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**BRUCELLOSIS IN SAIGA ANTELOPES (SAIGA TATARICA)
IN KAZAKHSTAN AMID POPULATION RECOVERY: RETROSPECTIVE DATA
AND A ONE HEALTH RISK-BASED APPROACH**

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*Brucellosis remains one of the key zoonotic infections of veterinary, epidemiological and socio-economic importance for Kazakhstan. With the rapid recovery of the saiga antelope (Saiga tatarica) population to more than 4 million individuals, the need is increasing for scientifically grounded monitoring of infections common to wild and farm animals. The purpose of this study was to summarize previously partially published data from experimental and field studies of brucellosis in saigas conducted at KazRVI in 2000–2004, to compare them with the results of diagnostic monitoring in 2023, and to relate them to current epizootiological challenges. The retrospective component of the study included examination of blood sera from 704 free-ranging saigas, 145 newborn saiga calves, 25 clinically healthy calves kept in a stationary facility, and experimental infection of 9 saigas with virulent strains *B. melitensis* 565 and *B. abortus* 54. The current 2023 monitoring covered 20 saigas and 159 biological-material samples. It was established that the saiga is susceptible to *B. melitensis* and *B. abortus*; the serological response developed in a regular pattern, with earlier appearance of agglutinins and later formation of complement-fixing antibodies. *Brucella* cultures isolated after passage through the saiga organism retained their main morphological, cultural, staining, agglutinable and virulent properties. In 2023, no positive serological or bacteriological results were detected; however, the limited sample size does not exclude the need for regular risk-based surveillance. The obtained data substantiate the inclusion of the saiga in an interdepartmental brucellosis monitoring system in the One Health format.*

Key words: brucellosis, natural focality, One Health, saiga antelope, serological monitoring, veterinary epizootiology.

**ҚАЗАҚСТАНДАҒЫ АҚБӨКЕНДЕРДЕГІ ПОПУЛЯЦИЯНЫҢ ҚАЛПЫНА
КЕЛУ ЖАҒДАЙЫНДАҒЫ БРУЦЕЛЛЕЗ (SAIGA TATARICA): РЕТРОСПЕКТИВТІ ДЕРЕКТЕР ЖӘНЕ
ONE HEALTH ТӘУЕКЕЛГЕ ҚАҒИДАТЫНА НЕГІЗДЕЛГЕН ТӘУЕКЕЛГЕ БАҒДАРЛАНҒАН ТӘСІЛ**

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*Бруцеллез Қазақстан үшін ветеринариялық, эпидемиологиялық және әлеуметтік-экономикалық маңызы бар негізгі зооантропоноздық инфекциялардың бірі болып қалып отыр. Киіктер (Saiga tatarica) санының жылдам қалпына келуі аясында 4 млн-нан астам дараққа дейін жабайы және ауыл шаруашылығы жануарларына ортақ жұқпалы ауруларға ғылыми негізделген мониторинг жүргізу қажеттілігі артуда. Жұмыстың мақсаты – 2000-2004 жылдары ҚазҒЗВИ-де орындалған киіктің бруцеллезін эксперименттік және далалық зерттеудің бұрын толық жарияланбаған материалдарын қорытындылау, оларды 2023 жылғы диагностикалық мониторинг нәтижелерімен және қазіргі заманғы эпизоотологиялық сын-қатерлермен салыстыру. Ретроспективті блок стационарда ұсталған 704 еркін киіктің, 145 жаңа туған киіктің, 25 клиникалық сау киіктің қан сарысуын зерттеуді, сондай-ақ 9 киіктің *B. melitensis* 565 және *B. abortus* 54 вируленттік штаммдарымен эксперименттік зақымдануын қамтыды. 2023 жылғы заманауи мониторинг 20 бас киік пен 159 биологиялық материал сынамасын қамтыды. Киіктің *B. melitensis* және *B. abortus* ауруларына бейім екені анықталды; серология-*

лық жауап агглютининдердің неғұрлым ерте пайда болуымен және комплементті байланыстыратын антиденелердің неғұрлым кеш қалыптасуымен заңды түрде дамыды. Киіктің ағзасы арқылы өткеннен кейін бөлінген *Brucella* дақылдары негізгі морфологиялық, культуральдық, тинкториальдық, агглютинабельді және вируленттік қасиеттерін сақтаған. 2023 жылы оң серологиялық және бактериологиялық нәтижелер анықталған жоқ, алайда іріктеменің шектеулі көлемі тұрақты тәуекелге бағдарланған қадағалау қажеттілігін жоққа шығармайды. Алынған деректер киіктерді бруцеллездің ведомствоаралық мониторингі жүйесіне One Health форматында қосуды негіздейді.

