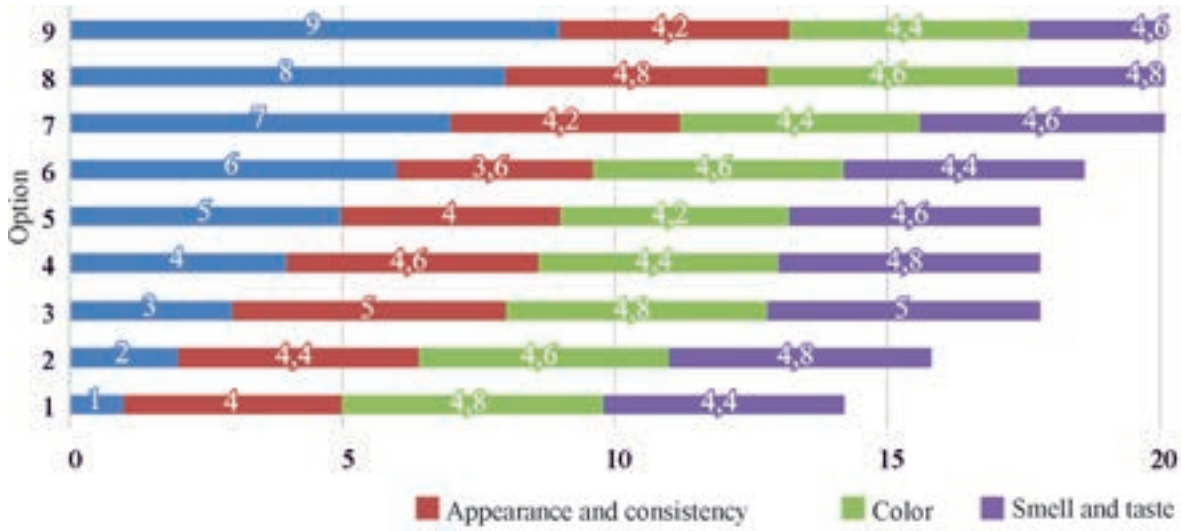

Рис. 1. Органолептическая оценка киселей питьевых шиповниковых, балл

Fig. 1. Organoleptic evaluation of rosehip potable kissels, point

The best variants in terms of "appearance and consistency" were recognized for samples of kissel 3 and 8 with xanthan gum (0.3%) and potato starch (1.8%).

Fig. 2 shows a basic technological scheme for obtaining rosehip drinking rosehip kissels. Hydroacoustic treatment of semi-finished product (mixture of fruit and water) in an apparatus equipped with a rotary-dispersing device creating an acoustic field with an intensity of 100-500 W/kg at 50-65 °C for 15-30 min resulted in physical and chemical changes in raw materials (partial destruction of cell walls, formation of new coloring substances, inactivation of enzymes, etc.).), which influenced the formation of organoleptic characteristics of new products and partial inhibition of microorganisms. Sterilization of the blend (semi-finished product and mixture consisting of white sugar, xanthan gum) in mechanoacoustic apparatus at the temperature of 95-97 °C for 20-60 sec completely inhibited microflora, which ensured later preservation of quality characteristics of the product.

Studies were carried out to determine the shelf life of the best options (3 and 8) of the drinking rosehip kissels. The kissels were poured into glass jars of type I with a crown

Табл. 2. Влияние продолжительности хранения киселей питьевых шиповниковых на органолептические показатели, балл (n = 5)

Table 2. Effect of potable rosehip kissels storage time on organoleptic characteristics, point (n = 5)

Storage time, months	Appearance and consistency	Color	Smell and taste
From fresh fruit (variant 3)			
6	5,0 ± 0,0	4,6 ± 0,5	4,8 ± 0,4
12	4,8 ± 0,4	4,4 ± 0,5	4,6 ± 0,5
14	4,6 ± 0,5	4,2 ± 0,4	4,2 ± 0,4
From dried fruit (variant 8)			
6	4,6 ± 0,5	4,4 ± 0,5	4,6 ± 0,5
12	4,4 ± 0,5	4,2 ± 0,4	4,4 ± 0,5
14	4,0 ± 0,0	4,0 ± 0,0	4,2 ± 0,4

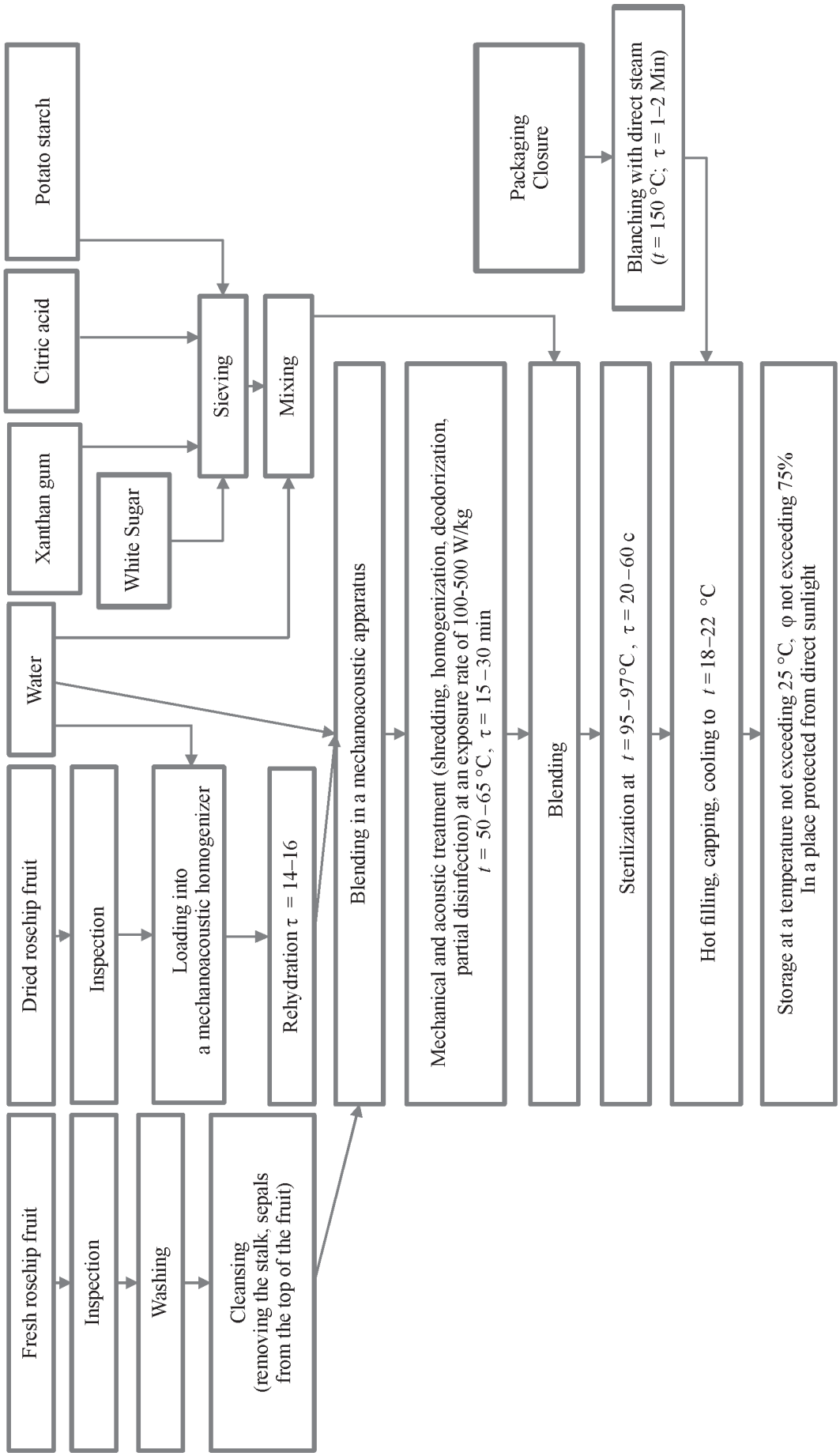

Рис. 2. Принципиальная технологическая схема производства киселей питьевых шиповниковых
Fig. 2. Principle technological scheme of production of rosehip potable kissels

Табл. 3. Влияние продолжительности хранения киселей питьевых шиповниковых на содержание основных пищевых веществ

Table 3. Effect of potable rosehip kissels storage time on the content of the main nutrients

Storage time, months	Mass fraction, %				
	sugar	protein	fat	organic acids (by malic acid)	ash
From fresh fruit (variant 3)					
0	9,1 ± 0,3	0,2 ± 0,1	0,09 ± 0,05	0,44 ± 0,03	0,29 ± 0,05
6	9,0 ± 0,2	0,2 ± 0,1	0,09 ± 0,05	0,43 ± 0,03	0,29 ± 0,05
12	8,8 ± 0,2	0,2 ± 0,1	0,09 ± 0,05	0,42 ± 0,02	0,28 ± 0,05
14	8,8 ± 0,3	0,2 ± 0,1	0,08 ± 0,04	0,41 ± 0,02	0,28 ± 0,04
From dried fruit (variant 8)					
0	9,9 ± 0,4	0,2 ± 0,1	0,07 ± 0,03	0,45 ± 0,03	0,15 ± 0,03
6	9,8 ± 0,3	0,2 ± 0,1	0,07 ± 0,03	0,44 ± 0,02	0,15 ± 0,03
12	9,6 ± 0,4	0,2 ± 0,1	0,07 ± 0,03	0,43 ± 0,02	0,14 ± 0,03
14	9,5 ± 0,5	0,2 ± 0,1	0,06 ± 0,02	0,42 ± 0,03	0,14 ± 0,02

Табл. 4. Влияние продолжительности хранения киселей питьевых шиповниковых на содержание биологически активных веществ

Table 4. Effect of potable rosehip kissels storage time on the content of biologically active substances

Storage time, months	Mass fraction			
	dietary fiber, %	ascorbic acid, mg/100 g	sums of phenolic substances, mg/100 g	β-carotene, mg/100 g
From fresh fruit (variant 3)				
0	0,80 ± 0,05	209 ± 14	181 ± 26	8,85 ± 0,81
6	0,79 ± 0,04	185 ± 16	168 ± 12	8,50 ± 0,76
12	0,79 ± 0,04	162 ± 12	157 ± 13	7,78 ± 0,75
14	0,78 ± 0,05	144 ± 11	152 ± 12	7,57 ± 0,80
From dried fruit (variant 8)				
0	0,37 ± 0,03	53 ± 11	16 ± 3	2,09 ± 0,26
6	0,37 ± 0,02	47 ± 10	15 ± 5	2,01 ± 0,20
12	0,37 ± 0,02	41 ± 10	14 ± 3	1,84 ± 0,19
14	0,36 ± 0,03	37 ± 9	13 ± 3	1,79 ± 0,22

number of 82 mm and a capacity of 500 cm3, sealed with lids of size 1-82-C, stored at a temperature of 25 °C, relative humidity of no more than 75% in a place protected from direct sunlight for 14 months with a reserve factor of 1.15 according to the methodological guidelines "Sanitary and epidemiological evaluation of the validity and storage conditions of food products" (2004).

During the storage of rosehip kissels there were changes in organoleptic parameters of the products (see Fig. 1, Table 2). By the indicators "appearance and consistency", "color" and "smell and taste" the decrease in scores by the end of the 12th month of storage was 7.3; 8.7 and 9.2%, in the 14th month - 12.6; 13.1 and 15.3%, respectively. By the end of the storage period under analysis, the appearance of the

Табл. 5. Влияние продолжительности хранения киселей питьевых шиповниковых на микробиологические показатели

Table 5. Effect of potable rosehip kissels storage time on microbiological parameters

Indicator	Storage time, months		
	0	12	14
From fresh fruit (variant 3)			
QMA&OAMO, CFU/g	9,54 × 10	9,09 × 10	8,64 × 10
Mould, CFU/g	No growth	No growth	No growth
Yeast, CFU/g	» »	» »	» »
CGB (coliforms)	Not detected	Not detected	Not detected
Bacteria of the genus *Salmonella*	» »	» »	» »
Staphylococcus	» »	» »	» »
Proteus	» »	» »	» »
From dried fruit (variant 8)			
QMA&OAMO, CFU/g	6,36 × 10	4,55 × 10	3,64 × 10
Mould, CFU/g	No growth	No growth	No growth
Yeast, CFU/g	» »	» »	» »
Bacteria of the genus *Salmonella*	Not detected	Not detected	Not detected
CGB (coliforms)	» »	» »	» »
Staphylococcus	» »	» »	» »
Proteus	» »	» »	» »

kissels became less attractive, the consistency became somewhat viscous, the smell and taste were less harmonious and weak. There was a slight darkening of the top layer.

During storage, there was a decrease in the content of the main nutrients in the drinking rosehip kissels regardless of whether the products were obtained from fresh or dried fruits (see Table 3). Thus, losses of sugars, proteins, fats, organic acids and ash by the end of 12 months of storage averaged 3.1; 12.5; 0.2; 6.5 and 4.2%, after 14 months. - 3.7; 16.7; 9.1; 9.0 and 5.1%, respectively.

The content of biologically active substances in the kissels decreased during storage (see Table 4). Ascorbic acid suffered great losses. Regardless of whether the fruit was fresh or dried, its loss after 12 months of storage averaged 69.0%, and after 14 months of storage - 77.5%. - 77,5%. Preservation of phenolic substances and β-carotene was comparable and averaged 87.0 and 88.0% after 12 months of storage, after 14 months - 84.0 and 86.0%, respectively. - 84.0 and 86.0%, respectively. Dietary fiber had the least losses during storage: after 12 months of storage losses averaged 0.9%, after 14 months - 14.5%. - 14,5%. Thus, the consumption of one portion of drinking rosehip kissels (200 cm^3) satisfied the daily requirement for ascorbic acid not less than 62%, β-carotene - not less than 66%.

To establish the shelf life of rosehip drinking kissels, studies of microbiological parameters were carried out (see Table 5).

The permissible number of cells of microorganisms in 1 g of the preserved product, which does not violate its microbiological stability during storage and does not pose a danger to humans, is up to 103 units. It is important that during storage the residual microflora

Табл. 6. Регламентируемые технические характеристики киселей питьевых шиповниковых
Table 6. Regulated technical characteristics of rosehip potable kissels

Indicator	Characteristic/norm
Appearance and consistency	Homogeneous, kisselike mass; no undissolved lumps
Color	Light brown, homogeneous throughout the mass
Smell and taste	Well pronounced, sweet and sour, typical of used rosehip berries, which have been heat-treated; no extraneous odors and flavors
Mass fraction of soluble solids, %	No less than 12
Mass fraction of the fruit part, %	No less than 20,0
Mass fraction of titratable acids (by malic acid), %	0,4–1,0
Impurities of plant origin (stalks, sepals, stems and other plant parts)	Are avoided
Extraneous impurities (not provided for in the recipe)	Are avoided

remain in a suppressed state. In the microbiota of samples of drinking rosehip kissels non-sporulating bacteria were not detected (see Table 5). Residual microflora was within the permissible values of TR CU 021/2011 "On food safety".

On the basis of this research, normative and technical documentation for rosehip drinking kissels was developed (see Table 6).

CONCLUSION

The recipes and technology of drinking kissels made of fresh or dried rose hips have been developed which allow expanding the assortment of new generation products containing biologically active substances. It has been established that the shelf-life of rosehip drinking jellies was 12 months when stored in glass jars of type I with a neck number of 82 mm and a capacity of 500 cm^3, sealed with lids of size 1-82-S, at a temperature and relative humidity of 25°C and 75% respectively and in a place protected from direct sunlight.

СПИСОК ЛИТЕРАТУРЫ

1. *Акимов М.Ю., Бессонов В.В., Коденцова В.М.* Биологическая ценность плодов и ягод российского производства // Вопросы питания. 2020. Т. 89. № 4. С. 220–232.
2. *Салманов М.М., Исригова Т.А., Салманов К.М.* Влияние экологических условий и сортовых особенностей на химико-технологические свойства и качество ягодных культур // Известия Дагестанского государственного аграрного университета. 2020. № 1 (5). С. 55–59.
3. *Кокаева Ф.Ф., Джатиева Д.Н.* Изучение химического состава плодов шиповника (*Rosa Majalis*) // Известия Горского государственного аграрного университета. 2018. Т. 55. № 1. С. 120–124.
4. *Магомедова З.М., Гасанова М.Г.* Исследование фитохимического состава шиповника // Вестник Дагестанского государственного университета. Серия 1: Естественные науки. 2016. Т. 31. № 2. С. 54–59.
5. *Петрова С.Н., Ивкова А.В.* Химический состав и антиоксидантные свойства видов рода *Rosa* L. // Химия растительного сырья. 2014. № 2. С. 13–19.
6. *Дубцова Г.Н., Негматуллоева Р.Н., Бессонов В.В.* Состав и содержание биологически активных веществ в плодах шиповника // Вопросы питания. 2012. Т. 81. № 6. С. 84–88.
7. *Patel S.* Rose hip as an underutilized functional food: Evidence-based review // Trends

in Food Science & Technology. 2017. N 63. P. 29–38. DOI: 10.1016/j.tifs.2017.03.001.
8. *Skrypnik L., Chupakhina G., Feduraev P., Chupakhina N., Maslennikov P.* Evaluation of the rose hips of *Rosa canina* L. and *Rosa rugosa* Thunb. as a valuable source of biological active compounds and antioxidants on the Baltic Sea coast // Polish journal of natural sciences. 2019. N 34. P. 395–413.
9. *Морозова С.С., Бакуменко О.Е., Тарасова В.В.* Разработка рецептур пищевых концентратов киселей с использованием сахарозаменителей и интенсивных подсластителей // Пищевая промышленность. 2020. № 6. С. 13–18. DOI: 10.24411/0235-2486-2020-10058.
10. *Майтаков А.Л., Берязева Л.Н., Ветрова Н.Т., Плотников К.Б.* Получение гранулированных быстрорастворимых киселей на основе молочной сыворотки и растительного сырья // Известия высших учебных заведений. Пищевая технология. 2020. № 2-3 (374-375). С. 38–42. DOI: 10.26297/0579-3009.2020.2-3.10.
11. *Снегирева А.В., Мелешкина Л.Е.* Возможности использования амаранта в технологии зерновых киселей // Ползуновский вестник. 2018. № 2. С. 60–64. DOI: 10.25712/ASTU.2072-8921.2018.02.011.
12. *Плотников К.Б., Попов А.М., Плотников И.Б.* Совершенствование технологического потока линии производства инстантированного киселя // Техника и технология пищевых производств. 2020. Т. 50. № 1. С. 96–105. DOI: 10.21603/2074-9414-2020-1-96-105.
13. *Соколов А.Ю., Акимова Н.А.* Управление качеством концентрированных киселей для профессионального питания // Вестник Российского экономического университета имени Г.В. Плеханова. 2020. Т. 17. № 6 (114). С. 208–214. DOI: 10.21686/2413-2829-2020-6-208-214.
14. *Шамова М.М., Австриевских А.Н., Вековцев А.А.* Разработка рецептуры и технологии производства злакового киселя. Кисель постный злаковый // Пиво и напитки. 2018. № 1. С. 26–29.
15. *Singleton V.L., Orthofer R., Lamuela-Raventós R.M.* Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent // Methods in enzymology. 1999. N 299. P. 152–178. DOI: 10.1016/S0076-6879(99)99017-1.

REFERENCES

1. Akimov M.Yu., Bessonov V.V., Kodentsova V.M. Biological value of fruits and berries of Russian production. *Voprosy pitaniya = Problems of nutrition*, 2020, vol. 89, no. 4, pp. 220–232. (In Russian).
2. Salmanov M.M., Isrigova T.A., Salmanov K.M. Influence of ecological conditions and variety features on chemical and technological properties and quality of berry crops. *Izvestiya Dagestanskogo gosudarstvennogo agrarnogo universiteta = Dagestan GAU Proceedings,* 2020, no.1 (5), pp. 55–59. (In Russian).
3. Kokaeva F.F., Dzhatieva D.N. Study of dog rose (*Rosa Majalis*) chemical composition. *Izvestiya Gorskogo gosudarstvennogo agrarnogo universiteta = Journal of Proceedings of the Gorsky SAU*, 2018, vol. 55, no. 1, pp. 120–124. (In Russian).
4. Magomedova Z.M., Gasanova M.G. The study of the phytochemical composition of the rosehip. *Vestnik Dagestanskogo gosudarstvennogo universiteta Seriya 1: Estestvennye nauki = Herald of Dagestan State University. Series 1. Natural Sciences,* 2016, vol. 31, no. 2, pp. 54–59. (In Russian).
5. Petrova S.N., Ivkova A.V. Chemical composition and anitioxidant properties of species of the genus *Rosa* L. *Khimiya rastitel'nogo syr'ya = Khimija Rastitel'nogo Syr'ja,* 2014, no. 2, pp. 13–19. (In Russian).
6. Dubtsova G.N., Negmatulloeva R.N., Bessonov V.V. Composition and content of biologically active substances in rose hips. *Voprosy pitaniya = Problems of nutrition,* 2012, vol. 81, no. 6, pp. 84–88. (In Russian).
7. Patel S. Rose hip as an underutilized functional food: Evidence-based review. *Trends in Food Science & Technology*, 2017, no. 63, pp. 29–38. DOI: 10.1016/j.tifs.2017.03.001.
8. Skrypnik L., Chupakhina G., Feduraev P., Chupakhina N., Maslennikov P. Evaluation of the rose hips of *Rosa canina* L. and *Rosa rugosa* Thunb. as a valuable source of biological active compounds and antioxidants on the Baltic Sea coast. *Polish journal of natural sci-*

ences, 2019, no. 34, pp. 395–413.
9. Morozova S.S., Bakumenko O.E., Tarasova V.V. Technology of kissel concentrates using natural sweeteners. *Pishchevaya promyshlennost' = Food Industry,* 2020, no. 6, pp. 13–18. (In Russian). DOI: 10.24411/0235-2486-2020-10058.
10. Maitakov A.L., Beryazeva L.N., Vetrova N.T., Plotnikov K.B. Production of granulated instant kissel based on whey and vegetable raw materials. *Izvestiya vysshikh uchebnykh zavedenii. Pishchevaya tekhnologiya = News of institutes of higher education. Food technology,* 2020, no. 2-3 (374-375), pp. 38–42. (In Russian). DOI: 10.26297/0579-3009.2020.2-3.10.
11. Snegireva A.V., Meleshkina L.E. Possibilities of using amaranth in the technology of grain kissels. *Polzunovskii vestnik = Polzunovskiy vestnik,* 2018, no. 2, pp. 60–64. (In Russian). DOI: 10.25712/ASTU.2072-8921.2018.02.011.
12. Plotnikov K.B., Popov A.M., Plotnikov I.B. Improving the line of instant starch soft drinks. *Tekhnika i tekhnologiya pishchevykh proizvodstv = Food Processing: Techniques and Technology,* 2020, vol. 50, no. 1, pp. 96–105. (In Russian). DOI: 10.21603/2074-9414-2020-1-96-105.
13. Sokolov A.Yu., Akimova N.A. Managing the quality of concentrated kissels for professional nutrition. *Vestnik Rossiiskogo ekonomicheskogo universiteta imeni G.V. Plekhanova = Vestnik of the Plekhanov Russian University of Economics,* 2020, vol. 17, no. 6 (114), pp. 208–214. (In Russian). DOI: 10.21686/2413-2829-2020-6-208-214.
14. Shamova M.M., Avstrievskikh A.N., Vekovtsev A.A. The formulation and production technology development of cereal kissel. Lenten cereal kissel. *Pivo i napitki = Beer and beverages,* 2018, no. 1, pp. 26–29. (In Russian).
15. Singleton V.L., Orthofer R., Lamuela-Raventós R.M. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in enzymology,* 1999, no. 299, pp. 152–178. DOI: 10.1016/S0076-6879(99)99017-1.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Щербинин В.В., младший научный сотрудник

(✉) **Голуб О.В.,** доктор технических наук, главный научный сотрудник; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: golubiza@rambler.ru

Чекрыга Г.П., кандидат биологических наук, ведущий научный сотрудник

Мотовилов О.К., доктор технических наук, главный научный сотрудник

AUTHOR INFORMATION

Vyacheslav V. Scherbinin, Junior Researcher

(✉) **Olga V. Golub**, Doctor of Science in Engineering, Head Researcher; **address:** PO Box 463, SFSCA RAS, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: golubiza@rambler.ru

Galina P. Chekryga, Candidate of Science in Biology, Lead Researcher

Oleg K. Motovilov, Doctor of Science in Engineering, Head Researcher

Дата поступления статьи / Received by the editors 14.01.2022
Дата принятия к публикации / Accepted for publication 25.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-9
УДК: 664.64
Тип статьи: оригинальная
Type of article: original

ПРИМЕНЕНИЕ ПЛОДОВОГО СЫРЬЯ СИБИРСКОГО РЕГИОНА КАК ОСНОВЫ НАЧИНОК ДЛЯ ХЛЕБОБУЛОЧНЫХ ИЗДЕЛИЙ

(✉) **Давыденко Н.И., Ульянова Г.С., Голубцова Ю.В., Сергеева И.Ю.**
Кемеровский государственный университет
Кемерово, Россия
(✉) e-mail: nat1861@yandex.ru

Представлены результаты изучения плодов и продуктов их переработки как источников веществ антиоксидантной направленности (витаминов, органических кислот и различных фенольных веществ) в рационе человека. Установлено, что существует вариативность содержащихся в плодах биологически ценных веществ в зависимости от места произрастания, условий культивирования и других. Цель исследования – дать оценку целесообразности применения традиционного для Сибирского региона плодового сырья (клюквы, брусники и аронии) как основы начинок для хлебобулочных изделий. Объект исследований – свежие дикорастущие плоды клюквы и брусники (урожай 2021 г., заготовка Томского Облпотребсоюза Центросоюза РФ) и плоды аронии (сортосмесь, выращенная на территории Кемеровской области и реализуемая на потребительском рынке). Органолептическую оценку начинок осуществляли по 5-балльной шкале, суммарную антиоксидантную активность – кулонометрическим экспресс-методом на приборе «Экспресс-006-Антиоксиданты». На основании проведенных исследований установлено, что свежие плоды по антиоксидантной активности ранжируются следующим образом: клюквы > аронии > брусники. Установлено, что на показатель «внешний вид и консистенция» начинок для хлебобулочных изделий оказывают основное влияние структурообразователи, которые ранжируются следующим образом: 1,0% агара > 2,0% пектина > 1,5% агара > 6,0% крахмала модифицированного. На запах и вкус начинок основное влияние оказывает используемое плодовое сырье, а структурообразователи – опосредованное. Суммарная антиоксидантная активность начинок для хлебобулочных изделий зависит от разрушения биологически активных веществ плодов при изготовлении, а не от используемых структурообразователей. Результаты данных исследований будут полезны при создании функциональной пищевой продукции.

Ключевые слова: плоды, антиоксидантная активность, начинки, структурообразователи, показатели качества

THE USE OF FRUIT RAW MATERIALS OF THE SIBERIAN REGION AS THE BASIS OF FILLINGS FOR BAKERY PRODUCTS

(✉) **Davydenko N.I., Ulyanova G.S., Golubtsova Yu.V., Sergeeva I.Yu.**
Kemerovo State University
Kemerovo, Russia
(✉) e-mail: nat1861@yandex.ru

The results of the study of fruits and their products as sources of antioxidant substances (vitamins, organic acids and various phenolic substances) in the human diet are presented. It was found that there is a variation in the biologically valuable substances contained in fruits depending on the place of growth, cultivation and other conditions. The purpose of the study is to assess the feasibility of using traditional for the Siberian region fruit raw materials (cranberry, lingonberry and chokeberry) as the basis for the filling of bakery products. The object of research was fresh wild fruits of cranberry and lingonberry (harvest of 2021, harvested by the Tomsk Regional Consumer Union of the Russian Federation) and chokeberry fruits (variety mix, grown in the Kemerovo region and sold in the consumer market). The organoleptic evaluation of the fillings was carried out on a 5-point scale, total antioxidant activity - by coulometric express method on the device "Express-006-Antioxidants". Based on the studies conducted, it was found that fresh fruits are ranked as follows in terms of antioxidant activity: cranberry > chokeberry > lingonberry. It was found that the indicator

"appearance and consistency" of fillings for bakery products is mainly influenced by structural formers, which are ranked as follows: 1.0% agar > 2.0% pectin > 1.5% agar > 6.0% modified starch. The smell and taste of fillings are mainly influenced by the fruit raw material used, and the structure-forming agents are indirectly influenced by them. Total antioxidant activity of bakery fillings depends on the destruction of biologically active substances of fruit during manufacturing, rather than on the used structure-forming agents. The results of these studies will be useful in the creation of functional food products.

Keywords: fruits, antioxidant activity, bakery fillings, structure-forming agents, quality indicators

Для цитирования: *Давыденко Н.И., Ульянова Г.С., Голубцова Ю.В., Сергеева И.Ю.* Применение плодового сырья Сибирского региона как основы начинок для хлебобулочных изделий // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 73–81. https://doi.org/10.26898/0370-8799-2022-2-9. EDN MEGHZI.

For citation: Davydenko N.I., Ulyanova G.S., Golubtsova Yu.V., Sergeeva I.Yu. The use of fruit raw materials of the Siberian region as the basis of fillings for bakery products. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 2, pp. 73–81. https://doi.org/10.26898/0370-8799-2022-2-9. EDN MEGHZI.

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

INTRODUCTION

The peculiarities of modern human nutrition, the emergence of new data on the functional properties of food ingredients, including natural origin, contribute to the development of technologies for obtaining food products with given properties having physiological value [1]. At the same time, plant raw materials are a valuable source of essential nutrients of different physiological orientation, allowing it to be used for the production of combined products in combination with the basis of animal origin [2].

Oxidative stress resulting from inadequate functioning of the antioxidant system leads to metabolic disorders. As a consequence, inflammatory processes arise in the human body, leading to chronic diseases, as well as widespread nutritional (food-related) diseases [3]. In this regard, the development and production of food products containing natural functional food ingredients are of interest in order to solve the problem of reducing oxidative stress.

The process of designing the ingredient composition of a food product with functional properties consists in a multivariate selection of valuable raw ingredients for all product systems under the condition of a complex structure. Products with fillings consisting of two ingredient systems with different properties can be used as an example [4].

Oxygen is the main guarantor of the vital activity of living organisms, but as a result of normal metabolic processes free radicals are formed in the cell, damaging the cell membranes. Therefore, the lack of timely neutralization of active oxygen leads to irreversible damage to the body. Humans exist under constant stress, the situation is exacerbated by emotional stress, environmental conditions, air pollution, and the prevalence of smoking. In this regard, free radical damage is due to their excessive amount. Antioxidant protection of the body is necessary for humans to level the consequences of destructive oxidative processes [5].

The main sources of antioxidants are fruits, especially those with a pronounced sour and sour-sweet taste, blue, red, and orange. Various groups of substances show antioxidant properties: vitamins E, C, carotenoids, flavonoids, polyphenols, trace elements (such as selenium) and others. Especially rich in antioxidants are rosehips, cranberries, blueberries, black currant, wild strawberries, blackberries, goji, sea buckthorn, cranberries, etc. Fruit flavonoids are mainly anthocyanins, proanthocyanides, flavonols, and catechins [6, 7]. A number of authors have shown that significant variation in the content of biologically valuable substances in fruits is associated with the variety, cultivation conditions, and place of growth [8-10]. At the same time, there are not enough studies of the variability of antioxidant activity of the ingredient composition of fruit processing products.

The purpose of the research is to assess the feasibility of using traditional for the Siberian region fruit raw materials (cranberries, lingonberries and chokeberries) as the basis for the filling of bakery products.

The following tasks were solved within the framework of the stated goal:

- the total antioxidant activity of cranberry, lingonberry and chokeberry fruits was determined;

- evaluation of organoleptic characteristics and total antioxidant activity of the toppings for bakery products from the studied fruit raw materials depending on the used structure-forming agent was carried out.

MATERIAL AND METHODS

Studies were conducted in October 2021 in the laboratories of the departments of technology and organization of public catering and technology of processing of raw materials of plant origin of Kemerovo State University.

The object of research is fruit raw material (cranberry, lingonberry and chokeberry), which has antioxidant activity, and semi-finished products (stuffing for bakery products) based on it.

Fresh wild fruits of cranberry and lingonberry of 2021 harvested by Tomsk Regional Consumer Union of the Central Union of Consumer Cooperatives of the Russian Federation, fresh fruits of chokeberry, mixed varieties grown in the Kemerovo region and sold on the consumer market were studied in the work.

For the structuring (thickening) of the fillings we used:

– pectin according to GOST 29186-91 "Pectin. Technical conditions";

– agar according to GOST 16280-2002 "Agar food. Technical Conditions";

– corn starch modified with cold swelling GLETEL BAW E1422.

Stuffing was prepared as follows: fresh chopped fruits (particle size 1-4 mm) were mixed with sugar in the ratio fruit: sugar - 80: 20, heated and brought to a boil; then thickener was added in various amounts, brought to a boil and boiled for 4 minutes. Then it was cooled at room temperature until formation of gelled structure. The amount of structure agents was introduced according to the manufacturers' recommendations for the fillings as percentage of the mass of fruit and sugar mixture: 1.0% and 1.5% agar, 2.0% pectin, 6.0% corn starch (GLETEL BAW-23).

Organoleptic evaluation of the fillings was carried out on a hedonic 5-point scale: 5 points - excellent quality; 4 - good; 3 - satisfactory; 2 - poor (unacceptable); 1 point - very poor (unacceptable). When examining the indicator "appearance and consistency" of the products, descriptive characteristics and scoring were carried out in terms of the behavior of fruit filling during baking, its uniform distribution inside the baked product, including after cooling.

Total antioxidant activity (AOA) was determined by the coulometric express method on the device "Express-006-Antioxidants". AOA was measured by preparing an aqueous-alcoholic extract of fruits or fillings: solid portions of crushed fruits or fillings were poured into aqueous-alcoholic mixture (40%) in the ratio 1: 4 (portions to mixture) and incubated in a cabinet without light at 20 ± 2 ° C for 2 hours. The duration of infusion was determined by experiment - after 2 h the AOA parameters were stabilized and did not change essentially. The use of water-alcohol mixture allowed maximum extraction of water- and alcohol-soluble substances exhibiting antioxidant activity.

When evaluating the antioxidant activity of the filling, it was preheated to 98 ° C and incubated for 10 minutes, simulating the heating of a bakery product during baking, then cooled and measured.

RESULTS AND DISCUSSION

At the first stage of the experiment, the total antioxidant activity of fruit samples was determined: cranberry, lingonberry and chokeberry. The choice of these fruits is explained by their local origin (within Siberia), as well as by the content of the nutrient composition of a significant number of physiologically valuable substances. According to the literature data [11-16], the fruits selected for the study contain the following biologically active substances that determine the antioxidant orientation:

– cranberry: citric, benzoic, quinic, ursolic, chlorogenic, apple, oleic, γ-oxy-α-ketobutyric, α-ketoglutaric acids; in trace amounts - oxalic and succinic acids; betaine and bioflavonoids: anthocyanins, leucoanthocyanins, catechins, flavonols and phenolic acids;

– lingonberry: citric, apple, oxalic, benzoic, acetic, glyoxylic, pyruvic, oxypyruvic, α-ketoglutaric acids, etc.;

– black chokeberry: rutin, anthocyanins, catechins, flavonols, organic acids: citric, malic, tartaric, salicylic, tartronic.

The results of AOA studies of cranberry, lingonberry and chokeberry fruits are presented in Table 1.

The studied fruits differ from each other by AOA, they can be ranked as follows: cranberry> chokeberry> lingonberry (see Table 1). It was noted that the AOA of chokeberry fruit is insignificantly inferior to cranberry fruit, on average, by 7%, but superior to lingonberry fruit, on average, by 20%.

Stuffings were prepared from cranberry, lingonberry and chokeberry fruits. The results of the evaluation of organoleptic characteristics of the fillings are presented in Tables 2, 3.

The data in Table 2 indicate that the best appearance and consistency were the fillings made from cranberry, lingonberry and chokeberry fruits, made with 1.0% agar as a structural agent, the average score being 4.7 (the mass is thick, jelly-like, and spreadable). Fruit fillings made with pectin were slightly inferior in appearance and consistency to products made with 1% agar, with a score only 5% lower (a thick, viscous, smeary mass). Stuffings made from cranberries, lingonberries and chokeberries containing 1.5% agar were inferior to the products containing 1.0% agar by an average of 7%, as the mass became excessively dense. Samples of stuffing from cranberry, lingonberry and chokeberry fruits with 6.0% modified cold swelling starch as a texture formulator, as recommended by the manufacturer, obtained low

Табл. 1. Суммарная антиоксидантная активность плодового сырья (n = 3)

Table 1. Total antioxidant activity of fruit raw materials (n = 3)

Fruit	Total antioxidant activity, mg/100 g rutin
Cranberry	219,24 ± 3,74
Lingonberry	162,33 ± 2,49
Chokeberry	204,12 ± 3,74

Табл. 2. Органолептическая оценка показателя «внешний вид и консистенция» плодовых начинок (n = 5)

Table 2. Organoleptic evaluation of the fruit fillings indicator "appearance and consistency" (n = 5)

Sample	Descriptive characteristics of the stuffing	Integral estimation, point
Cranberry + 1,5% agar	Thick, jelly-like mass that does not spread on the surface	4,5 ± 0,4
Lingonberry + 1,5% agar		4,4 ± 0,1
Chokeberry + 1,5% agar		4,1 ± 0,1
Cranberry + 1,0% agar	Thick, jelly-like, smearing mass	4,9 ± 0,1
Lingonberry + 1,0% agar		4,6 ± 0,3
Chokeberry + 1,0% agar		4,5 ± 0,2
Cranberry + 2,0% pectin	Thick, viscous, smearing mass	4,7 ± 0,2
Lingonberry + 2,0% pectin		4,5 ± 0,4
Chokeberry + 2,0% pectin		4,1 ± 0,3
Cranberry + 6,0% starch	Dense, kisselike mass	2,9 ± 0,7
Lingonberry + 6,0% starch		3,5 ± 0,5
Chokeberry + 6,0% starch		3,1 ± 0,5

organoleptic scores for the studied index (3.2 points on average), because the mass became too dense, jellylike. The results of organoleptic evaluations of the studied organoleptic indicator did not depend on the type of fruits used.

The smell and taste of the fillings depended primarily on the individual characteristics of cranberry, lingonberry and chokeberry fruits (see Table 3). The use of agar as a structuring agent in fruit fillings, regardless of its concentration, had no effect on product smell, but allowed creating a more pronounced bright taste of fruits used as a base, compared with pectin - the average score was 4.6 and 4.1, respectively. The smell of the fillings was characteristic of the fruit from which they were made; there were no extraneous tones. It should be noted that the products made with 1.0% agar had a more pronounced smell than those with 1.5% agar, and the products with 2.0% pectin had more softness. The taste was sour for fillings made from cranberry and lingonberry fruits, the latter had a slight pleasant bitterness in the aftertaste; sweet and astringent - from chokeberry. Cranberry

Табл. 3. Органолептическая оценка показателя «запах и вкус» плодовых начинок (n = 5)
Table 3. Organoleptic evaluation of the fruit fillings indicator "smell and taste" (n = 5)

Sample	Descriptive characteristics		Integral estimation, point
	Taste	Flavor	
Cranberry + 1,5% agar	A pronounced, sour-sweet characteristic of cranberries, with no off-flavor	Harmonious, characteristic of cranberries, odorless	4,5 ± 0,2
Lingonberry + 1,5% agar	Expressed, sour-sweet, peculiar to the lingonberry, with a slight bitterness in the aftertaste, with no off-flavor	Harmonious, characteristic of lingonberries, odorless	4,9 ± 0,1
Chokeberry + 1,5% agar	A pronounced, sweet and astringent characteristic of chokeberry, with no off-flavor	Harmonious, characteristic of chokeberry, odorless	4,1 ± 0,2
Cranberry + 1,0% agar	A pronounced, sour-sweet characteristic of cranberries, with no off-flavor	Harmonious, pronounced, characteristic of cranberries, odorless	4,6 ± 0,1
Lingonberry + 1,0% agar	Expressed, sour-sweet, peculiar to the lingonberry, with a slight bitterness in the aftertaste, with no off-flavor	Harmonious, pronounced, characteristic of lingonberries, odorless	4,9 ± 0,1
Chokeberry +1,0% agar	A pronounced, sweet and astringent characteristic of chokeberry, with no off-flavor	Harmonious, pronounced, characteristic of chokeberry, odorless	4,3 ± 0,2
Cranberry + 2,0% pectin	Sour-sweet, typical of cranberries, with no off-flavor	Harmonious, soft, characteristic of cranberries, odorless	4,0 ± 0,2
Lingonberry + 2,0% pectin	Sour-sweet, peculiar to the lingonberry, with a slight bitterness in the aftertaste, with no off-flavor	Harmonious, soft, characteristic of lingonberries, odorless	4,3 ± 0,4
Chokeberry + 2,0% pectin	A pronounced, sweet and astringent characteristic of chokeberry, with no off-flavor	Harmonious, soft, characteristic of chokeberry, odorless	3,9 ± 0,3
Cranberry + 6,0% starch	Sour-sweet, typical of cranberries, with an extraneous flavor	Characteristic of cranberries, with extraneous tones	2,7 ± 0,5
Lingonberry + 6,0% starch	Sour-sweet, typical of lingonberries, with an extraneous flavor	Characteristic of lingonberries, with extraneous tones	2,5 ± 0,4
Chokeberry + 6,0% starch	A pronounced, sweet and astringent flavor typical of chokeberry, with an extraneous flavor	Characteristic of chokeberry, with extraneous tones	2,5 ± 0,7

and lingonberry fillings made with agar regardless of its concentration had a more pronounced taste than products made with pectin. The indicator of "expressiveness" of taste of products made from chokeberry, the structure-forming agent (agar or pectin) did not have a significant effect, but only on its overall impression. The smell and taste of cranberry, lingonberry and chokeberry fillings are most influenced by modified starch, the organoleptic evaluation of the best samples showed that this occurs on average by 44% - there appeared "floury" tones and aftertaste (see Table 3). Figures 1-3 show the research data on the total antioxidant activity of fruit fillings.