Түйінді сөздер: бруцеллез, табиғи ошақ, One Health, сайғақ, серологиялық мониторинг, ветеринариялық індеттану.

БРУЦЕЛЛЕЗ У САЙГАКОВ (*SAIGA TATARICA*) В КАЗАХСТАНЕ НА ФОНЕ ВОССТАНОВЛЕНИЯ ПОПУЛЯЦИИ: РЕТРОСПЕКТИВНЫЕ ДАННЫЕ И РИСК-ОРИЕНТИРОВАННЫЙ ПОДХОД ONE HEALTH

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Бруцеллез остается одной из ключевых зооантропонозных инфекций, имеющих ветеринарное, эпидемиологическое и социально-экономическое значение для Казахстана. На фоне стремительного восстановления численности сайги (*Saiga tatarica*) до более чем 4 млн особей возрастает необходимость научно обоснованного мониторинга инфекций, общих для диких и сельскохозяйственных животных. Цель работы – обобщить ранее полностью не опубликованные материалы экспериментального и полевого изучения бруцеллеза сайги, выполненные в КазНИВИ в 2000-2004 гг., сопоставить их с результатами диагностического мониторинга 2023 г. и современными эпизоотологическими вызовами. Ретроспективный блок включал исследование сывороток крови 704 свободноживущих сайгаков, 145 новорожденных сайгачат, 25 клинически здоровых сайгачат, содержащихся в стационаре, а также экспериментальное заражение 9 сайгаков вирулентными штаммами *B. melitensis* 565 и *B. abortus* 54. Современный мониторинг 2023 г. охватывал 20 голов сайгаков и 159 проб биологического материала. Установлено, что сайга восприимчива к *B. melitensis* и *B. abortus*; серологический ответ развивался закономерно, с более ранним появлением агглютининов и более поздним формированием комплементсвязывающих антител. Культуры *Brucella*, выделенные после прохождения через организм сайги, сохраняли основные морфологические, культуральные, тинкториальные, агглютинабельные и вирулентные свойства. В 2023 г. положительных серологических и бактериологических результатов не выявлено, однако ограниченный объем выборки не исключает необходимости регулярного риск-ориентированного надзора. Полученные данные обосновывают включение сайги в систему межведомственного мониторинга бруцеллеза в формате One Health.

Ключевые слова: бруцеллез, природная очаговость, One Health, сайгак, серологический мониторинг, ветеринарная эпизоотология.

Introduction. Brucellosis is among the most significant zoonotic infections, because it affects a wide range of domestic, wild and laboratory animals, as well as humans. Agents of the genus *Brucella* are able to persist for long periods in the organism of susceptible hosts and to spread through reproductive discharges, biological fluids, aborted material, contaminated pastures and water sources. Therefore, control of brucellosis requires not only laboratory diagnostics in farm herds, but also an understanding of the role of wild fauna in the maintenance and movement of the pathogen [1, p.1].

For Kazakhstan, the problem of brucellosis is especially relevant due to developed pasture livestock farming, seasonal animal migrations, shared use of watering places and pastures, and the persisting probability of contact between domestic ruminants and wild ungulates. Under these conditions, studying the saiga as a mass migratory species has not only zoological, but also applied veterinary and epizootiological importance [2, p. 908].

In recent years, the importance of the saiga in the veterinary-safety system has increased substantially. According to official and open data, after a historical minimum of about 21 thousand individuals in 2003, the number of this species in Kazakhstan increased to 1,915,000 individuals in spring 2023, to 2,833,600 individuals according to the 2024 aerial census, and to more than 4 million individuals according to 2025

reports. Such growth is accompanied by an expansion of animal concentration areas and increases the importance of monitoring infections common to wild and farm animals [3, p. 98; 4, p. 1; 5, p. 1].