The data in Table 1 and Fig. 1-3 indicate that temperature exposure first during preparation of the filling and then during the simulated baking process reduced the antioxidant activity by more than 2-fold. At the same time, the strongest destruction of antioxidant substances was observed in chokeberry. The antioxidant activity of the toppings was influenced by the type of fruit rather than by the structural agent used (see Figs. 1-3). For example, cranberry fruit toppings, depending on the structure-forming agent used, ranked as follows in terms of antioxidant activity: 1.0% agar> 2.0% pectin> 1.5% agar> 6.0% starch. Stuffings from chokeberry fruit had almost the opposite ranking: 6.0% starch> 2.0% pectin> 1.0% agar> 1.5% agar. Stuffings from lingonberry fruits were ranked as follows in terms of antioxidant activity, depending on

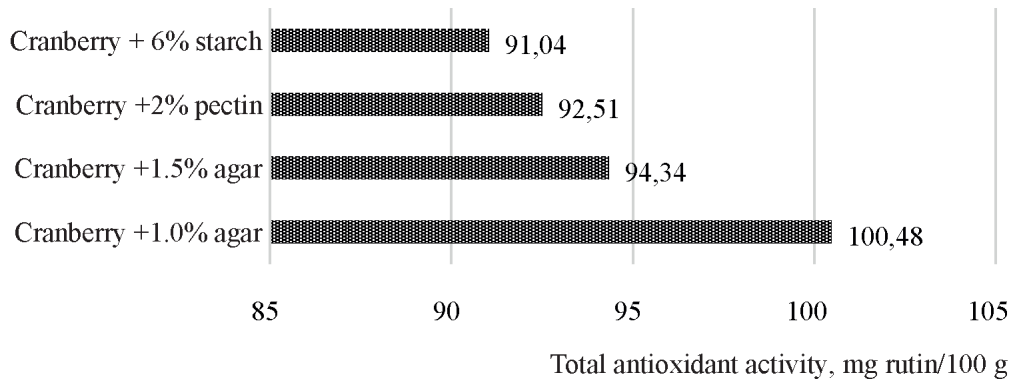

Рис. 1. Суммарная антиоксидантная активность клюквенных начинок (*n*=3)
Fig. 1. Total antioxidant activity of cranberry fillings (*n* = 3)

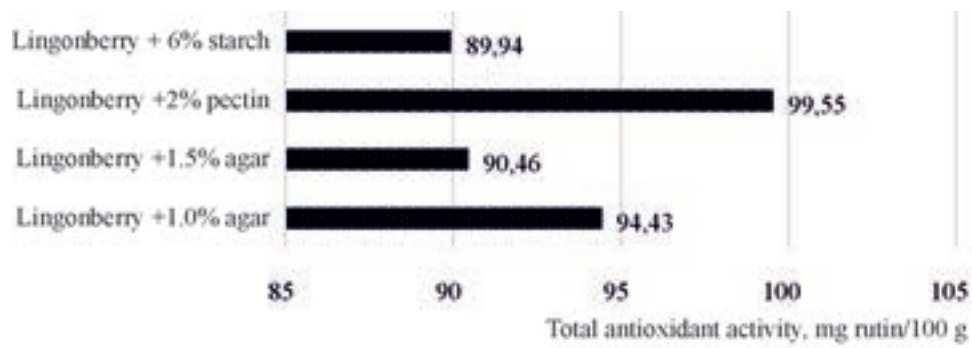

Рис. 2. Суммарная антиоксидантная активность брусничных начинок (*n* = 3)
Fig. 2. Total antioxidant activity of lingonberry fillings (*n* = 3)

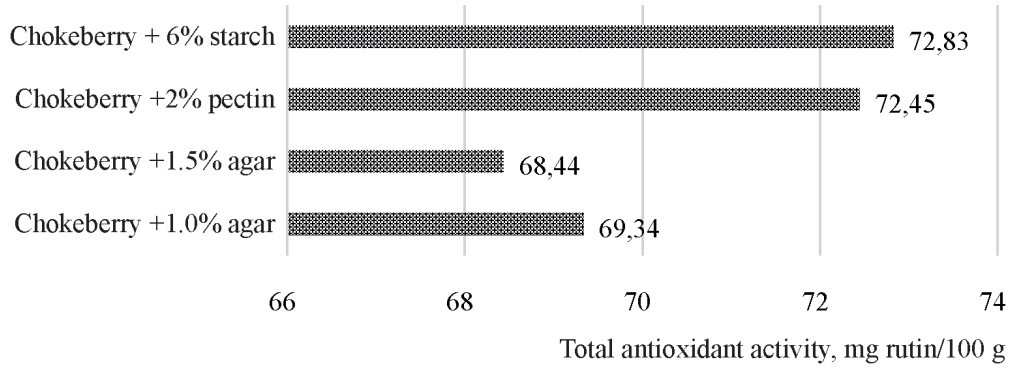

Рис. 3. Суммарная антиоксидантная активность арониевых начинок (n = 3)
Fig. 3. Total antioxidant activity of chokeberry fillings (n = 3)

the structural agent used: 2% pectin> 1% agar> 1.5% agar> 6% starch.

CONCLUSION

The paper presents data on the antioxidant status of wild cranberry, lingonberry and chokeberry cultivated in households. It was shown that according to the total antioxidant activity, the studied plant raw materials were distributed as follows: cranberry> chokeberry> lingonberry. Sensory characteristics of fillings for bakery products were significantly influenced not only by the type of fruit raw material, but also by the type of structure-forming agent used in their manufacture. Model samples with 1% agar and 2% pectin had the best indicators. It was revealed that during the preparation of the fillings there was a destruction of biologically active substances, depending on the type of fruit (ranking by antioxidant activity as follows: cranberry> lingonberry> chokeberry), but not on the used structure formers.

СПИСОК ЛИТЕРАТУРЫ

1. *Villaño D., Gironés-Vilapana A., García-Viguera C., Moreno D.A.* Development of functional foods. Innovation Strategies in the Food Industry. Academic Press. 2022. P. 193–207. DOI: 10.1016/B978-0-323-85203-6.00017-7.
2. *Решетник Е.И., Грибанова С.Л., Егоров Д.В., Грицов Н.В.* Использование растительного сырья при производстве кисломолочных продуктов для специализированного питания // Индустрия питания. 2021. Т. 6. № 4. С. 39-46. DOI: 10.29141/2500-1922-2021-6-4-4.
3. *Ходос М.Я., Казаков Я.Е., Видревич М.Б., Брайнина Х.З.* Окислительный стресс и его роль в патогенезе // Вестник Уральской медицинской академической науки. 2017. Т. 14. № 4. С. 381–398. DOI: 10.22138/2500-0918-2017-14-4-381-398.
4. *Сычева О.В., Стародубцева Г.П., Шлыков С.Н., Любая С.И., Омаров Р.С.* Развитие теории и практики индустрии питания // Аграрно-пищевые инновации. 2018. № 4(4). С. 69–76. DOI: 10.31208/2618-7353-2018-4-69-76.
5. *Лудан В.В., Польская Л.В.* Роль антиоксидантов в жизнедеятельности организма // Таврический медико-биологический вестник. 2019. Т. 22. № 3. С. 86–92.
6. *Чугунова О.В., Пастушкова Е.В., Вяткин А.В.* Практические аспекты использования плодово-ягодного сырья при создании продуктов, способствующих снижению уровня оксидативного стресса // Индустрия питания. 2017. № 2(3). С. 57–63.
7. *Акимов М.Ю., Макаров В.Н., Жданова Е.В.* Роль плодов и ягод в обеспечении человека жизненно важными биологически активными веществами // Достижения науки и техники АПК. 2019. № 33(2). С. 56-60. DOI: 10.24411/0235-2451-2019-10214.
8. *Жбанова Е.В.* Плоды малины *Rubus idaeus* L. как источник функциональных ингредиентов (обзор) // Техника и технология пищевых производств. 2018. Т. 48. № 1. С. 5–14. DOI: 10.21603/2074-9414-2018-1-5-14.
9. *Акимов М.Ю., Жбанова Е.В., Макаров В.Н., Перова И.Б., Шевякова Л.В., Вржесинская О.А., Бекетова Н.А., Кошелева О.В., Богачук М.Н., Рылина Е.В., Лукьянчук И.В., Миронов А.М.* Пищевая ценность плодов перспективных сортов земляники // Вопро-

сы питания. 2019. Т. 88. № 2. С. 64–72. DOI: 10.24411/0042-8833-2019-10019.
10. *Алексашина С.А., Макарова Н.В., Деменина Л.Г., Антипенко М.И.* Ягоды и косточковые плоды Самарского региона урожая 2016 года из коллекции НИИ "Жигулевские сады" как перспективное сырье в пищевой промышленности // Вестник Воронежского государственного университета инженерных технологий. 2018. Т. 80. № 2(76). С. 229–235. DOI: 10.20914/2310-1202-2018-2-229-235.
11. *Волкова Г.С., Серба Е.М., Фурсова Н.А., Соколова Е.Н., Куксова Е.В., Римарева Л.В.* Изучение качественного состава биологически активных веществ плодов брусники // Вопросы питания. 2018. Т. 87. № S5. С. 53–54. DOI: 10.24411/0042-8833-2018-10138.
12. *Лютикова М.Н., Ботиров Э.Х.* Химический состав и практическое применение ягод брусники и клюквы // Химия растительного сырья. 2015. № 2. С. 5–27.
13. *Логвинова Е.Е., Брежнева Т.А., Самылина И.А., Сливкин А.И.* Химический состав плодов аронии различных сортов // Фармация. 2015. № 6. С. 22–26.
14. *Цыбукова Т.Н., Петрова Е.В., Рабцевич Е.С., Зейле Л.А., Тихонова О.К., Агашева Е.А.* Элементный состав плодов брусники обыкновенной и клюквы болотной // Химия растительного сырья. 2017. № 4. С. 229–233. DOI: 10.14258/jcprm.2017041899.
15. *Jurendić T., Ščetar M.* Aronia melanocarpa products and by-products for health and nutrition: A Review. Antioxidants, 2021. N 10 (7). P. 1052. DOI: 10.3390/antiox10071052.
16. *Smirnov A., Birukova N.* Pharmaceutical sciences. Agricultural sciences, 2021. N 66. P. 14–18. DOI: 10.24412/9215-0365-2021-66-1-14-18.

REFERENCES

1. Villaño D., Gironés-Vilapana A., García-Viguera C., Moreno D.A. Development of functional foods. Innovation Strategies in the Food Industry. *Academic Press*, 2022, pp. 193–207. DOI: 10.1016/B978-0-323-85203-6.00017-7.
2. Reshetnik E.I., Gribanova S.L., Egorov D.V., Gritsov N.V. Plant materials use in the production of fermented milk products for specialized nutrition. *Industriya pitaniya = Food industry*, 2021, vol. 6, no. 4, pp. 39–46. (In Russian). DOI: 10.29141/2500-1922-2021-6-4-4.
3. Khodos M.Ya., Kazakov Ya.E., Vidrevich M.B., Brainina Kh.Z. Oxidative stress and its role in pathogenesis. *Vestnik Ural'skoi meditsinskoi akademicheskoi nauki = Journal of Ural Medical Academic Science*, 2017. vol.14, no. 4, pp. 381–398. (In Russian). DOI: 10.22138/2500-0918-2017-14-4-381-398.
4. Sycheva O.V., Starodubtseva G.P., Shlykov S.N., Lyubaya S.I., Omarov R.S. The development of the theory and practice of the food industry. *Agrarno-pishchevye innovatsii = Agrarian-and-Food Innovations*, 2018, no. 4(4). pp. 69–76. (In Russian). DOI 10.31208/2618-7353-2018-4-69-76.
5. Ludan V.V., Pol'skaya L.V. The role of antioxidants in the vital activity. *Tavricheskii mediko-biologicheskii vestnik = Tavricheskiy Mediko-Biologicheskiy Vestnik,* 2019, vol. 22, no. 3, pp. 86–92. (In Russian).
6. Chugunova O.V., Pastushkova E.V., Vyatkin A.V. Practical aspects of the fruit raw material usage while developing products aimed at oxidative stress decrease. *Industriya pitaniya = Food industry*, 2017, no. 2(3), pp. 57–63. (In Russian).
7. Akimov M.Yu., Makarov V.N., Zhdanova E.V. Role of fruits and berries in providing human with vital biologically active substances. *Dostizheniya nauki i tekhniki APK = Achievements of Science and Technology of AIC,* 2019, no. 33(2), pp. 56–60. (In Russian). DOI: 10.24411/0235-2451-2019-10214.
8. Zhbanova E.V. Fruit of raspberry *Rubus idaeus l.* as a source of functional ingredients (review). *Tekhnika i tekhnologiya pishchevykh proizvodstv = Food Processing: Techniques and Technology*, 2018, vol. 48, no. 1, pp. 5–14. (In Russian). DOI: 10.21603/2074-9414-2018-1-5-14.
9. Akimov M.Yu., Zhbanova E.V., Makarov V.N., Perova I.B., Shevyakova L.V., Vrzhesinskaya O.A., Beketova N.A., Kosheleva O.V., Bogachuk M.N., Rylina E.V., Luk'yanchuk I.V., Mironov A.M. Nutrient value of fruit in promising strawberry varieties. *Voprosy pitaniya = Problems of Nutrition*, 2019, vol. 88, no. 2, pp. 64–72. (In Russian). DOI: 10.24411/0042-8833-2019-10019.
10. Aleksashina S.A., Makarova N.V., Demenina L.G., Antipenko M.I. Berries and large fruits of the Samara region harvest 2016 year of the collection of the research institute "Zhigu-

levsky garden" as a perspective raw material in the food industry. *Vestnik Voronezhskogo gosudarstvennogo universiteta inzhenernykh tekhnologii = Proceedings of the Voronezh State University of Engineering Technologies*, 2018, vol. 80, no. 2(76), pp. 229–235. (In Russian). DOI: 10.20914/2310-1202-2018-2-229-235.
11. Volkova G.S., Serba E.M., Fursova N.A., Sokolova E.N., Kuksova E.V., Rimareva L.V., Study of the qualitative composition of biologically active substances of lingonberry fruits. *Voprosy pitaniya = Problems of nutrition*, 2018, vol. 87, no. 5, pp. 53–54. (In Russian). DOI: 10.24411/0042-8833-2018-10138.
12. Lyutikova, M.N., Botirov E.Kh. Chemical composition and practical application of lingonberries and cranberries. *Khimiya rastitel'nogo syr'ya = Chemistry of plant raw material*, 2015, no. 2, pp. 5–27. (In Russian).
13. Logvinova E.E., Brezhneva T.A., Samylina I.A., Slivkin A.I. Chemical composition of chokeberries (aronia) of different varieties. *Farmatsiya = Pharmacy,* 2015, no. 6, pp. 22–26. (In Russian).
14. Tsybukova T.N., Petrova E.V., Rabtsevich E.S., Zeile L.A., Tikhonova O.K., Agasheva E.A. The elemental composition of the fruits of common lingonberries and marsh cranberries. *Khimiya rastitel'nogo syr'ya = Chemistry of plant raw material,* 2017, no. 4, pp. 229–233. (In Russian). DOI: 10.14258/jcprm.2017041899.
15. Jurendić T., Ščetar M. Aronia melanocarpa products and by-products for health and nutrition: A Review. *Antioxidants,* 2021, no. 10 (7), p. 1052. DOI: 10.3390/antiox10071052.
16. Smirnov A., Birukova N. Pharmaceutical sciences. *Agricultural sciences,* 2021, no. 66, pp. 14–18. DOI: 10.24412/9215-0365-2021-66-1-14-18.

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Давыденко Н.И**., доктор технических наук, доцент, профессор, **адрес для переписки:** Россия, 650000, Кемерово, ул. Красная, 6; e-mail: nat1861@yandex.ru

Ульянова Г.С., аспирант

Голубцова Ю.В., доктор технических наук, профессор, заведующий кафедрой

Сергеева И.Ю., доктор технических наук, доцент, заведующий кафедрой

AUTHOR INFORMATION

(✉) **Nataliia I. Davydenko**, Doctor of Science in Engineering, Associate Professor, Professor; **address:** 6, Krasnaya St., Kemerovo, 650000, Russia, e-mail: nat1861@yandex.ru

Galina S. Ulyanova, Postgraduate Student

Yulia V. Golubtsova, Doctor of Science in Engineering, Professor, Department Head

Irina Yu. Sergeeva, Doctor of Science in Engineering, Associate Professor, Department Head

Дата поступления статьи / Received by the editors 13.01.2022
Дата принятия к публикации / Accepted for publication 24.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-10
УДК: 619:614.39(47+57)"1941/1945"
Тип статьи: обзорная
Type of article:

СТРАНИЦЫ ИСТОРИИ СОВЕТСКОЙ ВЕТЕРИНАРИИ В ПЕРИОД ВЕЛИКОЙ ОТЕЧЕСТВЕННОЙ ВОЙНЫ (1941–1945 гг.)

Донченко А.С., Голохваст К.С., (✉) Самоловова Т.Н., Донченко Н.А., Юшкова Л.Я.
Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: asdon@ngs.ru

Показана научно-практическая и военная деятельность советской ветеринарной службы во время Великой Отечественной войны 1941–1945 гг. Приведены данные о работе ветеринарных специалистов в условиях военного времени по обеспечению ветеринарно-санитарного благополучия животноводства страны, недопущению широкого распространения эпизоотических болезней и повышению эффективности лечебных мероприятий. Описана успешно проведенная эвакуация с оккупированных прифронтовых территорий людей, животных и соответствующей техники, затем реэвакуация животных с освобожденных районов. В начале войны военно-ветеринарная служба в короткие сроки была переведена на штатный режим военного времени: были созданы органы управления ветслужбой фронтов, армий, а также полевые ветеринарные учреждения. Уделено особое внимание конскому составу армии. Через ветеринарные лазареты Красной армии прошли 3 555 764 раненых и больных лошадей, из них вылечены и возвращены в строй 2 147 494 животных (91,59%). Приведены результаты деятельности Академии наук СССР в условиях военного времени. Научным учреждениям предлагалось пересмотреть тематику и методы научно-исследовательских работ по укреплению оборонно-военной мощи и народного хозяйства страны. Ветеринарная наука разработала и обеспечила гражданские и военные службы надежными способами профилактики опасных инфекционных болезней животных и эффективной помощи при хирургических и незаразных заболеваниях. Приведена оценка правительства страны работы военных, научных и гражданских ветеринарных специалистов. Многие из них получили государственные награды за доблестный труд в военное время.

Ключевые слова: Великая Отечественная война, эвакуация, фронтовые лазареты, болезни лошадей, ветеринарная наука

CHAPTERS OF HISTORY OF THE SOVIET VETERINARY SCIENCE DURING THE GREAT PATRIOTIC WAR (1941-1945)

Donchenko A.S., Golokhvast K.S., (✉) Samolovova T.N., Donchenko N.A., Yushkova L.Ya.
Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia
(✉) e-mail: asdon@ngs.ru

The research and military activities of the Soviet veterinary service in the context of the Great Patriotic War of 1941-1945 are shown. Data on the work of veterinary specialists under wartime conditions to ensure the veterinary and sanitary welfare of the country's livestock and to prevent the wide spread of epizootic diseases and increase the effectiveness of therapeutic measures are provided. The successful evacuation of people, animals and related equipment from the occupied front-line territories is described, followed by the re-evacuation of animals from the liberated

areas. At the beginning of the war the military veterinary service in a short time was transferred to a standard wartime mode: the bodies of the fronts and armies veterinary service management were established, as well as the field veterinary institutions. Particular attention was paid to the army's cavalry. 3,555,764 wounded and sick horses were treated at the veterinary clinics of the Red Army, of whom 2,147,494 animals (91.59%) were cured and returned to service. The results of the activities of the Academy of Sciences of the USSR in wartime conditions were given. Scientific institutions were asked to review the topics and methods of research work to strengthen the defense and military power and national economy of the country. Veterinary science developed and provided civilian and military services with reliable ways to prevent dangerous infectious and effective care for surgical and non-contagious diseases. The national government's assessment of the work of military, scientific, and civilian veterinary specialists was given. Many of them received state awards for their valorous labor during wartime.

Keywords: The Great Patriotic War, evacuation, front infirmaries, horse diseases, veterinary science

Для цитирования: *Донченко А.С., Голохваст К.С., Самоловова Т.Н., Донченко Н.А., Юшкова Л.Я.* Страницы истории советской ветеринарии в период Великой Отечественной войны (1941–1945 гг.), 2022, Т. 52. № 2. С. 82–94. https://doi.org/10.26898/0370-8799-2022-2-10. EDN NEBXQR.

For citation: Donchenko A.S., Golokhvast K.S., Samolovova T.N., Donchenko N.A., Yushkova L.Ya Chapters of history of the Soviet veterinary science during the Great Patriotic War. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 2, pp. 82–94. https://doi.org/10.26898/0370-8799-2022-2-10. EDN NEBXQR.

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

The Great Patriotic War was a terrible ordeal for the Soviet people. By this time Hitler's Germany had conquered and enslaved half of Europe, while our country experienced years of devastation, war communism, prodrazverstka (requisitioning of agricultural products), the NEP and political repression.

The war interrupted the beginning of peaceful labor of the citizens of the country, aimed at implementing the third five-year plan for the development of the national economy of the USSR (1938-1942). Since the end of June 1941 all sectors of economic activity of the country switched to the rails of war, were subordinated to a single defensive goal - the fight against the Nazi invasion. To accelerate the mobilization and efforts in the economy, politics and ideology, an extraordinary body, the State Defense Committee (SDC), was created on June 30, 1941, where all the full power was concentrated, i.e. the state, military and economic leadership [1].

From the first days of the war, agriculture suffered enormous losses. The western regions were occupied by the enemy. The area under crops and the number of cattle decreased significantly. Gross agricultural output declined to 37% of the prewar level [2].

Great damage was done to livestock production. In the areas of the RSFSR temporarily occupied by the German fascist troops, the number of cattle was reduced in comparison with the pre-war level by 60%, horses by 77, pigs by 90, sheep and goats by 70% [3].

The Great Patriotic War was a challenge for the entire Soviet veterinary system: civil, educational, scientific and military. In the difficult wartime environment, the management of veterinary services had to promptly solve many new problems in organizational, personnel, treatment and evacuation and anti-epizootic directions.

In general, the veterinary service, as well as the whole country, was to some extent preparing for the beginning of the war. The management of the Glavvetupr of Narkomzem (Chief Veterinary Administration of the People's Commissariat of Agriculture) and the People's Commissariat of Defense were constantly practicing some elements of veterinary activities in wartime conditions. Before the war through the efforts of Narkomzem a food fund was created, in March 1939 a fund "Red Army Horse" (RAH) was organized, intended "to meet the needs of the workers and peasants of the Red Army in

the military remount horse". The fund was allocated the best part of horses meeting certain artillery and riding requirements for service in the Red Army. The work was carried out jointly with the district military committees in state farms, collective farms, state cooperative institutions and enterprises which had horses. The procedure for allocating horses and the responsibility for quality, maintenance, care and veterinary service were reflected in a special instruction approved by the commissariats of the People's Commissariat of Agriculture and the People's Commissariat of Defense of the USSR [4].

In the conditions of the outbreak of war it was necessary to evacuate people, livestock and appropriate equipment from the occupied and front-line territories. The People's Commissariat of Agriculture of the USSR and the People's Commissariat of Defense of the USSR state farms were in charge of the evacuation of the material resources of agriculture and the population.

Glavvetupr together with the Main Directorate of Livestock and other subdivisions of the Narkomzem of the USSR worked out the routes for the cattle evacuated to the east, the order of its veterinary service on the way, accommodation on the routes of ferrying and veterinary inspection points and provision of animals with forage, and also solved other organizational and special issues. A special group of veterinary specialists was formed to organize and accompany the animals, and the necessary veterinary supplies and service items were allocated.

In October 1941 the head of Glavvetupr G.G. Ryabov and the head of Glavzhivupr (the Main Directorate of Livestock) N.N. Terentyev were sent to organize the evacuation of cattle from Penza and Kuibyshev regions [5]. Much work was done by veterinary specialists on the preservation of cattle during their transfer from Ukraine, Belarus and the Baltic states to the eastern regions of the USSR. In 1941-1942 enormous territorial transfer of huge herds, amounting to many hundreds of thousands of animals, from the west to the east took place. Endless flow of animals, day and night, with small stops, moved eastward in numerous herds. It was necessary to get the cattle out of the combat zone and enemy fire quickly, to provide veterinary care for the weakened animals. Some herds were encircled and suffered heavy losses from bombing and shelling by the Nazi air force [6].

Rivers were a serious obstacle to moving cattle to the east. Animals swam across small bodies of water. In a short time, several crossings over the Volga were built. Many horses on the way were transferred to the army, some were sold for meat. On some crossing routes there were cases of foot and mouth disease outbreaks. Such herds were quarantined and slaughtered, and bypass roads were found for the following herds.

At the same time, it was necessary to save the number of animals in the rear, where there were no military operations. In March 1942 the Council of People's Commissars of the USSR and the Central Committee of the All-Union Communist Party approved the decree "On measures to preserve young stock and increase the number of cattle on collective and state farms", which established plans for the growth of the number of cattle, horses, pigs, goats, sheep, rabbits and poultry, It was prohibited to slaughter and sell adult cattle during the war without the permission of Rayzo (District Land Department), collective and state farms, collective farmers were asked not to slaughter young cattle under one year of age, a system of incentives for the preservation and growth of livestock was introduced. In 1942 5.4 million head of cattle were bought from collective farmers by way of contracting, which allowed to increase the public herd of cattle, sheep and goats in the collective farms of the rear by about 10% [7].

In December 1941 the Nazi troops were rapidly advancing and were on the outskirts of Moscow. The urgent evacuation of organizations and population from the capital began. A huge number of businesses of various kinds were evacuated to the eastern regions of the country. They had to be accommodated and put to work in completely new conditions.

The main apparatus of the People' Commissariat of Agriculture of the USSR and with it the apparatus of Glavvetupr and other veterinary

institutions of national standing were evacuated to Omsk, Kuibyshev, Petropavlovsk and other cities of the rear. An operative group headed by Commissar of Agriculture I. A. Benediktov remained in Moscow and then from 1943 it was headed by Commissar A. A. Andreev. The Omsk group of the People's Commissariat of Agriculture of the USSR was headed by People's Commissar E. M. Chekmenev.

The head of Glavvetupr NKZ (People's Commissariat of Agriculture) of the USSR G.G. Ryabov and his deputy N.I. Leonov organized the evacuation from Moscow to Omsk some of the staff of Glavvetupr and the allied research veterinary institutions: the All-Union Research Institute of Experimental Veterinary Medicine (VIEV), the State Scientific Control Institute of Veterinary Drugs (GNKI), the All-Union Research Institute of Helminthology (VIGIS) and others.

N.I. Leonov remained in Moscow, in the operative group of the People' Commissariat of Agriculture of the USSR, and acted as the head of Glavvetupr. At that time there were in fact two Chief Veterinary Administration groups: one in Moscow, which dealt with operational issues of the front, and the other, which ensured all the necessary veterinary activities in the rear, in Omsk. There was constant communication between both groups of the Glavvetupr. After the defeat of the Germans near Moscow in winter 1941/42 and a further successful offensive of the Red Army, in March 1942 the office of the Glavvetupr of the USSR NKZ returned to Moscow. During the war five heads of the Chief Veterinary Administration of Narkomzem of the USSR were changed for various reasons (V.S. Kiselev, G.G. Ryabov, E.I. Leonov, V.A. Ivanovsky, A.M. Laktionov). Despite the difficulties of the war time the well-established pre-war rhythm of work of the heads and local veterinary bodies remained, which allowed to promptly perform the necessary actions and solve the problems of veterinary service of cattle breeding in the country. In the difficult conditions of the defense of Moscow, the veterinary service maintained and ensured veterinary and sanitary order in the capital, headed by the chief veterinarian P.T. Orlov [8].

The war was a serious challenge for scientific veterinary medicine as well, which had to solve many new problems in both organizational and highly specialized areas of research. On June 28, 1941 the Academy of Sciences of the USSR appealed to scientists of all countries to rally their forces to protect humanity from Hitler's barbarians: "In these days, when by the fault of the fascist rulers the land is flooded with more streams of human blood, the USSR Academy of Sciences appeals to all scientists of the world, to all friends of science and progress, to rally all forces to protect human culture from the Nazi barbarians.

Can any of us - the workers of science - look calmly at the fact that the fascist soldier's boot threatens to crush the bright light of humanity all over the world - the freedom of human thought, the right of peoples to develop their own culture?

For eight years Hitler and his clique have been torturing Germany. What have they turned this country, which gave mankind great geniuses of science and art, into? What has become of German scientists? They are either destroyed or wandering in foreign lands. What has become of German science? It has been replaced by deeply anti-scientific misanthropic, racist racial nonsense that the German race is supposedly the chosen race and this gives it the right to dominate the world, the right to turn all other peoples into slaves.

Having trampled their own country in mud and blood, the Hitlerites have enslaved and robbed half of Europe and threaten the whole world. The scientists of the Soviet Union express their deepest sympathy for the nations groaning under the yoke of the most heinous regime known to history...

In this hour of decisive battle, Soviet scientists go with their people, giving all their strength to fight the fascist warmongers - in the name of defending their homeland and in the name of protecting the freedom of world science and saving the culture that serves all mankind...

All those who cherish the cultural heritage of the millennia, for whom the great ideals of science and humanism are sacred, must put all

their efforts to ensure that the insane and dangerous enemy is destroyed" [9].

In this difficult time the USSR Academy of Sciences moved to the wartime rails. Scientific institutions were asked to revise the topics and methods of research work, to direct the initiative and energy of scientific workers to the tasks of strengthening the defense and military power and the national economy of the country. The activity of the institutes was restructured in accordance with the needs of the front and home front. The country's leadership did its best to preserve scientific personnel and institutions.

The Presidium of the Academy of Sciences sought to organize the work so that the scientists were able to give the maximum benefit to the country. The heads of the Presidium, headed by Academician V.L. Komarov, were first evacuated to Kazan, then in 1942 - to Sverdlovsk, where necessary specialists were summoned to solve current problems. Academicians of VASKHNIL headed by T D. Lysenko, president of the Academy, V.P. Mosolov (vice president), E.F. Liskun (director of the institute of animal breeding), P.N. Konstantinov (agronomist) and M.M. Zavadovsky (biologist) were evacuated to Omsk from Moscow during wartime. The Presidium of the Agricultural Academy was housed in one of the buildings of the Omsk Veterinary Institute [10].

On the initiative of V.L. Komarov the Academic Commission on mobilization of resources of the Urals, Siberia and Kazakhstan for the needs of the army and national economy of the country was created. Prominent scientists of the Academy in close contact with practitioners - metallurgists and miners - organized intense work to fulfill the tasks, on which depended the production of weapons for the Soviet army. The Academic Commission also helped to solve national economic problems, including the country's agriculture. In August 1942 the section of zootechnics and veterinary science which was headed by the academician K.I. Skryabin was created under the Academic Commission in order to solve and coordinate the problems of cattle breeding and veterinary science and the relationship between science and practice. E.N. Pavlovsky was elected as the scientific secretary of the section, P.Y. Sergeev was elected as the scientific secretary of the section, and V.G. Mukhin as the deputy chairman of the section on zootechnics [11].

The main task of the scientific and practical veterinary science was to maintain veterinary and epizootic welfare of the front and rear, animal health, to provide the army with good quality livestock products. The newly created section of zootechnics and veterinary medicine also had to participate in this.

The Academy's work was of particular importance. The head of the Soviet government I.V. Stalin telegraphed to V.L. Komarov: "I express confidence that, despite the difficult conditions of the wartime, the scientific activity of the Academy of Sciences will develop in step with the increased demands of the country, and the Presidium of the Academy of Sciences under your leadership will do everything necessary to implement the tasks facing the Academy." [12].

At the beginning of the war the military veterinary service in a short time was transferred to a standard wartime regime: veterinary service management bodies of fronts and armies were established, as well as the field veterinary institutions. For stage treatment of the wounded and sick horses in the army a network of hospitals was deployed: in regiments - regimental, in divisions - divisional, in armies - field and evacuation, at the fronts - front hospitals. The work of the military veterinary service in wartime was solved by veterinary personnel in the necessary volume. From the beginning of the war almost 2/3 of civilian doctors and paramedics of the national economy were called up for military service. During the war alone the Military Veterinary Academy trained 1178 veterinarians, and the Leningrad Military Veterinary School trained 1220 paramedics [13].

Horses, i.e. the army's cavalry, were an important fighting weapon, a means of transportation in the artillery and the rear services. The mobility and combat effectiveness of cavalry and rifle units depended on the staffing of these units with healthy animals. By the end of 1941 the number of horses in the active army

increased significantly, the number of cavalry divisions increased from 13 to 22.

By the end of 1941, 8.4 million horses (39.8% of the prewar herd) remained in the countryside. During six months of the war, the collective farms of Western Siberia alone gave 202,100 horses to the army [14].

The large number of horses in formations, units, and rear facilities, and the harsh conditions in which they operated, dramatically increased the importance of the veterinary service in ensuring the combat effectiveness of the troops. The volume of its work was constantly increasing and often went beyond the functions stipulated by the previously issued instructions and statutes. By that time the veterinary service of the Red Army had an established structure and basically possessed the necessary administrative, educational, research, treatment, supply and other organs for veterinary support. All units of the army in service had full-time military veterinarians, in divisions and corps - division and corps veterinarians, in armies and at the fronts - veterinary departments. Veterinary service of the army in the field was headed by a single central governing body - Veterinary Administration of the Red Army, which included prominent specialists N.M. Vlasov, G.M. Gradyushko, B.A. Levadny, N.I. Titov, F.A. Shustovsky and others. The chief of the department was a talented organizer and an experienced manager, Lieutenant-General V. M. Lekarev (1902-1955) who did much for the development and improvement of organization of the veterinary and military service. In the military districts the veterinary service was headed by the chiefs of the district veterinary services, in the fronts and armies there were the corresponding heads of veterinary departments which had military veterinary chief specialists: epizootologists, surgeons, therapists. S.L. Alichkin, I.D. Bystrov, L.S. Goberman, P.G. Galushko, E.I. Kuznetsov, P.A. Kovalev, A.P. Kornienko, Y.A. Lyanda, I.V. Novikov, A. Ostrovsky, I.I. Rebrov, P.I. Svetlov, S.P. Finansov, A.V. Chesnokov, A.M. Penionzhko, A.A. Petukhovsky, N.M. Speyer successfully headed the front veterinary service. [15].

From the very first days of the war about 500 army and front-line veterinary units were formed within a short period of time.

3,555,764 wounded and sick horses passed through the Red Army veterinary infirmaries, of which 2,147,494 animals (91.59%) were cured and returned to service. The incidence of contagious diseases in horses (in different years of the war) was 2.97 million head. - 8% to the average of the stock, while in the Civil War it was 36.01-44.71%. A great volume was also carried out on veterinary service of food cattle procurement, mastering and processing of trophy cattle and supervision over the supply of troops with meat and meat products. During the war about 20 million tons of food, including 3.4 million tons of meat and meat products, were subjected to veterinary and sanitary expertise [16].

Employees of almost all veterinary research institutes, including (VIEV): retired Colonel P.I. Pritulin, retired Major V.E. Shchurevsky, retired Captain V.A. Gorbatov, F.T. Tereshkov, V.M. Nakhmanson, V.A. Sharov, N.I. Korolev, A.A. Klochkov and others took an active part in the war. [17].

The Omsk Veterinary Institute organized the enrollment of volunteers in the active army and the national militia. N.A. Sokolov, A.M. Tsiro, K.P. Safronkov and S.I. Ivanov were the first to sign up. Through the military registration and enlistment office were called up and went to the front 25 scientific workers, 22 workers and employees, 103 graduates of the 5th year. Employees and students heroically fought at the fronts of the Great Patriotic War and were awarded high government awards. Among them I.S. Pomiluyko, A.I. Simkin, A.I. Averikhin, A.N. Kadenatsii, N.A. Obukhov, M.P. Solomatin and others. Eleven students and employees of the institute did not return from the fields of battle, were killed. And those who returned were engaged in the restoration of the institute's buildings, which during the war housed a factory of defense value and other services [18].

From the beginning of the war the staff of the Novosibirsk veterinary research station (NIVS) as well as veterinary specialists of the practical veterinary medicine in Novosibirsk were also drafted into the army. In June 1941

in Novosibirsk the Siberian Military District established the front veterinary infirmary under the number 365, subsequently assigned to the North-Western Front. With this veterinary front infirmary (there were various dislocations and relocations) academician of VASKHNIL A.A Sviridov as the chief of infectious diseases department (future first director of IEVSFE), N.N. Shabalin - the head of the surgical department, B.E. Krotkov - the head of the therapeutic department, M.M. Yagodin - the head of the remedial part of the infirmary, N.G. Kazantsev - the head of the training and construction department, veterinarian G.M. Ustyuzhaninov, served in the divisional infirmary experienced all the war hardships. A school of veterinary military paramedics was created at the infirmary. The veterinarians P.D. Shatko (director of the Novosibirsk NIVS), Sukhomlinov and Perevozchikov were appointed the teachers. During the war, the veterinary front infirmary No.365 (school) prepared several classes of veterinary military paramedics [19].

Fierceness and intensity of fighting, a massive equipment of troops with firearms led to the fact that the number of wounded and sick horses in the active army was increasing. If during the first month of the war, according to incomplete data, about 19 thousand wounded and sick horses were admitted to veterinary hospitals, then during the next two months - 76 thousand. The number of surgical patients and wounded horses in some years of the war ranged from 50 to 70% of the total sickness rate, but the therapeutic efficiency of the activities was quite high and in the last year of the war reached 93% for the war injuries of horses and 97% - for the operational injuries. This was facilitated by well-organized treatment and evacuation work. By the beginning of the war the medical institutions, from regimental to frontal, constituted a quite complete structure with evacuation stages in each rear area. Such a system was continuously improved. In the veterinary infirmaries of formations, armies, and fronts 46.9% of the listed horses were treated in the first and second years of the war, 44.3% in the third, and 27.4% in the fourth [20].

Throughout the war the veterinary and sanitary condition of the active army and the troops in the rear was stable. Of the total number of wounded and sick horses treated, more than 90% were returned to service.

For the first time in the history of Russian military veterinary medicine the military field surgery became an independent clinical branch. Creation of the institute of military surgeons in the center, at the fronts and in the armies during the war resulted in increasing the efficiency of the treatment work and raised the veterinary military field surgery to a higher level. The chief veterinary surgeons of the Soviet Army were Professors G. V. Degtyarev and I. D. Medvedev.

During the war the veterinary military field therapy, which in the previous wars did not exist as an independent direction, got its organizational form. The therapeutic service at the center was headed by the chief therapist Professor P.S. Ionov. The well-arranged prophylactic work provided the reduction of noncontagious diseases of horses from 38.7% in the first year of the war to 19.6% - in 1945. 2.1 million horses were returned to the service during the war [21].

The constant recruitment of horses threatened to introduce various infections into the troops. In 1943-1945 trophy and derelict horses were a serious source of disease entering the troops. For example, among trophy horses many were found to be sick with glanders, infectious anemia, and the incidence of scabies reached 60-92%. During the Great Patriotic War for the first time in the history of veterinary service of our country it was possible to prevent wide spread of epizootics - inevitable satellites of the past wars that caused great damage to the combat ability of troops.

Thanks to the selfless work of a large group of specialists-epizootologists of fronts, armies and military districts, infectious diseases of animals were not widespread in the units of the active army. In the first year of the war in horses they amounted to 6.6% to the list composition, in the second - 8, in the third - 4.08 and in the fourth - 2.97% [22]. This is a great merit of the Soviet scientists of the leading veterinary

research institutes, which laid the foundations for the prevention and elimination of such infectious animal diseases as sap, plague of cattle, pneumonia, ringworm, blastomycosis, etc. (VIEV, VIGIS, GNKI, SibNIVI, etc.).

One of the main tasks of the science of those years - in the near future to develop a set of measures to combat injuries of horses in the front conditions and to offer a typical harness for cattle in the rear for practice , because in the collective and state farms almost all the horses were taken to the front, and the main tractive force were cows and bulls.

A lot of damage was caused by the loss of young animals. First of all, infertile mares had to be eliminated, because they were essential for replenishing foals both for the army and the rear. There was a lack of disinfectants, without which it was impossible to carry out veterinary and anti-epizootic measures. For this purpose, local suitable raw materials were often used as disinfectants.

The war undermined the material and personnel base of scientific institutions and made adjustments to the thematic plans of the R&D, slowing down the development of some current areas and outlining a new "defense" theme. Some employees of research and educational institutions went to the front. The rest, together with the structural subdivisions, were evacuated to the interior of the country.

In Omsk on the basis of the Siberian Research Veterinary Institute (SibNIVI) some laboratories and staff of the VIEV and GNKI, evacuated from Moscow, conducted scientific research.

While being evacuated to Omsk, the staff of the GNKI had a close connection with the Omsk biofactory. In particular, the future corresponding member of VASKhNIL S.G. Kolesov, head of the laboratory for control of siberian-ulcer preparations, was appointed the chief veterinarian of the Omsk biofactory, M.A. Babich, the head of the biochemical laboratory of the GHKI, during the war years was sent to Alma-Ata, to the Kazakh Research Institute of Veterinary Medicine, and there he organized a biochemistry laboratory; A.G. Malyavin, the head of the paratyphoid laboratory (GHKI), in 1942-1945, being in Omsk, served as an authorized director of the GHKI branch. Of great importance was the fact that the evacuated researchers of the GNKI were able to timely bring to Omsk the production strains of microorganisms and viruses, ensure their safety, maintenance and organize their shipment to biofactories for the production of vaccines, serums and other biopreparations (A.G. Malyavin, N.M. Nikiforova and A.O. Kolesova) [23].

The methods and means of fighting many animal diseases developed during this period by scientists of the Veterinary Institute were included in the guiding materials of the military veterinary service and veterinary legislation of our country. Subsequently, veterinary schools were established: helminthologists (Academician K.I. Skryabin), epizootologists (Academician S.N. Vyshelessky), pharmacologists and toxicologists (Professor N.A. Sohestvensky), microbiologists (Professor N.A. Mikhin), immunologists (Academician Y.R. Kovalenko), protozoologists and arachnologists (Professor A.A. Markov), physiologists and hematologists (Professor A.A. Kudryavtsev), zoohygienists (Professor N.M. Komarov), biochemists (A.N. Bakh), infectiologists of pig pathology (A.P. Uranov), mycologists and mycotoxologists (Academician A.Kh. Sarkisov) etc.