The rapid recovery of the saiga population is a major conservation achievement of Kazakhstan. At the same time, a multimillion population of freely migrating animals raises new questions: sanitary assessment of materials obtained during population regulation, safety of contact with domestic livestock, the risk of contamination of pastures and water sources, and the need for interdepartmental monitoring in the One Health format [6, p. 2].

The concept of natural focality of brucellosis in wild animals is not new. Classical studies by M. M. Rementsova showed the presence of natural *Brucella* carriers among the wild fauna of Kazakhstan, including data on the isolation of *Brucella* cultures from saigas and serological reactivity in a part of the examined animals [7, p. 14].

Studies of infections in saigas and domestic animals in Kazakhstan are also of additional importance, since they emphasize the need for an integrated approach to evaluating interspecific epizootiological links [8, p. 1].

The scientific significance of the present article lies in the fact that it combines retrospective experimental material obtained from a unique object, the saiga, with current monitoring data and the present situation of a sharp increase in the number of the species. This approach makes it possible to consider the previously obtained results not as an archival fragment of a dissertation, but as a basis for a modern system of brucellosis surveillance in wild ungulate populations.

Aim and objectives of the study

The aim was to present previously partially published experimental and field materials on brucellosis in saigas, supplement them with the results of 2023 monitoring, and substantiate a modern risk-based approach to veterinary surveillance of this species under conditions of a multimillion population size.

- summarize materials of the retrospective experimental and field study of brucellosis in saigas carried out in 2000–2004;
- evaluate the diagnostic significance of serological and bacteriological methods in the examination of saigas;

- include the results of the 2023 studies covering 20 saigas and 159 biological-material samples;
- update the relevance of the topic taking into account official data on the growth of the saiga population to more than 4 million individuals;

- substantiate proposals for risk-based monitoring of brucellosis in saigas within the One Health system.

Materials and methods

The retrospective block was based on the materials of the doctoral dissertation of Sh. A. Baramova, completed at the Kazakh Research Veterinary Institute in 2000–2004. The analysis included experimental, serological, bacteriological, biological and pathomorphological data obtained during the study of naturally occurring and experimentally infected saigas [9, p. 14].

For experimental reproduction of infection, virulent strains *B. melitensis* 565 and *B. abortus* 54, which had undergone passage through guinea pigs, were used. Saigas were infected by conjunctival, alimentary and subcutaneous routes. Blood sera were examined dynamically on days 2, 4, 7, 14–15, 20, 25 and 28 after infection; after 28 days, bacteriological examination of lymph nodes, parenchymal organs, bone marrow and other materials was performed.

Serological studies were conducted using RBT, AT, PCFT/CFT and ELISA. An AT titer of 1:25, tested in the materials of KazRVI and used in the interpretation of the 2023 monitoring results, was considered diagnostically significant for saiga blood sera. Bacteriological studies were performed according to regulated methods, with inoculation of material onto nutrient media and subsequent identification of the isolated cultures [10, p. 5; 11, p. 5].

The current block included the 2023 internal report of the brucellosis laboratory of KazRVI LLP on the diagnostic examination of saigas from the Ural and Betpakdala populations. The results of serological reactions and bacteriological examination of biological material from saigas (n = 20) were evaluated [12, p. 1].

In 2023, biological materials from saigas (n = 20) originating from West Kazakhstan Region and Dzhangeldy District of Kostanay Region were examined. A total of 159 samples were studied, including serum samples (n = 20), whole-blood samples (n = 20), parenchymal organs, lymph nodes, bone marrow, fetuses, horns and wool. Sera were examined by RBT, AT, CFT and ELISA; the bacteriological block included microscopy of impression smears and inoculation onto nutrient media with observation for up to 30 days [12, p. 1].

Results

Classical materials on wild animals of Kazakhstan show that brucellosis infection can be maintained not only in populations of farm animals, but also among representatives of wild fauna. Data by M. M. Rementsova and subsequent studies indicate the presence of natural *Brucella* carriers capable of preserving the pathogen without rapid death of the host and participating in the maintenance of natural focality [7, p. 14; 8, p. 1].