The SibNIIVI (Omsk) research plan was also adjusted in accordance with the wartime requirements. Most of the researchers of SibNIIVI were drafted into the army. Nevertheless, the institute worked quite effectively. It was headed by V. V. Slivko, then N.E. Sarminsky, from April 1943 - Associate Professor D.V. Kopyrin. During the war years the Institute organized manufacturing of glandered antivirus, trypanosome antigen, positive trypanosome serum, established a chemical laboratory for manufacturing saponin, which was extremely necessary for biological industry (earlier it was imported from Germany), ammargene, copper sulfate, potassium iodide, urotropin and other preparations. Employees of the Institute provided practical assistance to land bodies, collective and state farms in organizing scientifically substantiated measures to eliminate foot and mouth disease, scabies, helminthia-

sis, anthrax, epizootic lymphangitis and equine influenza, sheep brucellosis, young animals diseases (Sarminsky N.E., A.V. Kopyrin, V.Y. Fishbein, S.K. Bezzubets, Z.A. Norkina, A.V. Romodanovskaya, A.N. Kadenatsii, O.A. Amelina, etc.) [24].

The Scientific Council of the Red Army Veterinary Administration, the Veterinary Section of VASKHNIL (headed by Academician K.I. Skryabin) and scientists from the country's veterinary institutes provided great assistance in the generalization and dissemination of best practices and the latest scientific achievements.

During the war, enterprises of the biological industry of the USSR NKZ worked at full capacity. They provided the front and rear with the necessary therapeutic, prophylactic and diagnostic biological preparations despite the fact that some of them (from the Orel, Kursk, Kharkov regions, etc.) were evacuated to the east. During the wartime, new biopreparations were mastered at the biofactories of the People's Commissariat of Agriculture of the USSR: serums against tetanus, anatoxin, STI vaccine, anti-vax vaccines, bacteriophages against diseases of young animals, mass production of gramicidin. New technological processes allowing to save livestock raw materials were introduced into practice. In particular, the use of hydrolysate agents in the preparation of nutrient media provided great savings of meat [25].

The leadership of the Chief Veterinary Administration of Narkomzem of the USSR (A.M. Laktionov, V.A. Ivanovsky, A.I. Glumakov) together with scientists placed special emphasis on rehabilitation of the livestock industry from contagious diseases. Much work was done to eliminate infectious anemia in horses. Special courses for the retraining of veterinary surgeons were organized at the Institute which were able to eliminate the centers of that desease very quickly applying the scientifically grounded measures. In June 1943 Lieutenant-General Lekarev, the head of the Red Army Veterinary Department, approved and "put into effect" three documents on combating infectious anemia in horses (Order No. 251 of June 2, 1943, Moscow): the instruction on combating anemia in military units, the instruction on its diagnosis, the instruction on making a biological diagnosis of infectious anemia in horses. Responsibility for implementing preventive measures against infectious anemia and, where it appeared, for its rapid and complete elimination was assigned to commanders and veterinarians of military units.

Epizootic lymphoguitis of horses caused considerable damage to horse breeding in the pre-war and war periods. Many herds of animals even before the war were susceptible to this disease. A comprehensive study of epizootic lymphogoeitis was entrusted to the staff of the Novosibirsk Research Institute of Veterinary Medicine (N.S. Shepilov, K.F. Lamikhov, B.I. Bogoletov, N.A. Sviridov, P.D. Shatko). During the war period and in the following years the biology of the pathogenic agent, diagnostics and pathogenesis of the disease were studied, the schemes of sanitation measures with the use of isolators for the maintenance and treatment of sick horses were worked out. According to the results of the scientific work, the NIVS staff published and defended four Ph.D. theses [26].

Throughout the war years the main goal of the country's veterinary specialists was to maintain the epizootic well-being of livestock, fully promote the growth of livestock and its productivity. Military veterinary medicine was a single unit with civil veterinary medicine of all departments. The unity and coherence of action was the key to the successful fulfillment of common goals and objectives - ensuring the veterinary welfare of animals in the rear and at the war fronts. In March 1942 the USSR PCU and the Central Committee of the Communist Party (b) adopted a resolution "On measures to increase the number of cattle on collective and state farms and increase their productivity", according to which veterinary specialists were assigned responsible tasks for the development of livestock on collective and state farms and the prevention of epizootics [27].

Anti-epizootic work faced great difficulties: many farms were economically weak, there was a shortage of antipsoric preparations and disinfectants, vaccines, syringes, needles, thermometers and other veterinary supplies for animals. Despite this, veterinary specialists carried

out extensive measures to improve the health of horses, cattle, sheep and prevent contagious and other diseases, so during the Great Patriotic War there were no mass epizootics in the country. Small pockets of infection appeared in some areas were quickly eliminated. In 1941 9 times less cattle died of brucellosis than in 1940; 16 times less cattle died of equine encephalitis and 10 times less cattle died of anthrax and infectious anemia. The same was true of other diseases. The total withdrawal of animals from all contagious diseases during the war was steadily decreasing. Thus, in 1942-1943 it decreased by 13.5% as compared with 1939 [28]. The rear veterinary specialists withstood the test of war by preventing the widespread development of glanders, foot and mouth disease, widespread pneumonia in cattle and other diseases.

After the defeat of the Nazi troops near Moscow, Stalingrad and at the Kursk Bulge, a significant part of the country, which was under temporary occupation, was liberated. The Party and the government undertook a number of measures to restore the liberated areas. In August 1943 the USSR PCU and the Central Committee of the CC AUCPb (the All-Union Communist Party of the Bolsheviks) issued a decree "On Urgent Measures to Restore the Economy in the Areas Liberated from the German Occupation" [29]. The leadership of the Glavvetupr Narkomzem of the USSR organized veterinary reconnaissance in the liberated territories, again developed routes and determined the order of veterinary service for livestock returning from the east to the west. At the same time, measures were taken to restore the veterinary institutions in these territories.

Scientists during the war proposed and put into practice dozens of effective methods and means to combat contagious and noncontagious animal diseases, significantly expanded the arsenal of the means ensuring a good therapeutic effect. The major achievements of the veterinary science during the years of war include a quinazole vaccine and an immunotherapeutic serum against leptospirosis (S.Y. Lyubashenko, 1941), an anti-syribriosis vaccine STI (N.N. Ginsburg, 1943) and a hydroxylurea formolvaccine against sheep pox (N.V. Likhachev, 1944). Reconvalescent sera were widely used as a prophylactic agent against foot and mouth disease in calves, piglets and lambs. Bacteriophage therapy for diseases of young animals was successfully used.

In 1941, Academician S.N. Vyshelessky was awarded the State Prize for his scientific work on the study of infectious diseases of animals and the development of methods of their treatment [30].

Widespread development of traumatism in connection with the war necessitated the search for more effective methods of wound treatment. In this direction many new methods were proposed: treatment by leukocyte transplantation, autoanavaccines, reticulin (Bogomoletz cytotoxic anti-reticular serum), Gramicidin, onion plant antisepticophytocide, para-drug treatment of wounds, bacteriophage therapy in purulent lesions, tissue therapy in purulent-necrotic processes by Filatov and others. New chemical therapeutic and prophylactic agents, including sulfamide agents (red and white streptocide), successfully used for streptococcal and other infectious diseases of animals, etc., were widely introduced into medical practice [31].

With the development of the Soviet army's offensive operations, the veterinary service faced a very difficult task of organizing the collection and servicing of captured animals sent into the interior of the country. In 1944-1945 a significant number of reparation cattle began to arrive in the country from Germany. The veterinary and sanitary condition of these cattle was extremely unfavorable (glanders, foot and mouth disease, tuberculosis, brucellosis, etc.). Heads of the Glavvetupr together with the scientists determined the locations of livestock, measures for its treatment and quarantine. Some of the cattle affected by tuberculosis, brucellosis and foot-and-mouth disease were forced to be slaughtered for meat.

Domestic animal husbandry suffered great losses during the war. During the occupation Nazi invaders destroyed or took away to Germany 7 million horses, 17 million head of cattle, 20 million pigs, 27 million sheep and goats and 110 million poultry. The number of all kinds of cattle by the end of 1944 in the coun-

try decreased significantly in comparison with 1940. The occupants completely demolished and destroyed 2,180 veterinary institutions in the Ukrainian SSR, and in the Belarusian SSR almost all were destroyed [32].

In the closing period of the war the military veterinary service together with the civil veterinary service solved the main task of preventing the introduction of infectious diseases into our territory. For this purpose, an indissoluble connection of military and civil veterinary services, mobilization and effective use in the interests of the front of all the country's veterinary personnel potential were carried out.

Thousands of military veterinarians, paramedics and nurses were awarded orders and medals for their self-sacrificing service.

In 1945, after the victorious end of the Great Patriotic War by the decision of the Presidium of the Supreme Soviet of the USSR a large group of scientists and practitioners, organizers of the Soviet veterinary was awarded orders and medals for the successful fulfillment of the government's task in difficult war conditions to provide the front and the population, and the industry with agricultural raw materials. The Order of Lenin was awarded to A. M. Laktionov, head of the Main Veterinary Administration of the People's Commissariat of the USSR, the Order of the Red Banner of Labor was awarded to Academicians S. N. Vyshelessky (VIEV), K.I. Skryabin (VIGIS), Professors P.N. Andreev, N.A. Mikhin, V.M. Koropov, A.A. Polyakov, D.S. Ruzhencev, V.V. Slivko, A.P. Studentsov, A.A. Sviridov, P.D. Shatko, etc.

Thus, veterinary specialists of the USSR front and rear withstood the test of war, preventing the widespread development of epizootics of glanders, foot and mouth disease, widespread pneumonia in cattle and other infectious diseases. Stable veterinary and sanitary welfare and high therapeutic and prophylactic effectiveness of measures were achieved. The Soviet veterinary profession fulfilled its tasks thanks to the inseparable link between the military and civil veterinary services, mobilization and effective use of the country's veterinary personnel potential, the selfless work of scientific and practical veterinary specialists as well as the organizational activities of the heads of veterinary departments of the Soviet army (Lieutenant General of Veterinary Service V. I. Lekarev, N.V. Vlasov) and the Main Veterinary Administration of the People's Commissariat of Agriculture of the USSR (G. Ryabov, N. Leonov, V. Ivanovsky, A. Laktionov). Veterinary science provided the veterinary service with reliable ways and means of mass prevention of dangerous infections and effective help for surgical wounds of horses and non-communicable animal diseases.

СПИСОК ЛИТЕРАТУРЫ

1. История Коммунистической партии Советского Союза. М., 1963. 542 с.
2. *Никитин И.Н., Иванов А.В.* История ветеринарии Татарстана. Казань, 2002. С. 51.
3. Официальный интернет портал Минсельхоза Российской Федерации «Животноводство в годы Великой Отечественной войны 1941–1945 гг.».
4. Инструкция по организации и содержанию фонда «Лошадь Красной Армии» в колхозах, совхозах государственных, кооперативных учреждениях и предприятиях. Издательство Наркомзема Союза ССР. М., 1939. 14 с.
5. История советского крестьянства. М., 1987. Т. 3. С. 151–153.
6. *Голощапов Ю.Н.* Руководители и организаторы ветеринарной службы СССР 1901–1983 гг. М., 1984. С. 87–88.
7. *Черноиванов В.И.* Комиссары и министры сельского хозяйства СССР 1917–1991 гг. М., 1997. С. 118.
8. *Голощапов Ю.Н.* Руководители и организаторы ветеринарной службы СССР (1901–1983 гг.). М., 1984. С 88, 91.
9. *Скрябин К.И.* Моя жизнь в науке. М.: Издательство политической литературы, 1969. С. 316, 317.
10. История Омского ветеринарного института. Омск, 2008. С. 49.
11. *Скрябин К.И.* Моя жизнь в науке. М.: Издательство политической литературы, 1969. 323 с.
12. *Скрябин К.И.* Моя жизнь в науке. М.: Издательство политической литературы, 1969. С. 321.
13. Ветеринарный энциклопедический словарь. М.: Сельхозгиз, 1950. Т. 1. С. 161.

14. *Черноиванов В.И.* Комиссары и министры сельского хозяйства СССР 1917–1991 гг. М., 1997. С. 119.
15. *Беленький О.С.* Вклад ветеринарии в достижение великой победы // Труды ВИЭВ. 1985. Т. 62. С. 147.
16. *Бурков В.И., Колесниченко И.С.* Ветеринарно-санитарной службе вооруженных сил Российской Федерации 295 лет // Ветеринария. 2002. № 7. С. 5.
17. *Беленький О.С.* Вклад ветеринарии в достижение великой победы // Труды ВИЭВ. 1985. Т. 62. С. 147.
18. *Рябиков А.Я.* История института ветеринарной медицины Омского государственного аграрного университета. Омск, 2008. С. 48, 59.
19. Из рукописи воспоминаний о войне Н.Н. Шабалина, П.Д. Шатько, А.А. Свиридова.
20. *Бурков В.И., Колесниченко И.С.* Ветеринарно-санитарной службе вооруженных сил Российской Федерации 295 лет // Ветеринария. 2002. № 7. С. 4.
21. *Беленький О.С.* Вклад ветеринарии в достижение великой победы // Труды ВИЭВ. Т. 62. 1985. С. 151, 152.
22. *Беленький О.С.* Вклад ветеринарии в достижение великой победы // Труды ВИЭВ. Т. 62. 1985. С. 149.
23. *Голощапов Ю.Н.* Руководители и организаторы ветеринарной службы в СССР (1901–1983 гг.). М., 1984. С. 91.
24. *Копырин А.В*. 50-летие сибирского научно-исследовательского ветеринарного института // Сборник научных работ СибНИВИ. Омск: Западно-Сибирское книжное издательство, 1971. Вып. 19. С. 9, 10.
25. *Коропов В.И.* История ветеринарии. М., 1954. С. 300.
26. Сборник научных работ Новосибирской научно-исследовательской ветеринарной станции. Новосибирск, 1958. Вып. 1. С. 5, 6.
27. Ветеринария в Великой Отечественной войне (к 20-летию великой победы) // Ветеринария. 1965. № 5. С. 7.
28. *Коропов В.М.* История ветеринарии в СССР. М., 1954. С. 298.
29. *Голощапов Ю.Н.* Руководители и организаторы ветеринарной службы СССР (1901–1983 гг.). М., 1984. С. 91.
30. *Никитин И.Н., Калугин В.И.* История ветеринарии. М., 1988. С. 146.
31. *Коропов В.И.* История ветеринарии. М., 1954. С. 299.
32. *Коропов В.И.* История ветеринарии. М., 1954. С. 301.

REFERENCES

1. *History of the Communist Party of the Soviet Union.* Moscow, 1963, 542 p. (In Russian).
2. Nikitin I.N., Ivanov A.V. *History of veterinary science of Tatarstan*. Kazan', 2002, p. 51. (In Russian).
3. The official Internet portal of the Ministry of Agriculture of the Russian Federation «Livestock breeding during the Great Patriotic War 1941–1945».(In Russian).
4. Instruction on the organization and maintenance of the Red Army Horse Fund in collective and state farms, state and cooperative institutions and enterprises. Publishing house of the People' Commissariat of the SSR. Moscow, 1939, 14 p. (In Russian).
5. *History of the Soviet Peasantry*. Moscow, 1987, vol. 3, pp. 151–153. (In Russian).
6. Goloshchapov Yu.N. *Leaders and organizers of the veterinary service of the USSR 1901–1983*. Moscow, 1984, pp. 87–88. (In Russian).
7. Chernoivanov V.I. *Commissars and Ministers of Agriculture of the USSR 1917–1991*. Moscow, 1997, p. 118. (In Russian).
8. Goloshchapov Yu.N. *Leaders and organizers of the veterinary service of the USSR (1901-1983).* Moscow, 1984, pp. 88, 91. (In Russian).
9. Skryabin K.I. *My life in science*. Moscow, Izdatel'stvo politicheskoi literatury = Publishing house of political literature, 1969, pp. 316, 317.
10. History of the Omsk Veterinary Institute. Omsk, 2008, p. 49. (In Russian). (In Russian).
11. Skryabin K.I. *My life in science*. Moscow, Izdatel'stvo politicheskoi literatury = Publishing house of political literature, 1969, 323 p. (In Russian).
12. Skryabin K.I. *My life in science*. Moscow, Izdatel'stvo politicheskoi literatury = Publishing house of political literature, 1969, p. 321. (In Russian).
13. Veterinary Encyclopedic Dictionary. Moscow, Sel'khozgiz Publ., 1950, vol. 1, p. 161. (In Russian).
14. Chernoivanov V.I. *Commissars and Ministers of Agriculture of the USSR* 1917–1991. Moscow, 1997, p. 119. (In Russian).
15. Belen'kii O.S. The contribution of veterinary medicine to the great victory. *Trudy VIEV = Pro-*

ceedings of the VIEV, 1985, vol. 62, p. 147. (In Russian).
16. Burkov V.I., Kolesnichenko I.S. Veterinary and sanitary service of the Armed Forces of the Russian Federation is 295 years old. *Veterinariya = Veterinary medicine*, 2002, no. 7, p. 5. (In Russian).
17. Belen'kii O.S. The contribution of veterinary medicine to the great victory. *Trudy VIEV = Proceedings of the VIEV*, 1985, vol. 62, p. 149. (In Russian).
18. Ryabikov A.Ya. *History of the Institute of Veterinary Medicine of the*. Omsk State Agrarian University, Omsk, 2008, pp. 48, 59. (In Russian).
19. From the manuscript memories of the war N.N. Shabalin, P.D. Shatko, A.A. Sviridov. (In Russian).
20. Burkov V.I., Kolesnichenko I.S. Veterinary and sanitary service of the Armed Forces of the Russian Federation is 295 years old. *Veterinariya = Veterinary medicine*, 2002, no. 7, p. 4. (In Russian).
21. Belen'kii O.S. The contribution of veterinary medicine to the great victory. *Trudy VIEV = Proceedings of the VIEV*, 1985, vol. 62, pp. 151, 152. (In Russian).
22. Belen'kii O.S. The contribution of veterinary medicine to the great victory. *Trudy VIEV = Proceedings of the VIEV*, 1985, vol. 62, p. 149. (In Russian).
23. Goloshchapov Yu.N. *Leaders and organizers of the veterinary service of the USSR* (1901–1983). Moscow, 1984, p. 91. (In Russian).
24. Kopyrin A.V. 50th Anniversary of the Scientific-Research Veterinary Institute of Siberia. Collection of scientific works of SibNIVI. Issue 19: Omsk, *Zapadno-Sibirskoe knizhnoe izdatel'stvo = West Siberian book publishing house,* 1971, issue 19, pp. 9, 10. (In Russian).
25. Koropov V.I. *History of veterinary medicine*. Moscow, 1954, p. 300. (In Russian).
26. Collection of scientific papers of the Novosibirsk Veterinary Research Station. Novosibirsk, 1958, issue 1, pp. 5, 6. (In Russian).
27. Veterinary medicine in the Great Patriotic War (to the 20th anniversary of the great victory). *Veterinariya = Veterinary medicine*, 1965, no. 5, p. 7. (In Russian).
28. Koropov V.M. *History of veterinary medicine in the USSR*. Moscow, 1954, p. 298.
29. Goloshchapov Yu.N. *Leaders and organizers of the veterinary service of the* USSR (1901–1983). Moscow, 1984, p. 91.
30. Nikitin I.N., Kalugin V.I. *History of veterinary medicine*. Moscow, 1988, p. 146.
31. Koropov V.I. *History of veterinary medicine*. Moscow, 1954, p. 299.
32. Koropov V.I. *History of veterinary medicine*. Moscow, 1954, p. 301.

ИНФОРМАЦИЯ ОБ АВТОРАХ

Донченко А.С., академик РАН, главный научный сотрудник, руководитель научного направления

Голохваст К.С., доктор биологических наук, профессор РАН, член-корреспондент РАО, директор СФНЦА РАН

(✉) **Самоловова Т.Н.,** кандидат ветеринарных наук, ведущий научный сотрудник; **адрес для переписки**: Россия, 630501, Новосибирская область, р.п. Краснообск, а/я 463; e-mail: asdon@ngs.ru

Донченко Н.А., член-корреспондент РАН, руководитель ИЭВСиДВ СФНЦА РАН

Юшкова Л.Я., доктор ветеринарных наук, главный научный сотрудник

AUTHOR INFORMATION

Alexander S. Donchenko, Academician RAS, Head Researcher, Head of Research Group

Kirill S. Golokhvast, Doctor of Science in Biology, Professor RAS, Corresponding Member RAE, Director SFSCA RAS

(✉) **Tamara N. Samolovova,** Candidate of Science in Veterinary Medicine, Lead Researcher; **address:** PO Box 463, SFSCA RAS, Krasnoobsk, Novosibirsk Region, 630501, Russia; e-mail: asdon@ngs.ru

Nikolay A. Donchenko, Corresponding Member RAS, Head of IEVSSFE SFSCA RAS

Liliya Ya. Yushkova, Doctor of Science in Veterinary Medicine, Head Researcher

Дата поступления статьи / Received by the editors 25.01.2022
Дата принятия к публикации / Accepted for publication13.04.2022
Дата публикации / Published 25.05.2022

https://doi.org/10.26898/0370-8799-2022-2-11
УДК: 630:551.56
Тип статьи: оригинальная
Type of article: original

УСОВЕРШЕНСТВОВАНИЕ ГТК СЕЛЯНИНОВА ДЛЯ РАСШИРЕНИЯ ВОЗМОЖНОСТЕЙ ЕГО ПРИМЕНЕНИЯ

(✉) **Потанин В.Г.**
Сибирский федеральный научный центр агробиотехнологий Российской академии наук
Новосибирская область, р.п. Краснообск, Россия
(✉) e-mail: wgp@ngs.ru

Приведены основные моменты, определившие необходимость и сущность разработки комплексного гидротермического коэффициента (ГТКк). Данную разработку следует рассматривать как процесс усовершенствования гидротермического коэффициента Г.Т. Селянинова. Предложенный ГТКк позволяет более детально характеризовать территорию. Комплексный ГТКк включает в себя две составляющие: тангенсальную ГТК*t* и радиальную ГТК*r*. При графическом отображении ГТКк рационально выделять зоны, соответствующие ГТК*t*, внутри которых формировать зоны, соответствующие ГТК*r*. Приведено распределение ГТКк в Новосибирской области. Величина интервала тангенсальной зоны выбрана постоянной и составляет 0,2 мм/град. Величина радиальной зоны несколько варьируется для исключения мелких образований на границах зон. Приведенная карта-схема агроландшафтного районирования Новосибирской области позволяет сопоставить ее с распределением ГТКк. Определенное их сходство подчеркивает соответствие комплексного ГТКк тем природным процессам, которые определяют развитие растений. Дан пример применения ГТКк при его отображении на мелкомасштабной карте. Показано, что при перемещении в выбранной полосе карты Российской Федерации с севера на юг среднее значение радиальной составляющей последовательно изменяется от 70,5 до 155. Это соответствует изменению условий для произрастания растительности, в то время как предшествующий ГТК находится в одном и том же интервале. Переход к комплексному ГТКк также предоставляет возможность оценить распространение тех или иных растений на новых территориях при возрастающем потеплении. Исходя из положений модели, определяющих развитие растений в зависимости от погодных условий, возможно выделить набор параметров конкретного растения. Данные параметры соответствуют оптимальным значениям температуры и осадков на определенных фенологических фазах растения, а также определяют соответствующие им показатели климата, по близости данных наборов оценивают уровень благоприятности распространения растения.

Ключевые слова: климат, гидротермический коэффициент, осадки, температура, модель

IMPROVEMENT OF THE SELYANINOV HTC TO EXPAND THE POSSIBILITIES OF ITS APPLICATION

(✉) **Potanin V.G.**
Siberian Federal Scientific Center of Agro-Biotechnologies of the Russian Academy of Sciences
Krasnoobsk, Novosibirsk region, Russia
(✉) e-mail: wgp@ngs.ru

The main points that determined the necessity and essence of the development of the complex hydrothermal coefficient (HTCc) are given. This method should be considered as a process of improving the hydrothermal coefficient of Selyaninov G.T. The proposed HTCc allows for a more

detailed characterization of the territory. The complex HTCc includes two components: the tangential HTC*t* and the radial HTC*r*. In the graphical representation of HTCc, it is rational to allocate zones corresponding to HTC*t* within which to form zones corresponding to HTC*r*. The distribution of HTCc in the Novosibirsk region is given. The value of the tangential zone interval is chosen constant and is 0.2 mm/degree. The size of the radial zone varies slightly to exclude small formations at the boundaries of the zones. The given map-scheme of agro-landscape zoning of the Novosibirsk region allows to compare it with the distribution of HTCc. A certain similarity between them emphasizes the correspondence of the complex HTCc to those natural processes that determine the development of plants. An example of the application of HTCc when it is displayed on a small-scale map is given. It is shown that when moving in a selected zone of the map of the Russian Federation from north to south the average value of the radial component consistently changes from 70.5 to 155. This corresponds to a change in the conditions for vegetation growth, while the preceding HTC is in the same interval. The transition to a complex HTCc also provides an opportunity to assess the distribution of certain plants on new territories with increasing warming. Based on the provisions of the model determining the development of plants depending on weather conditions, it is possible to identify a set of parameters of a particular plant. These parameters correspond to the optimum values of temperature and precipitation at certain phenological phases of the plant and determine their corresponding climate indicators, and by the proximity of these sets assess the level of favorability of the spread of the plant.

Keywords: climate, hydrothermal coefficient, precipitation, temperature, model

Для цитирования: *Потанин В.Г.* Усовершенствование ГТК Селянинова для расширения возможностей его применения // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 95–104. https://doi.org/10.26898/0370-8799-2022-2-11. EDN OOXLNZ.

For citation: Potanin V.G. Improvement of the Selyaninov HTC to expand the possibilities of its application. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science*, 2022, vol. 52, no. 2, pp. 95–104. https://doi.org/10.26898/0370-8799-2022-2-11. EDN OOXLNZ.

Конфликт интересов
Автор заявляет об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

In market conditions the purpose of any enterprise is to increase the efficiency of its activities, and the way of increasing - intensification. However, as follows from the work [1], regardless of the level of intensity of agricultural technologies used, there is an increase in the cost of obtaining an additional unit of agricultural production. The data given by FAO on the world grain production shows that both the decline and the rise in this process are determined by climatic conditions. Scientists believe that in the next decade the growth of production in agriculture on the basis of scientific and technological progress will occur due to the improvement of ways to obtain and effectively use information about the climate[1]. It is believed [2-5] that the territorial organization of natural-agrarian systems largely depends on the solution of problems of efficient and ecological use of land for agricultural purposes. In this connection, higher and higher requirements are imposed on the characteristics and indicators determining the state of territories [6, 7]. The implementation of the topical issue of improving the known and developing new models of the basic agricultural processes also stimulates the above trend [8, 9].

Of the existing indicators used to assess agroclimatic resources, the most widely used is the hydrothermal coefficient (HTC) of G.T. Selyaninov, calculated by the formula

$$\text{HTC} = \Sigma p \cdot 10/\Sigma t,$$

where Σp is the sum of precipitation for the period with average daily air temperatures above

[1]Climate and Agriculture: [Electronic resource] - http://collectedpapers.com.ua/ru/climate_and_human_activities/klimat-ta-silske-gospodarstvo (accessed: 14.01.2021).

10 ºC, Σ*t* is the sum of active temperatures accumulated during the same period.

In 1928, G.T. Selyaninov proposed the term "climatic factors of crops", which over time was transformed into "agro-climatic indicators". One of such indicators - the hydrothermal coefficient (HTC) - entered the practice of the world science getting his name.

Despite its widespread use, HTC has certain disadvantages. The main drawback is that for areas with low temperatures and humidity (the Arkhangelsk Region, the Komi Republic), as well as for areas with high temperatures and precipitation (the Black Sea coast of the Transcaucasian Region), HTC has approximately equal value, although agroclimatic conditions in these areas are incomparable[2]. There is a need to supplement HTC with a component of amplitude nature (for example, such as z = *f1 (p) + f2 (t),* where *p* is precipitation; *t* is temperature).

The purpose of the research is to develop a promising agro-technical indicator to assess the state of the territories, ensuring the achievement of practically significant results in agricultural production.

RESULTS AND DISCUSSION

To elaborate the issue of eliminating the shortcomings of HTC and expanding its possibilities of practical application, let us consider the mapping of temperature (*t)* and precipitation (*p*) factors on a graphical plane in which temperature (*t*) is represented by abscissa. Let the point A_i with coordinates p_i and t_i be a characteristic of climatic (or weather) conditions of a particular small area. In this case, the ratio P_i/t_i is the tangent of the angle α′ formed by the abscissa and the line extending from the origin to point A_i. Nothing will basically change if the variable ∑*t* is plotted along the abscissa axis and ∑*p* along the ordinate, which are characteristic of the chosen time interval *ΔT*. Then the similar point A_j, being a characteristic of the climatic conditions in the time interval *ΔT*, is uniquely defined by the coordinates $S'p_j$ and St_j:

$$S'p_j = \sum_{i=k_j}^{l_j} p_i,$$

where p_i is the measured value of precipitation with the number *i*; *j* is the number of interval *ΔT*; k_j is the number of measurement corresponding to the starting point of the *j*-th interval; lj is the number of measurement corresponding to the end point of the *j*-th interval:

$$St_j = \sum_{i=k_j}^{l_j} t_i$$

where t_i is the measured temperature value with number *i*; *j* is the number of interval *ΔT*; k_j is the number of measurement corresponding to the starting point of the *j*-th interval; l_j is the number of measurement corresponding to the end point of the *j*-th interval.

The ratio $10 \cdot S'p_j/St_j$ corresponds to the Selyaninov HTC and simultaneously, as noted above, is the tangent of the angle α.

Next, it is advisable to switch to the polar coordinate system. In this coordinate system, the point Aj noted above is described by the angle α′ (uniquely defined by tgα′) and a radius equal to $\sqrt{(S'p_j)^2 + (St_j)^2}$.

Thus, the climatic characteristic of the chosen territory is rationally presented in the complex variant (complex hydrothermal coefficient - HTCc), represented by two components: tangential ($10 \cdot S'p_j / St_j$) and radial ($\sqrt{(10 \cdot S'p_j)^2 + (St_j)^2}$). It should be noted that the complex hydrothermal coefficient can be equally represented by two variants: the first in the form of tangential and radial components and the second in the form of angular and radial components. However, taking into account G.T. Selyaninov's huge contribution, his intuition and ability to identify indicators of undoubted practical value, it is proposed to use the variant with tangential and radial components as the main variant in the future, and to pass to application of the following expressions:

$$Sp_j = 10 \cdot S'p_j;$$

$$\text{HTC}t = Sp_j/St_j;$$

$$\text{HTC}r = \sqrt{(Sp_j)^2 + (St_j)^2}.$$

[2]Konstantinov A.R. Weather, soil and yield of winter wheat. L.: Gidrometeoizdat, 1978. 248 p.

Although the variant with tangential and radial components is the most acceptable for most cases, this does not exclude the use of the second variant, if necessary.

The schematic map of the Novosibirsk region is shown in Fig. 1 to demonstrate the capabilities of the proposed HTCc. On this schematic map, the zones to which a given interval of the tangential component of the HTCc corresponds are highlighted. Most of the above mentioned zones are subdivided into small zones, which correspond to the radial components of the HTCC. The zones are designated by a two-digit code, in which the first digit determines the number of the tangential component, and the second digit corresponds to the radial component of HTCc. If there is only one radial zone within a particular tangential zone, then in Figure 1 the zone number is indicated by one digit corresponding to the number of the tangential zone, and a two-digit code is added in brackets next to this number in the text. Thus, in Fig. 1, the zones that do not have a small (radial) zone split are identified. Proceeding from the prevalence of knowledge on Selyaninov's HTC among specialists of this subject, it was decided to apply the same units for quantitative characterization of the tangential component of the HTCc as for Selyaninov's HTC.

The value of the tangential zone interval is chosen constant and is 0.2 mm/degree. The value of the radial zone varies slightly. This is caused by the desire to reflect the change in the radial component inside the tangential zone and to exclude small formations at the boundaries of the zones, arising due to the possible inter-

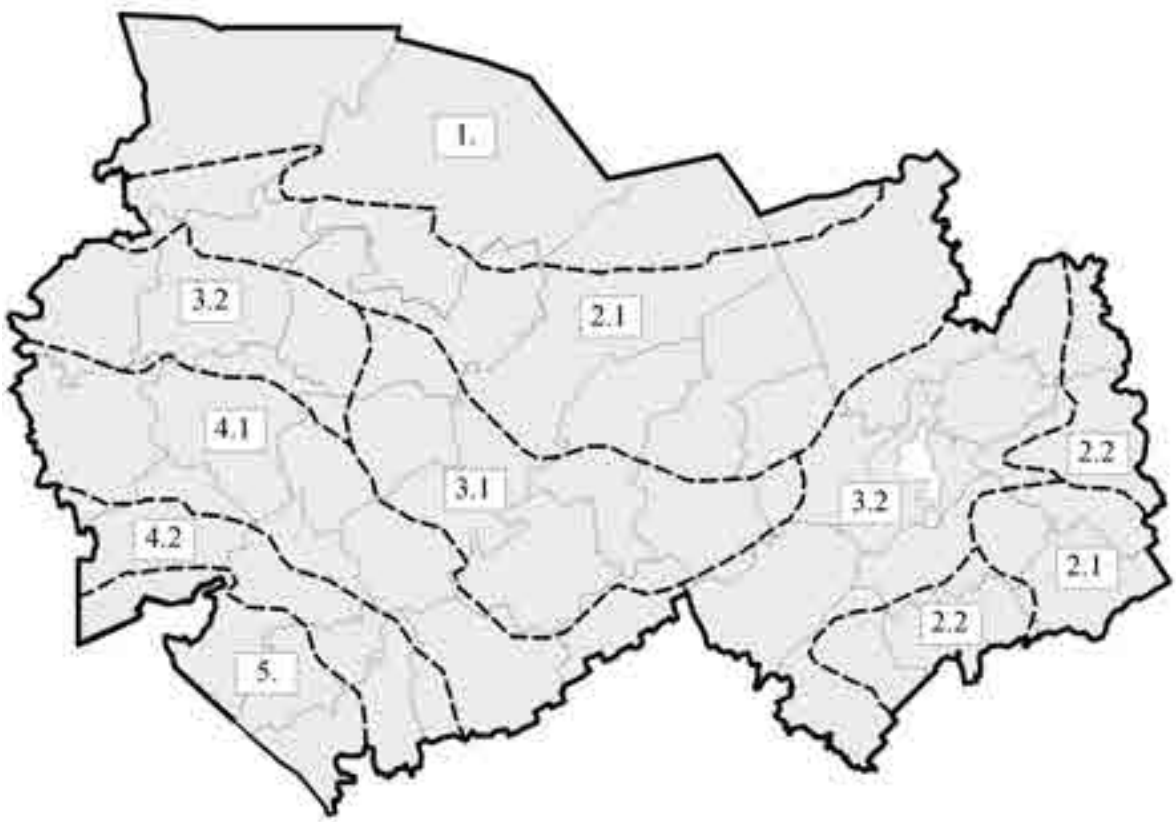

Рис. 1. Распределение ГТКк в Новосибирской области:

1.; 5. – номера зон, не имеющих дробления зонами другого вида; 1.1; 1.2; …; 4.1; 4.2. – комплексные номера зон, где первая цифра соответствует номеру зоны с тангенсальной составляющей, вторая – номеру зоны с радиальной составляющей

Fig. 1. Distribution of HTCc in the Novosibirsk Region:

1.; 5. - numbers of zones that have no fragmentation by zones of another type; 1.1; 1.2; ...; 4.1; 4.2. - complex zone numbers, where the first number corresponds to the number of the zone with tangential component, the second number corresponds to the number of the zone with radial component

section of the constant zones. The specific magnitudes of the zones are given in the table.

Figure 2 shows the agrolandscape zoning map of the Novosibirsk Region [10]. It is the result of long-term research by researchers at the Siberian Research Institute of Soil Management and Chemicalization of Agriculture of the Siberian Branch of the Russian Academy of Agricultural Sciences, which made it possible to include the results in the materials on the formation of adaptive-landscape farming systems.

Comparison of the two given schematic maps allows us to note their certain similarity in spite of the fact that they differ significantly in the data used for their development. This circumstance emphasizes the correspondence of the complex HTCc to those natural processes that determine the development of plants. Moreover, there is a high probability that the farming systems proposed by the first and second schematic maps will be almost indistinguishable if a narrower interval of values within the zones is applied.

Another example of the application of GTCc when it is displayed on a small-scale map is shown in Fig. 3. The map "Hydrothermal coefficient for vegetation period" developed by a team of authors (Afonin A.N., Lee Y.S., Lipi-

Распределение составляющих ГТКк на рис. 1
Distribution of HTCc components in Fig. 1.

Area designation	Tangential component	Radial component
1 (1.2)	1,6–1,4	285–329
2.1	1,4–1,2	265–295
2.2	1,4–1,2	295–344
3.1	1,2–1,0	225–267
3.2	1,2–1,0	267–312
4.1	1,0–0,8	230–269
4.2	1,0–0,8	269–310
5 (5.1)	0,8–0,6	234–280

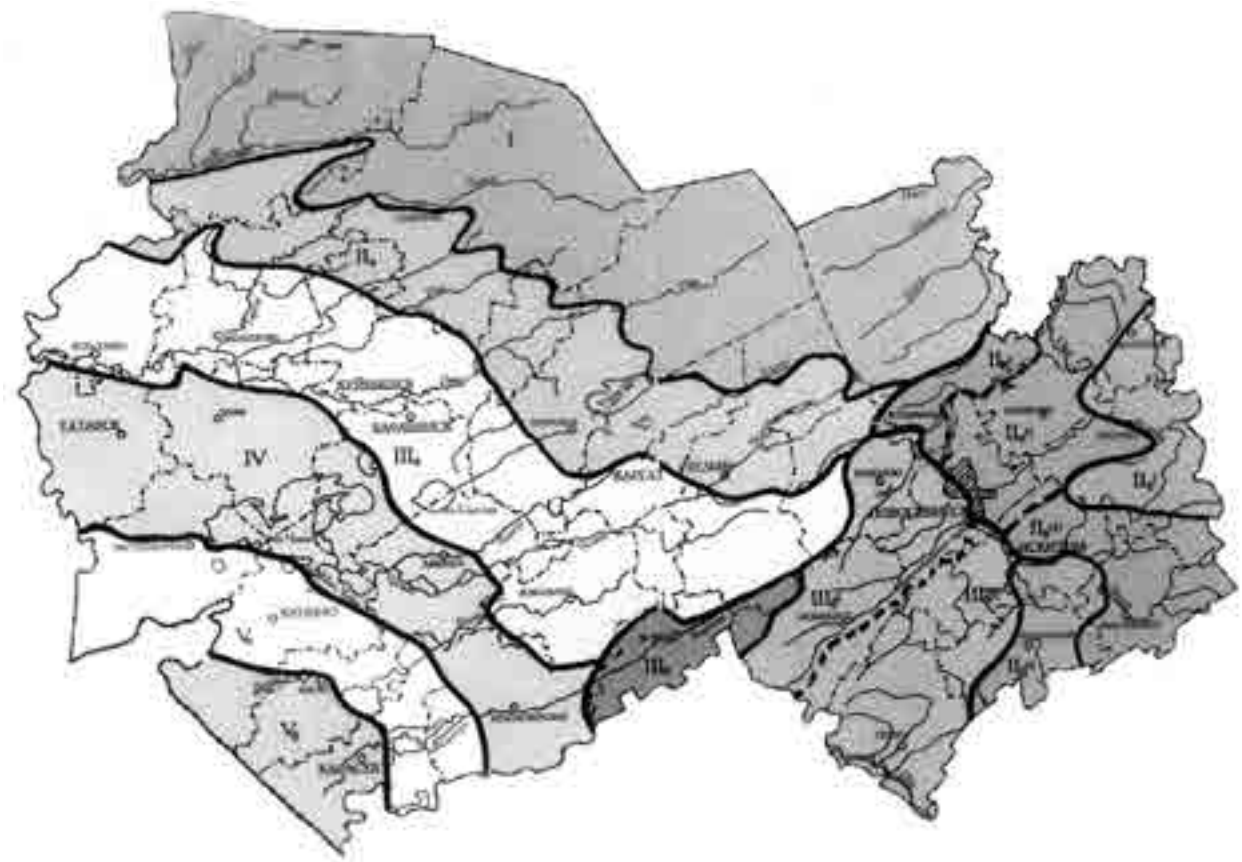

Рис. 2. Агроландшафтное районирование Новосибирской области:
I; IIа; . . .; Va; Vб – индексы агроландшафтных районов
Fig. 2. Agrolandscape zoning of the Novosibirsk region:
I; IIa; . . .; Va; Vb - indices of agrolandscape areas

yainen K.L., Tsepelev V.Yu.) is used as the basis in Fig. 3.[3]

On this map, the bold line indicates a strip of land along the meridian of 120 degrees, which corresponds to the interval of the Selyaninov HTC in the range from 0.7 to 1.3. The calculation carried out allows us to subdivide the selected band into four zones (with a thin line). Zone 1 corresponds to the average value of the radial component equal to 70.5; 2 - 99; 3 - 127 and 4 - 155. Thus, the strip of land, which has the same HTC Selyaninov interval and, consequently, the same degree of moistening, is subdivided into areas with different radial components and different climatic possibilities, as it should be expected when moving along the meridian from north to south. The HTCc describes the real situation of the territory in more detail (in terms of climatic conditions) and allows identifying the territorial divisions most suitable for certain economic purposes.

The transition to an integrated HTCc also provides an opportunity to estimate the spread of certain plants into new areas under increasing warming. The seemingly simple assumption that plants will seek locations where climatic conditions will be more favorable leads to a difficult question: what are these favorable conditions for plants in quantitative terms? To answer it, we should refer to the work of A.R. Konstantinov (see footnote 2). Studying winter wheat yield, he showed on experimental material that the yield value (hence, the level of development of this plant) depending on weather conditions graphically represents a set of decreasing in size quasi-ellipses. Each value of the yield corresponds to a closed line in the form of a quasi-ellipse. Moreover, the higher the yield, the smaller the quasi-ellipse; at its maximum value the closed line turns into a point. Although A.R.