The results of the authors' own studies in 2000–2004 confirmed the susceptibility of the saiga to *B. melitensis* and *B. abortus* under experimental conditions. Serological, bacteriological and biological data showed that, after the pathogen entered the saiga organism, an infectious process formed, accompanied by the appearance of specific antibodies and the isolation of *Brucella* cultures from organs and lymph nodes [9, p. 14].

Serological reactivity of experimentally infected saigas

Before infection, all experimental saigas of the three experimental groups, as well as control ewes, were examined by RBT, AT and PCFT; negative results were obtained in all cases. This made it possible to consider the subsequent appearance of agglutinating and complement-fixing antibodies as a direct immunological response to the administration of virulent cultures of *Brucella melitensis* 565 and *B. abortus* 54. Dynamic examination of blood sera was performed on days 2, 4, 7, 14–15, 20, 25 and 28 after infection, which made it possible to trace the early and subsequent phases of the serological response in the saiga.

When infection was caused by *B. melitensis* 565, the earliest appearance of agglutinating antibodies was established in animals infected by the conjunctival and subcutaneous routes. As early as day 7, the blood sera of these animals reacted positively in AT and RBT. In the saiga infected by the conjunctival route, the agglutinin titer reached 1:800, and after subcutaneous infection it reached 1:400. In subsequent observation periods, titers in these two animals increased to 1:1600 and remained at a high level on days 20–25, indicating a pronounced immunological reactivity of the saiga organism to *B. melitensis*.

Alimentary infection with *B. melitensis* 565 was accompanied by later development of the serological response. On day 7, AT and RBT remained negative, while the appearance of agglutinins was recorded only on days 14–15 after infection, when the serum reacted at a final dilution of 1:200. Subsequently, the titer gradually increased to 1:400, and serum samples during these periods gave positive results in RBT. This dynamic shows that the oral route of infection in saigas is also capable of leading to the formation of a specific humoral response, but with some delay compared with the conjunctival and subcutaneous routes.

When infection was caused by *B. abortus* 54, serological reactivity developed more slowly and was less pronounced. On days 2, 4 and 7 after infection, AT and RBT results remained negative in animals infected by all three routes. The first agglutinins were recorded approximately on days 14–15: at a titer of 1:100 after conjunctival infection, 1:50 after subcutaneous infection and 1:25 after alimentary infection. On day 20, titers increased further to 1:400, 1:200 and 1:200, respectively, and by days 25–28 serum activity increased by approximately one further dilution.

Comparison of data for the two *Brucella* species shows that *B. melitensis* 565 induced an earlier and more intense agglutination response in the saiga than *B. abortus* 54. This was manifested not only in the earlier appearance of positive reactions, but also in higher terminal titers. The results were especially indicative after conjunctival and subcutaneous infection, where AT titers with *B. melitensis* reached 1:1600, whereas the increase in antibodies with *B. abortus* occurred gradually and within lower limits.

PCFT results confirmed the general pattern of development of brucellosis infection: complement-fixing antibodies appeared later than agglutinins. When infection was caused by *B. melitensis* 565, positive reactions in PCFT began to appear after formation of the agglutination response and reached diagnostically significant titers at later observation periods. When infection was caused by *B. abortus* 54, the appearance of complement-fixing antibodies was recorded mainly from day 20: in animals infected by the subcutaneous and alimentary routes, reactions were recorded at a final dilution of 1:320, and in subcutaneous infection the titer increased to 1:640 by day 28. In conjunctival infection with *B. abortus* 54, complement-fixing antibodies were detected later, from day 25, at a titer of 1:640, which was maintained on day 28.

Thus, the experiment in saigas clearly demonstrated the sequence of serological changes typical of brucellosis infection: earlier appearance of agglutinins and later detection of complement-fixing antibodies. This pattern has practical significance for selecting diagnostic reactions when examining saigas. At early stages of the infectious process, RBT and AT are more informative, whereas PCFT/CFT should be used as an additional reaction to confirm and assess the later phase of the immune response.

Of particular importance is the AT diagnostic titer for saiga blood serum of 1:25 established in the materials of KazRVI, which was also used in the current 2023 studies. Taking into account the biological features of the saiga as a wild migratory animal, the use of a set of serological reactions is a more reliable approach than the use of a single test. The obtained results make it possible to recommend intravital examination of saiga blood sera by RBT and AT with subsequent confirmation by CFT/PCFT and, where conditions permit, by ELISA [9, p. 14; 11, p. 5; 12, p. 1].