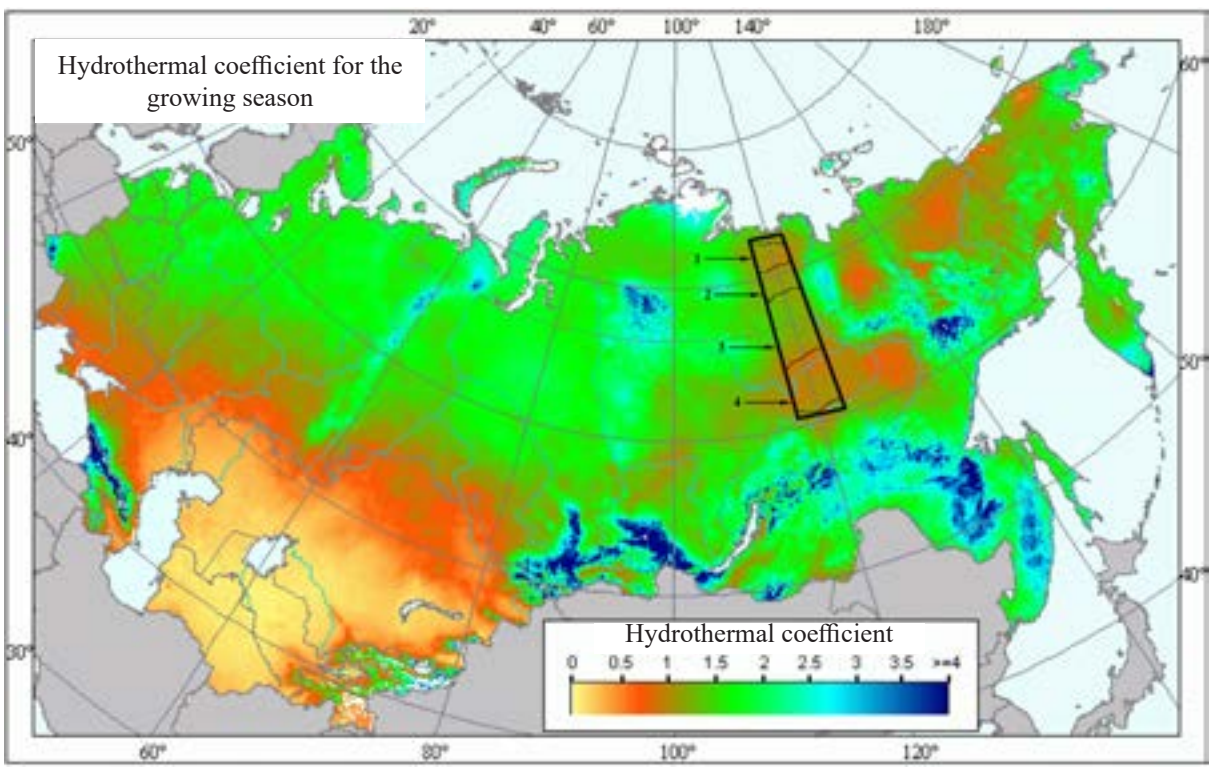

Рис. 3. Распределение радиальной составляющей ГТКк в выделенной полосе:
1; 2; 3; 4 – номера зон, сформированных относительно радиальной составляющей ГТКк

Fig. 3. Distribution of the radial component of HTCc in the selected zone:
1; 2; 3; 4 - numbers of the zones formed relative to the radial component of the HTCc

[3]Агроэкологический атлас России и сопредельных стран. Климат, Гидротермический коэффициент за вегетационный период: [Электронный ресурс]: URL: http://www.agroatlas.ru/ru/content/Climatic_maps/GTK/GTK/index.html. (дата обращения: 08.04.2020).

Konstantinov did not mention it, but it is easy to assume that this point corresponds to the optimal values of weather (climate) factors. It is especially important that each phenological phase (or interphase period) corresponds to its own set of quasi-ellipses and its own point of optimal factor values.

A.R. Konstantinov chose temperature (*t*) and absolute air humidity (*e*) as weather factors. In his calculations he used the average values of the factors for the interval of phenological phase of a plant (or for the selected interphase period).

Taking into account that air humidity e is considered in A.R. Konstantinov's work as a value suitable for characterizing water consumption conditions of plants, and that precipitation is the main reason for formation of air humidity, then transition from average air humidity to average precipitation value will not lead to principal change of graphs and will allow determining average optimal values of temperature and precipitation for each phenological phase based on newly constructed graphs.

I have performed an elaboration that offers an analytical model of yield (or level of plant development) based on four statements:

– yield losses are proportional to the deviation of weather (or climatic) factors from their optimal values;

– cumulative losses from two or more factors determines the vector sum of losses on individual factors, represented by orthogonal vectors;

– dependence of total loss value (in graphical representation) on weather and climatic factors represents a set of increasing ellipses for each phenological phase. Each set of ellipses has a turn by a certain angle, which in the analytical formulas is taken into account by the introduction before the factors of co-multipliers in the form of cosine or sine of a particular angle;

– the yield or level of development of the plant is defined as the difference between the maximum possible and real losses.

In fact, the third position is mainly a consequence of the first two, given in analytical form, supplemented by the peculiarity of the real situation in the form of the necessity to rotate the ellipse by a specific angle. The fact that the summation of two orthogonal vectors often leads to the formation of an ellipse will be demonstrated by a simplified example. Let the two vectors x_1 and y_1 have their origin at the zero point of the coordinate system, i.e., the point of optimal factor values is located at the beginning of the coordinate system. As a result of summation, we have a vector of length $R_1 = \sqrt{x_1^2 + y_1^2}$. Often in the real situation the summands of the vector have different scaling. In accordance with this we replace y_1 with kz_1 and obtain $R_1 = \sqrt{x_1^2 + (kz_1)^2}$.

Squaring the left and right parts of the last expression and dividing all the terms of the equation by R_1^2, we get:

$$\frac{R_1^2}{R_1^2} = \frac{x_1^2}{R_1^2} + \frac{k^2 z_1^2}{R_1^2}$$

or

$$1 = \frac{x_1^2}{R_1^2} + \frac{z_1^2}{R_1^2/k^2}.$$

The last expression is the classical equation of the ellipse, taking into account that $R_1^2 = a$, a $R_1^2/k^2 = b$, and taking into account that for the same length R_1 of the total vector different arbitrary values of x_1 and z_1 can correspond. Rotation of coordinate system or corresponding rotation of ellipse by a given angle and transfer of initial point of vectors will not basically change anything, but only lead to some difficulties in obtaining the same result.

The analytical form of the model is constantly being improved, sometimes undergoing significant changes. Recently a variant has been presented in which the factor "precipitation" has been replaced by the factor "soil moisture"[4] derived from it. Graphical constructions concerning weather conditions made by A.R. Kon-

[3]Agroecological Atlas of Russia and the Neighboring Countries. Climate, Hydrothermal coefficient for the growing season: [Electronic resource]: URL: http://www.agroatlas.ru/ru/content/Climatic_maps/GTK/GTK/index.html. (accessed 08.04.2020).

[4]Patent No. 2,733,728. Method of estimating the yield of spring wheat depending on weather conditions. Moscow: State Register of Inventions of the Russian Federation, 2020; Bulletin No. 28.

stantinov in the course of experimental studies are in good agreement with the proposed provisions of the model. It gives grounds to expect with high enough probability correspondence of provisions to real natural phenomena and on this basis to use identified properties and peculiarities in the following way. Each phenological phase corresponds to average values of temperature and precipitation factors, which can be calculated using the residual method outlined in the work of A.R. Konstantinov. It should be noted the rationality of combining very short phenological phases with their neighbors because of their probable instability, thus forming interphase periods. Hereinafter, the mean annual interval of the phenological phase and the mean annual interphase period will be referred to as the analyzed interval, which has the value n_i, where i is the number of the measuring interval, according to the number of days included in it. Knowing the duration of the analyzed interval n_i and the average value of the factor, it is easy to go to the following integral values:

$$S_{p_i}^{\text{plant}} = p_{\text{cp}_i} \cdot n_i$$

$$\text{и } S_{p_i}^{\text{plant}} = t_{\text{cp}_i} \cdot n_i.$$

Then, using techniques typical for polar coordinates, we get

$$\text{tg } a_i^{\text{plant}} = S_{p_i}^{\text{plant}} / S_{t_i}^{\text{plant}}$$

and the radial indicator

$$r_i^{\text{plant}} = \sqrt{\left(S_{p_i}^{\text{plant}}\right)^2 + \left(S_{t_i}^{\text{plant}}\right)^2}.$$

Thus, the plant under study has a set of pairs of indicators, which is equal in volume to the number of analyzed intervals.

Then we proceed to the climatic characteristics in terms of temperature and precipitation for the warmed area. We select analyzed intervals corresponding to the selected plant (or plant variety), and calculate complex HTCc for these intervals. Thus, we obtain a set of indicators similar to the first set for the plant under study. On the one hand, we establish plant requirements to climatic factors, which provide the maximum possible level of plant development, on the other hand, we obtain real climatic conditions in the form of similar indices, represented by complex HTCc. According to the closeness of the data in the sets, the level of plant propagation favorability (from climatic positions) is evaluated. It is estimated on the basis of the mean-square criterion of closeness of the sets or more simple variants are applied: for example, the maximum level of favorability is recognized if the average level of deviation module in the sets does not exceed 12% and the maximum deviation is less than 26% (when deviations are measured in percentages), etc.

CONCLUSION

The hydrothermal coefficient (HTC) of G.T. Selyaninov has been improved. A complex HTCc, represented by tangential (HTCt) and radial (HTCr) components, has been obtained. The new HTCc allows obtaining more detailed and complete information on the climatic situation of the territory, which is demonstrated by large- and small-scale graphical constructions. In fact, the complex HTCc compared to the previous variant allows increasing the volume of obtained information about the studied territory by about 2 times. As a variant of more complex application of HTCc, the study of the progression of a particular plant to new territories in the case of climate warming is presented. In addition, in the future we can expect with great probability the application of HTCc in breeding (to reduce the duration of the breeding process in crop production), farming (to reduce costs when solving land typing problems) and some other directions.

СПИСОК ЛИТЕРАТУРЫ

1. *Лачуга Ю.Ф.* Сельскохозяйственному производству – новые знания // Сельскохозяйственные машины и технологии. 2011. № 3. С. 3–8.
2. *Арефьев Н.В., Бреусов В.П., Осипов Г.К.* Основы формирования природно-аграрных систем. Теория и практика: монография. СПб.: Издательство Политехнического университета, 2011. 532 с.

3. Научные основы производства высококачественного зерна пшеницы / под ред. В.Ф. Федоренко, А.А. Завалина, Н.З. Милащенко: монография. М.: Росинформагротех. 2018. 396 с.
4. *Конишев А.А.* Прошлое и будущее обработки почвы под зерновые культуры // Аграрный вестник Урала. 2020. № 3 (194). С. 21–27.
5. *Сиптиц С.О., Романенко И.А., Евдокимова Н.Е.* Размещение аграрного производства как механизм адаптации к климатическим изменениям // Экономика сельского хозяйства России. 2018. № 5. С. 71–76.
6. *Булгаков Д.С., Рухович Д.И., Шишкова Е.А.* Использование почвенно-климатического индекса при оценке агрономического потенциала пахотных земель в лесостепной зоне России // Почвоведение. 2018. № 4. С. 473–485.
7. *Иванько Я.М., Полковская М.Н.* Оптимизация структуры посевов с учетом изменчивости климатических параметров и биопродуктивности культур: монография. Иркутск: Издательство Иркутского государственного аграрного университета, 2016. 150 с.
8. *Асалханов П.Г., Иваньо Я.М.* Прогнозирование и планирование агротехнологических операций для природно-климатических зон региона: монография. Иркутск: Издательство Иркутского государственного аграрного университета, 2014. 144 с.
9. *Якушев В.П., Михайленко И.М., Драгавцев В.А.* Агротехнологические и селекционные резервы повышения урожаев зерновых культур России // Сельскохозяйственная биология. 2015. Т. 50. № 5. С. 550–560.
10. *Кирюшин В.К., Власенко А.Н., Каличкин В.К., Власенко Н.Г., Филимонов Ю.П., Иодко Л.Н., Шарков И.Н., Тарасов А.С., Понько В.А., Южаков А.И., Хмелев В.А., Семендяева Н.В., Киншт А.В., Синещеков В.Е., Новиков В.М., Шоба В.Н., Кожевников А.И., Усолкин В.Т., Добротворская Н.И., Ким С.А., Солосич Н.А., Филимонова Л.Н., Коняева Н.М., Полухин Н.И.* Адаптивно-ландшафтные системы земледелия Новосибирской области: монография. Новосибирск: Издательство СО РАСХН, 2002. 387 с.

REFERENCES

1. Lachuga Yu.F. New knowledge for agricultural production. *Sel'skokhozyaistvennye mashiny i tekhnologii = Agricultural Machinery and Technologies,* 2011, no. 3, pp. 3–8. (In Russian).
2. Aref'ev N.V., Breusov V.P., Osipov G.K. Fundamentals of formation of natural-agrarian systems. Theory and practice. St. Petersburg, *Izdatel'stvo Politekhnicheskogo universiteta = Polytechnic University Press,* 2011, 532 p. (In Russian).
3. Fedorenko V.F., Zavalina A.A., Milashchenko N.Z. Scientific basis for the production of high-quality wheat grain. Moscow, Rosinformagrotekh Publ, 2018, 396 p. (In Russian).
4. Konishev A.A. Past and future for tillage for grain crops. *Agrarnyi vestnik Urala = Agrarian Bulletin of the Urals,* 2020, no. 3 (194), pp. 21–27. (In Russian).
5. Siptits C.O., Romanenko I.A., Evdokimova N.E. Allocation of agrarian products as a mechanism of adaptation to climate changes. *Ekonomika sel'skogo khozyaistva Rossii = Economics of Agriculture of Russia*, 2018, no. 5, pp. 71–76. (In Russian).
6. Bulgakov D.S., Rukhovich D.I., Shickova E.A. The application of soil-agroclimatic index for assessing the agronomic potential of arable lands in the forest-steppe zone of Russia. *Pochvovedenie = Eurasian Soil Science,* 2018, no. 4, pp. 473–485. (In Russian).
7. Ivan'ko Ya.M., Polkovskaya M.N. *Optimization of cropping pattern taking into account variability of climatic parameters and bioproductivity of crops:* Irkutsk, Izdatel'stvo Irkutskogo gosudarstvennogo agrarnogo universiteta = Publishing House of Irkutsk State Agrarian University, 2016, 150 p. (In Russian).
8. Asalkhanov P.G., Ivan'o Ya.M. *Forecasting and planning of agrotechnological operations for natural and climatic zones of the region:* Irkutsk, Izdatel'stvo Irkutskogo gosudarstvennogo agrarnogo universiteta = Publishing House of Irkutsk State Agrarian University, 2014, 144 p. (In Russian).
9. Yakushev V.P., Mikhailenko I.M., Dragavtsev V.A. Reserves of agro-technologies and breeding for cereal yield increasing in the Russian Federation. *Sel'skokhozyaistvennaya biologiya = Agricultural biology*, 2015, vol. 50, no. 5, pp. 550–560. (In Russian).
10. Kiryushin V.K., Vlasenko A.N., Kalichkin V.K., Vlasenko N.G., Filimonov Yu.P., Iodko L.N., Sharkov I.N., Tarasov A.S., Pon'ko V.A., Yuzhakov A.I., Khmelev V.A., Semendyaeva N.V., Kinsht A.V., Sineshchekov V.E., Novikov V.M., Shoba V.N., Kozhevnikov A.I., Usolkin V.T., Dobrotvorskaya N.I., Kim S.A., Solosich N.A., Filimonova L.N., Konyaeva N.M., Polukhin N.I. *Adaptive Landscape Systems of Farming in the Novosibirsk Region:* Novosibirsk, Izdatel'stvo SO RASKhN = The Publishing House of the Siberian Branch of the Russian Academy of Sciences, 2002, 387 p. (In Russian).

ИНФОРМАЦИЯ ОБ АВТОРЕ

(✉) **Потанин В.Г.,** научный сотрудник; **адрес для переписки:** Россия, 630501, Новосибирская область, р.п. Краснообск, д. 3, кв. 12; e-mail: wgp@ngs.ru

AUTHOR INFORMATION

(✉) **Veniamin G. Potanin,** Researcher associate; **address:** 3–12, Krasnoobsk, Novosibirsk region, 630501, Russia; e-mail: wgp@ngs.ru

Дата поступления статьи / Received by the editors 16.12.2021
Дата принятия к публикации / Accepted for publication 02.03.2022
Дата публикации / Published 25.03.2022

https://doi.org/10.26898/0370-8799-2022-2-12
УДК: 633.85(574.2)(045): 632.3:632.912(045)

Тип статьи: оригинальная
Type of article: original

УРОЖАЙНОСТЬ СЕМЯН РЫЖИКА В ЗАВИСИМОСТИ ОТ ПРИМЕНЕНИЯ РАЗЛИЧНЫХ ПРЕПАРАТОВ И СРОКОВ ПОСЕВА НА СЕВЕРЕ КАЗАХСТАНА

(✉) **Мусынов К.М., Аринов Б.К., Абышева Г.Т.**
Казахский агротехнический университет имени С. Сейфуллина
Нур-Султан, Республика Казахстан
(✉) e-mail: kazeke1963@mail.ru

Представлены результаты полевого опыта по влиянию микробиологических и химических средств защиты растений на продуктивность семян рыжика посевного. Препараты (обработка семян перед посевом произведена Экстрасолом, по вегетации – инсектицидом Протеус и фунгицидом Пиктор) изучены на фоне разных сроков посева (15–20 мая, 25–30 мая). В качестве контроля исследовали вариант без применения препаратов. Полевой опыт закладывали в четырехкратном повторении, площадь делянки 63 м^2. Способ посева – рядовой с нормой высева 6,0 млн всхожих семян/га. Предшественник – 1-я пшеница после пара. Работа проведена в 2018–2020 гг. в условиях Северного Казахстана. Объект изучения – семена, посевы рыжика посевного Исилькулец. Почва участка – чернозем, содержание гумуса – 2,50–3,89%, азота – 30,80–81,20 мг/кг, фосфора – 11–30 мг/кг, калия 620–770 мг/кг. Семена обрабатывали раствором Экстрасола из расчета 2 л (10 л рабочего раствора)/т семян в день посева. Рекомендован оптимальный срок посева рыжика (25–30 мая) и оптимальное сочетание препаратов с обработкой семян и опрыскиванием посевов фунгицидом. Выявлена продолжительность вегетационного периода рыжика в условиях Северного Казахстана, которая составила в среднем 72–81 день. Высокая продуктивность отмечена при применении микробиологического препарата Экстрасол (обработка семян) и опрыскивания посева фунгицидом Пиктор (11,5–16,0 ц/га). Достоверная ($НСР_{05}$ = 0,52) прибавка урожая семян составила 0,77 т/га. Установили, что обильные дожди в период вегетации способствуют развитию и распространению болезней (фузариоз: R = 14,3–21,5% и P = 27,5–86,4%; альтернариоз: R = 14,3–20,6% и P = 25,2–84,3%).

Ключевые слова: рыжик, срок посева, биологические и химические препараты, урожайность семян

CAMELINA SEEDS YIELD DEPENDING ON THE USE OF DIFFERENT PREPARATIONS AND SOWING DATES IN THE NORTH OF KAZAKHSTAN

(✉) **Mussynov K.M., Arinov B.K., Abysheva G.T.**
Saken Seifullin Kazakh Agrotechnical University
Nur-Sultan, Kazakhstan
(✉) e-mail: kazeke1963@mail.ru

The results of a field experiment on the effect of microbiological and chemical plant protection agents on the productivity of camelina seeds are presented. The preparations (seed treatment before sowing was made with Extrasol, during vegetation - with insecticide Proteus and fungicide Pictor) were studied against the background of different sowing dates (15-20 May; 25-30 May). As a control, the version without the use of drugs was investigated. The field experiment was laid in quadruple repetition, the plot area was 63 m^2. The seeding method is row seeding with a seeding

rate of 6.0 million germinating seeds/ha. The forecrop is the 1st wheat after fallow. The work was carried out in 2018-2020 in the conditions of Northern Kazakhstan. The object of the study are the seeds and plantings of camelina Isilkulets variety. The soil of the site is chernozem, humus content - 2.50-3.89%, nitrogen - 30.80-81.20 mg/kg, phosphorus - 11-30 mg/kg, potassium 620-770 mg/kg. The seeds were treated with Extrasol solution at the rate of 2 l (10 l of working solution)/t of seeds on the day of seeding. The optimal seeding date for camelina (May 25-30) and the optimal combination of preparations with seed treatment and spraying of crops with fungicide are recommended. The duration of the growing season of camelina in the conditions of Northern Kazakhstan was revealed, which averaged 72-81 days. High productivity was noted with the microbiological preparation Extrasol (seed treatment) and spraying of crops with fungicide Pictor (11.5-16.0 c/ha). A significant (LSD_{05} = 0.52) increase in seed yield was 0.77 t/ha. It was found that abundant rains during the growing season contribute to increased development and spread of diseases (fusariosis: R = 14.3-21.5% and P = 27.5-86.4%; alternariosis: R = 14.3-20.6% and P = 25.2-84.3%).