The reliability of the experimental data is confirmed by the fact that all animals were serologically negative at baseline, while seroconversion occurred after infection in a regular dependence on the species of pathogen, route of infection and timing of examination. At the same time, interpretation of results in free-ranging saigas requires caution, since under field conditions it is impossible to establish precisely the duration of infection, the pathogen dose and the route of infection. Therefore, detection of antibodies in saigas should be evaluated in combination with epizootiological data, bacteriological results and the nature of contact with domestic animals, pastures and water sources. The comparative characteristics of antibody appearance and maximum titers are presented in Table 1.

The summarized serological data show that the earliest and most intense AT response formed after infection with *B. melitensis* 565, especially after conjunctival and subcutaneous administration of the culture. In all experiments, complement-fixing antibodies appeared later than agglutinins, which is consistent with general patterns of immunogenesis in brucellosis infection.

Table 1 – Comparative characteristics of the timing of appearance and maximum antibody titers in saigas after experimental infection with *Brucella* spp.

Pathogen and route of infection	First positive AT results	Maximum AT titer	First positive PCFT results	Maximum PCFT titer
<i>B. melitensis</i> 565, conjunctival	day 7, 1:800	1:1600 (days 15–25)	day 15, 1:160	1:640 (days 25–28)
<i>B. melitensis</i> 565, subcutaneous	day 7, 1:400	1:1600 (days 15–25)	day 20, 1:320	1:320 (days 20–28)
<i>B. melitensis</i> 565, alimentary	day 15, 1:200	1:400 (days 20–28)	day 20, 1:320	1:640 (days 25–28)
<i>B. abortus</i> 54, conjunctival	day 15, 1:100	1:800 (days 25–28)	day 25, 1:640	1:640 (days 25–28)
<i>B. abortus</i> 54, subcutaneous	day 15, 1:50	1:400 (days 25–28)	day 20, 1:320	1:640 (day 28)
<i>B. abortus</i> 54, alimentary	day 15, 1:25	1:400 (days 25–28)	day 20, 1:320	1:320 (days 20–28)

The graphical presentation of serological data clearly confirms differences in the timing and intensity of the immune response after infection with different *Brucella* species. The most demonstrative finding is the rapid rise of AT titers after *B. melitensis* 565 infection, especially with conjunctival and subcutaneous infection, as well as the more delayed and moderate increase in titers after *B. abortus* 54 infection.

For the article, it is fundamentally important to emphasize that the serological block has not only experimental, but also applied diagnostic significance: it substantiates the possibility of using the standard set of reactions for brucellosis in saigas, while taking into account the species and population characteristics of the wild animal. Therefore, when monitoring saigas, it is advisable to combine screening reactions (RBT, AT) with confirmatory tests (CFT/PCFT, ELISA) and bacteriological examination of pathological material [1, p. 1; 10, p. 5; 11, p. 5].

Bacteriological results and biological properties of cultures

After experimental infection, inoculations from lymph nodes and internal organs were performed in saigas. The isolated cultures were studied according to typical biological characteristics. The dissertation materials indicate that *B. melitensis* 565 and *B. abortus* 54, after passage through the saiga organism, retained their main species properties, including growth characteristics, agglutinability and the S-form of colonies. In saigas infected with *B. melitensis* 565, a larger number of seeded organs was observed, indicating a more pronounced pathogenicity of this *Brucella* species for the saiga organism compared with *B. abortus* 54 [9, p. 14].

The preservation of the biological properties of cultures after passage through the organism of an atypical host is of fundamental importance: it shows that the saiga can be not only an accidentally reacting animal, but also a potential host in whose organism brucellae are able to retain virulent and diagnostically significant traits. This fact strengthens the need for bacteriological confirmation when brucellosis is suspected in wild ungulates, especially in areas of contact with domestic herds unfavorable for brucellosis [1, p. 1; 10, p. 5].