Keywords: Camelina, sowing time, biological and chemical preparations, seed yield

Для цитирования: *Мусынов К.М., Аринов Б.К., Абышева Г.Т.* Урожайность семян рыжика в зависимости от применения различных препаратов и сроков посева на севере Казахстана // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 2. С. 105–112. https://doi.org/10.26898/0370-8799-2022-2-12. EDN TREPBW.

For citation: Mussynov K.M., Arinov B.K., Abysheva G.T. Camelina seeds yield depending on the use of different preparations and sowing dates in the north of Kazakhstan. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 2, pp. 105–112. https://doi.org/10.26898/0370-8799-2022-2-12. EDN TREPBW.

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

INTRODUCTION

Currently, there is a steady trend of expansion of sowing and production of oilseeds in Kazakhstan [1]. Cabbage crops occupy one of the leading positions in the world production of oilseeds. They successfully combine large potential yield with high content of oil and protein in seeds and provide a real opportunity for more rational use of plant resources due to enrichment of assortment of used species. Oilseeds production is one of the components of the agricultural industry, which provides industry with raw materials, and livestock - with fodder. The value of oilseeds is determined by the versatility of their use in the food industry, in agriculture and as a biofuel [2].

The promising oil-bearing crop camelina arouses great interest among agricultural producers. It successfully combines a high potential seed yield (up to 2.0 t/ha) with a high content of drying oil (36-40%) and protein (25-30%). Among the priority indicators of the quality of camelina seeds is the content of oil and protein. Studies by various authors have shown that the oil content in the seeds is about 40%, protein content is 30% [3].

Camelina is drought-resistant, with a growing season of 65-90 days, depending on the region of cultivation. It is undemanding to environmental conditions, has high ecological plasticity and can grow in a wide range of soil and climatic conditions. The plant is a good phytosanitary plant and forecrop for other crops. The early maturity is an important biological advantage of camelina, as it allows to significantly reduce the intensity of harvesting [4-6]. Therefore, the cultivation of camelina for oil seeds in the north of Kazakhstan is relevant.

The purpose of the research is to study the effect of microbiological, chemical preparations and timing of sowing on growth, plant development, spread of diseases and seed yield of camelina in the conditions of Northern Kazakhstan.

MATERIAL AND METHODS

Field experiments were laid in the experimental plot of "Kamenka and D" LLP, located in Sandyktau district of the Akmola region. The object of the research was the camelina variety Isilkulets. The effect of the combined application of biological and

chemical preparations (treatment of seeds with Extrasol before sowing, and by vegetation - with insecticide Proteus and fungicide Pictor), sown against different sowing dates (May 15-20; May 25-30) on the yield of camelina seeds was studied.

Extrasol is a safe preparation of exclusively biological origin, it improves the supply of nutrients to plants, increases seed germination, accelerates plant development, reduces plant infestation by phytopathogenic microorganisms, which significantly increases plant productivity. Pictor is a systemic combined fungicide containing two active substances (boscalid and dimoxystrobin) with different mechanisms of action on a wide range of rapeseed pathogens. Proteus is a new generation insecticide with systemic contact action, destroys pests at all stages of development (from eggs and larvae to the adult stage).

The variant without the use of preparations was used as a control. The seeding method was row seeding with a seeding rate of 6.0 million germinated seeds/ha. The forecrop was the 1st wheat after fallow. Minimum tillage was used in the experiments. No tillage was done after the previous crop and before sowing, the seeding was carried out by SZS-2.1 seeders. Harvesting was carried out by direct combine harvesters (Vector, etc.) in the phase of economic full ripeness, when the lower pods turn brown and the seeds in them harden.

According to the agrochemical survey of the experimental field soil was common chernozem, humus content 2.50-3.89%, nitrogen 30.80-81.20 mg/kg, phosphorus 11-30 mg/kg, potassium 620-770 mg/kg.

The hydrothermal coefficient in the years of research was from 0.75 in 2020 to 1.4 in 2018, the sum of positive temperatures above +10 ° C - 2295 °.

RESULTS AND DISCUSSION

The main limiting factor of yield in the area of experiments is moisture. The climate in the study area is sharply continental. This feature of the climate of Northern Kazakhstan was manifested in all the years of research, significantly affecting the productivity of camelina plants. During the growing season (from May to August inclusive) in 2018, 235 mm of precipitation fell, which amounted to 137% of the average annual rainfall. According to the value of the hydrothermal coefficient, 2018 is characterized as well-wetted (HTC = 1.4). In 2019 for the growing season precipitation was at the level of the norm (154 mm, which is 24 mm below the mean annual amount of precipitation), only in May precipitation was below the norm, in the third ten-day period of July - 3.5 times less than the mean annual rates. According to the value of the hydrothermal coefficient, the year is characterized as dry (HTC = 0.77). In 2020 during the growing season precipitation amounted to 177.5 mm, which was 95% of the average annual amount of precipitation. According to the value of the hydrothermal coefficient 2020 is characterized as dry (HTC = 0.75). Distribution of precipitation during the growing season was uneven. Thus, in 2018 their main amount was in the whole August (102 mm), in 2019 - in the II ten-day period of June, III ten-day periods of July and August (149-232% of the average annual amount of precipitation). The sum of positive temperatures for the growing season 2018 was above the norm, in 2019, 2020 - below the norm by 66-328°.

The onset of the main phenological growth phases of camelina in the years of the study depended on both the studied agricultural practices and the weather conditions (see Table 1).

In the late crops the onset of the interphase periods sowing - sprouting and sprouting - branching took place 1-2 days earlier than in the early crops. The data obtained show that, on average, the duration of the interphase period sowing - sprouting was 7-10 days. This period was characterized by average daily air temperature of 11.7-13.9 °C and the sum of precipitation from 6.3 to 24 mm.

The length of the interphase period sprouting - flowering is one of the main, because at this time there occurs the growth of the vegetative mass. When a certain amount of temperatures is reached, one phase of plant development is replaced by the next [7, 8]. If it took on average

Табл. 1. Даты наступления основных фаз роста и развития рыжика, среднее за 2018–2020 гг.
Table 1. Dates of the main phases of growth and development of camelina, average for 2018-2020

Option	Sprouts	Branching	Flowering	First pod formation	Full ripeness
Sowing dates 15-20 May					
Control	28 May	13 June	29 June	16 July	7 August
Extrasol	26 May	10 June	26 June	13 July	4 August
Extrasol + Pictor	26 May	10 June	26 June	13 July	4 August
Extrasol + Proteus	26 May	10 June	26 June	13 July	4 August
Sowing dates 25–30 May					
Control	6 June	20 June	5 July	20 July	11 August
Extrasol	4 June	18 June	3 July	18 July	8 August
Extrasol + Pictor	4 June	18 June	3 July	18 July	8 August
Extrasol + Proteus	4 June	18 June	3 July	18 July	8 August

61,5-261,8° of the sum of positive temperatures to pass the first period of sowing - sprouting when sowing on May 15-20, the period from sprouting to flowering took on average 347,1-890,1°. As a result, the duration of sprouting - flowering period averaged 28-32 days.

Observations have shown that camelina finishes the interphase period of flowering - full ripeness in 35-40 days, depending on the hydrothermal conditions.

In our studies, the shortest period of flowering - full ripeness was observed in 2019 (with average daily temperature of 19.3 °C and precipitation of 60 mm) and the longest - in 2018 (with temperature of 16.7 °C and 127 mm). This is explained by the fact that high average daily temperatures and lack of moisture lead to a shortening of this period and, conversely, lower temperatures in combination with abundant precipitation contribute to its increase.

Camelina is an early maturing crop. Despite the great role of individual periods of plant growth and development, the duration of the entire growing season is decisive in the economic evaluation of the variety. The growing season is one of the main biological traits in plant breeding and is crucial for high yields. It is one of the means of plant adaptation to habitat conditions, which is determined by genetic characteristics and the totality of the environment [9].

On average, the growing season of camelina was 75-81 days. At the sowing date of May 15-20, this figure was 5-6 days shorter than at sowing on May 25-30. The longest vegetation period of camelina (89-102 days) was observed in 2018 under relatively cool and rainy weather (HTC = 1.4). In 2019, under dry conditions, the duration of the growing season of camelina decreased to 64-67 days (HTC = 0.77). The duration of the growing season as a whole and the individual interphase periods of development of camelina plants depended on the varietal characteristics and growing conditions (see Table 2).

Under conditions of excess moisture and low air temperature, the duration of the growing season increases and, conversely, under conditions of drought, the period from sprouting to maturity decreases sharply. Observations suggest that camelina has a relatively short growing season, which is one of the main positive biological qualities of the crop. Thanks to this property, the development of culture occurs in the best conditions for the provision of moisture. It ripens much earlier than other crops.

Over the years of research, the duration of the growing season of the crop was influenced by the use of microbiological preparation, as well as the sowing period. It averaged 72-81 days, at a late sowing date a decrease in this period by 5-6 days was observed.

Phytosanitary condition of crops at any level of agrotechnics is in a certain dependence on climatic conditions of the area and the weather, which is established in the period from seedlings to maturity of seeds. At the same time, especially noticeable influence on this indicator have moisture and heat regime during the growing season. Camelina, unlike other crops of the cabbage family, is practically not infested by pests and not affected by diseases. At a time of constant increases in energy and pesticide prices this makes it possible to significantly reduce the level of costs for its cultivation. Infestation of culture by various fungal diseases directly depends on climatic and weather conditions. In laboratory and field studies, scientists found symptoms of Alternaria and Fusarium infestation. Leaves, stems and pods are affected [10]. Meteorological conditions in the years of research differed from the average annual data, as well as by decade and month as a whole, which made it possible to comprehensively assess the effectiveness of various drugs against the diseases.

In our studies of phytosanitary conditions in camelina crops, the amount of precipitation and temperature regime had a significant impact. Thus, in 2018 weather conditions were favorable for the development of fungi of the genus Fusarium and Alternaria. Reduced average daily air temperature, good soil moisture in the III ten-day periods of May and June, as well as abundant precipitation in the I and II ten-day periods of August contributed to the infestation of camelina plants with diseases.

The combined use of seed treatment and fungicide treatment of crops in the hearted state against Fusariosis and Alternariosis significantly stopped the development and spread of the diseases and kept them in check until the phase of the formation of the first pods. Low precipitation in 2018 (8 mm, or 44% of the mean annual data) with the temperature regime at the level of the long-term average annual also contributed to this. In early August, heavy rains occurred (256% of the mean annual data) and the dynamics of development and spread changed dramatically towards an increase in diseases (Fusariosis: R = 14.3-21.5% and P = 27.5-86.4% Alternariosis: R = 14.3-20.6% and P = 25.2-84.3%). Compared with the control variant, a significant reduction in the development and spread of diseases was observed in the variant with the fungicide Pictor. Weather conditions

Табл. 2. Продолжительность основных межфазных периодов роста и развития рыжика, среднее за 2018–2020 гг., день

Table 2. Duration of the main interphase periods of growth and development of camelina, average for 2018-2020, day

Option	Sowing - sprouting	Sprouts– branching	Branching–flowering	Flowering–full ripeness	Vegetation period
Sowing dates 15-20 May					
Control	10	16	16	39	81
Extrasol	8	15	16	39	77
Extrasol + Pictor	8	15	16	39	77
Extrasol + Proteus	8	15	16	39	77
Sowing dates 25–30 May					
Control	9	14	15	36	75
Extrasol	7	13	15	36	72
Extrasol + Pictor	7	13	15	36	72
Extrasol + Proteus	7	13	15	36	72

in 2019 and 2020 were similar (HTC = 0.77 and 0.75). Thus, in 2019 during the growing season of the crop, little precipitation and a high temperature background were observed, which caused a slow increase in the disease. In such years, the development and spread of diseases decreased in all the growth phases and development of the crop compared to 2018.

The crop yield is determined by its main elements: the number of plants per unit area, productive bushiness, the number of grains per plant and the weight of 1000 seeds. The conditions for their most successful development depend on the temperature and water regimes, availability of mineral nutrients, as well as on technological methods of cultivation.

The yield of camelina in the years of research was significantly influenced by both the prevailing weather conditions during the growing season of the crop, and the timing of the seeds sowing. Camelina yield from the combined use of microbiological and chemical preparations increased in comparison with the variant without their use (see Table 3).

Thus, when dressing the seeds before sowing, the yield of camelina increased at the sowing date of May 15-20 compared with the control variant by 2.8 c/ha, and with additional spraying of crops with fungicides - by 3.8 c/ha and insecticides by 1.2 c/ha. A similar pattern was found in the variant with the sowing date of May 25-30 and was, respectively, 5.4; 7.7 and 6.5 c/ha.

The yield differed significantly between the early and later sowing dates, at sowing in May 25-30 it varied from 8.3 to 16.0 c/ha, which is by 0.4-4.5 c/ha higher than in the variant with the sowing date of May 15-20. At the same time, sowing of seeds treated with Extrasol and application of fungicide Pictor during the vegetation period of camelina contribute to obtaining higher seed yields than in other variants, regardless of the sowing dates.

Табл. 3. Влияние применения разных препаратов и сроков посева на урожайность семян рыжика в 2018–2020 гг.

Table 3. Effect of the use of different preparations and seeding dates on the yield of camelina seeds in 2018-2020

Sowing date	Preparation	Yield, c/ha
15–20 May	Control	7,9
	Extrasol	10,5
	Extrasol + Pictor	11,5
	Extrasol + Proteus	9,1
LSD_{05}		0,52
25–30 May	Control	8,3
	Extrasol	13,7
	Extrasol + Pictor	16,0
	Extrasol + Proteus	14,8
LSD_{05}		0,54

CONCLUSIONS

1. As a result of the research it was found that the duration of the growing season of camelina in the conditions of Northern Kazakhstan is 72-81 days. The optimal sowing date of sowing camelina is the III ten-day period of May, which provides the maximum seed yield of 13.7-16.0 c/ha, which is 23-28% higher compared to the earlier sowing date (15-20 May).

2. The optimal efficiency is provided by the combined use of preparations with seed treatment Extrasol and spraying of crops with fungicide Pictor, it contributes to obtaining the yield by 2.4-2.8 c/ha higher than in the variant with the seed dressing before sowing and insecticide Proteus during the growing season. Sowing with dressed seeds and spraying of camelina with fungicides during the vegetation period against diseases increases the yield by 1.4-1.9 times compared to the variant without their application.

3. Over the years, studies have shown that the use of combined treatment of seeds with preparations and seeds with fungicides reduces the development and spread of diseases to the phase of the formation of the first pods.

СПИСОК ЛИТЕРАТУРЫ

1. *Тулькубаева С.А., Васин В.Г.* Формирование урожайности и качество семян ярового рыжика при использовании регуляторов роста // Известия Самарской государственной сельскохозяйственной академии. 2017. № 2. С. 3–7.

2. *Кузнецова Г.Н., Лошкомойников И.А., Кривошлыков К.М.* Экономическая эффективность возделывания масличных культур в Омской области // Масличные культуры. 2021. Вып. 3 (187). С. 53–57.
3. *Конькова Н.Г., Малышев Л.Л., Асфандиярова М.Ш.* Исходный материал для селекции ярового рыжика (*Camelina sativa* (L.) Crantz.) в условиях Астраханской области // Масличные культуры. 2020. Вып. 3 (183). С. 75–83.
4. *Кузнецова Г., Полякова Р.* Сурепица и рыжик – скороспелые масличные культуры // Международный сельскохозяйственный журнал. 2017. № 3. С. 44–46.
5. *Шевцова Л.П., Шьюрова Н.А., Каленюк А.В.* Агробиологические особенности и продуктивность традиционных и редких видов масличных культур в засушливом Поволжье // Нива Поволжья. 2008. № 4 (9). С. 36–39.
6. *Аринов К.К., Мусынов К.М., Апушев А.К., Серекпаев Н.А., Шестакова Н.А., Арыстангулов С.С.* Растениеводство: монография. Алматы: Ассоциация вузов МОН РК, 2011. 631 с.
7. *Семенова Е.Ф., Буянкин В.И., Тарасов А.С.* Масличный рыжик: биология, технология, эффективность: монография. Волгоград: Изд-во ВолГУ, 2007. 78 с.
8. *Прахова Т.Я.* Рыжик посевной (*Camelina sativa* (L.) Grantz): монография. Пенза: РИОПГСХА, 2013. 209 с.
9. *Вавилов Н.И.* Ботанико-географические основы селекции (Учение об исходном материале в селекции): монография. М.: Колос, 1966. С.176–225.
10. *Zahoor Ahmad Mir, Sajad Ali, Shivaraj S.M., Javaid Akhter Bhat, Apekshita Singh, Prashant Yadav, Sandhya Rawat, Pradeep K. Paplao, Anita Grover.* Genome-wide identification and characterization of Chitinase gene family in Brassica juncea and Camelina sativa in response to Alternaria brassicae // Genomics. 2020. Т. 112. № 1. С. 749–763.

REFERENCES

1. Tul'kubaeva S.A., Vasin V.G. Crop capacity forming and spring false flax seeds quality by use of growth regulators. *Izvestiya Samarskoj gosudarstvennoj sel'skohozyajstvennoj akademii = Bulletin Samara State Agricultural Academy,* 2017, no. 2, pp. 3–7. (In Russian).
2. Kuznecova G.N., Loshkomojnikov I.A., Krivoshlykov K.M. Economic efficiency of cultivation of oil crops in the Omsk region. *Maslichnye kul'tury = Oil crops*, 2021, is. 3 (187), pp. 53–57. (In Russian).
3. Kon'kova N.G., Malyshev L.L., Asfandiyarova M.SH. Germplasm material for false flax (*Camelina sativa* (L.) Crantz.) breeding in the conditions of the Astrakhan region. *Maslichnye kul'tury = Oil crops,* 2020, is. 3 (183), pp. 75–83. (In Russian).
4. Kuznecova G., Polyakova R. Barbarea and camelina – early maturing oilseeds. *Mezhdunarodnyy sel'skokhozyaystvennyy zhurnal = International Agricultural Journal, 2*017, no. 3, pp. 44–46 (In Russian).
5. Shevtsova L.P., Sh'yurova N.A., Kalenyuk A.V. Agrobiological features and productivity of traditional and rare types of oilseeds in the arid Volga region. *Niva Povolzh'ya = Volga Region Farmland*, 2008, no. 4 (9), pp. 36–39. (In Russian).
6. Arinov K.K., Musynov K.M., Apushev A.K., Serekpaev N.A., Shestakova N.A., Arystangulov S.S. *Plant growing.* Almaty, Association of Universities of the Ministry of Education and Science of the Republic of Kazakhstan Publ., 2011, 631 p. (In Russian).
7. Semenova E.F., Buyankin V.I., Tarasov A.S. *Oil camelina: biology, technology, efficiency.* Volgograd, VolGU Publishing House, 2007, 78 p. (In Russian).
8. Prakhova T.Ya. *Sowing mushroom (Camelina sativa* (L.) *Grantz).* Penza, RIOPGSKhA Publ., 2013, 209 p. (In Russian).
9. Vavilov N.I. *Botanical and geographical bases of breeding (The doctrine of the source material in breeding).* Moscow, Kolos, 1966, pp. 176–225. (In Russian).
10. Zahoor Ahmad Mir, Sajad Ali, Shivaraj S.M., Javaid Akhter Bhat, Apekshita Singh, Prashant Yadav, Sandhya Rawat, Pradeep K. Paplao, Anita Grover. Genome-wide identification and characterization of Chitinase gene family in Brassica juncea and Camelina sativa in response to Alternaria brassicae. *Genomics*, 2020, vol. 112, no. 1, pp. 749–763.

ИНФОРМАЦИЯ ОБ АВТОРАХ

(✉) **Мусынов К.М.,** доктор сельскохозяйственных наук, профессор; **адрес для переписки:** Республика Казахстан, 010011, г. Нур-Султан, пр. Женис, 62; e-mail: kazeke1963@mail.ru

Аринов Б.К., кандидат сельскохозяйственных наук, ассоциированный профессор

Абышева Г.Т., магистр наук, ассистент

AUTHOR INFORMATION

(✉) **Kazhimurat M. Mussynov,** Doctor of Science in Agriculture, Professor**; address:** 62, Pobedy ave., Nur-Sultan, 010011, Republic of Kazakhstan; e-mail: kazeke1963@mail.ru

Bauyrzhan K. Arinov, Candidate of Science in Agriculture, Associate Professor

Gaukhartas T. Abysheva, Master of Science, Assistant

Дата поступления статьи / Received by the editors 24.11.2021
Дата принятия к публикации / Accepted for publication 15.03.2022
Дата публикации / Published 25.05.2022

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.

РЕКОМЕНДАЦИИ АВТОРУ ДО ПОДАЧИ СТАТЬИ

Представление статьи в журнал «Сибирский вестник сельскохозяйственной науки» подразумевает, что:

- статья ранее не была опубликована в другом журнале;
- статья не находится на рассмотрении в другом журнале;
- все соавторы согласны с публикацией текущей версии статьи.

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, 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 отзыва статьи. 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:

- на сайте Почта России. Зайти в раздел «Онлайн-сервисы», затем – «Подписаться на газету или журнал». Подписной индекс издания ПМ401;
- в агентстве подписки ГК «Урал-Пресс» по индексу 46808. Ссылка на издание http://ural-press.ru/catalog/97210/8656935/?sphrase_id=319094. 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.