Results of diagnostic monitoring in 2023

In 2023, no positive results were obtained when 20 saiga blood-serum samples were examined by RBT, AT, CFT and ELISA. In RBT, agglutination was absent; in AT, no clearing of the fluid or formation of an agglutinate “umbrella” was observed; in CFT, complete hemolysis was observed, corresponding to a negative reaction. During bacterioscopy of impression smears, *Brucella*-like Gram-negative coccobacilli were not detected; during culture examination on nutrient media for 30 days, no growth characteristic of brucellae was observed [12, p. 1].

The negative results of 2023 are of important practical significance, but they must be interpreted with caution. A sample of 20 animals cannot characterize the entire multimillion saiga population, especially taking into account the spatial heterogeneity of migrations, seasonality, contact with domestic animals and differences among the Ural, Betpakdala and Ustyurt populations. Therefore, the 2023 data should be regarded as a current monitoring cross-section, not as a basis for excluding brucellosis risk in the species as a whole. The results of the 2023 diagnostic examination are summarized in Table 2.

Table 2 – Results of the diagnostic examination of saigas in 2023

Indicator	Material volume	Methods	Result
Blood serum	20 samples	RBT, AT, CFT, ELISA	No positive reactions detected
Whole blood	20 samples	Bacterioscopy/bacteriology	<i>Brucella</i> -like microorganisms not detected

Continuation of Table 1

Organs, lymph nodes, bone marrow, fetuses, horns, wool	159 samples in total, including blood and sera	Impression smears, inoculation onto nutrient media, observation for up to 30 days	Growth of bacteria characteristic of <i>Brucella</i> spp. not detected
General interpretation	20 saigas	Integrated serological and bacteriological block	Signs of brucellosis infection were not established in this sample

Discussion

The experimental results demonstrate biological susceptibility of the saiga rather than proving that free-ranging saigas currently maintain an autonomous reservoir of brucellosis. This distinction is essential. Modern reviews show that the host range of *Brucella* is broader than the traditional livestock associations and that wildlife can participate in either spillover or spillback cycles when ecological contact is sufficient [14, p. 1; 15, p. 1]. In the present study, seroconversion, organ colonization and preservation of the principal phenotypic properties of the isolates after passage provide experimental evidence that infection can develop in the saiga. However, reservoir status would additionally require repeated field detection, evidence of persistence and proof of transmission within the population or across the wildlife-livestock interface.

The sequence of serological reactions has a plausible immunological explanation. Agglutinating antibodies are expected to become detectable during the early humoral response, whereas complement-fixing activity usually becomes more evident after maturation of the antibody response and increasing contribution of immunoglobulin classes capable of efficient complement activation [14, p. 1]. This mechanism is consistent with the earlier positivity of RBT/AT and the delayed PCFT response observed here. It also explains why a single test performed at one time point may miss either an early infection or a later stage with changing antibody profiles; serial or parallel testing is therefore more defensible than reliance on one reaction.

The faster and more intense response after conjunctival and subcutaneous inoculation than after alimentary exposure can be interpreted cautiously in terms of access to susceptible tissues. Conjunctival exposure provides direct contact with mucosa-associated lymphoid tissues, and subcutaneous inoculation bypasses gastrointestinal barriers; oral exposure is affected by dilution, gastric conditions and variable uptake across the intestinal mucosa. These mechanisms could delay systemic antigen presentation after alimentary infection. Likewise, the stronger response and wider organ recovery after *B. melitensis* 565 may reflect differences in strain virulence, inoculum-host interaction and tissue tropism. Because the number of animals in each experimental combination was small and strain and route effects were not factorially separated, these explanations should be regarded as biologically plausible interpretations, not as definitive causal estimates.

The bacteriological findings add information that serology alone cannot provide. *Brucella* is a facultative intracellular pathogen able to survive in cells of the mononuclear phagocyte system; therefore, recovery from lymph nodes and internal organs is consistent with systemic dissemination rather than transient antibody reactivity [14, p. 1]. Preservation of cultural, agglutinable and virulent properties after passage indicates that the saiga organism did not eliminate the diagnostically important phenotype of the strains. At the same time, an experimental infection under controlled exposure cannot by itself quantify the probability of natural transmission, which depends on dose, shedding, environmental survival and frequency of effective contacts.

Interpretation of field monitoring and risk-based sampling

The 2023 results establish absence of detected infection in the examined material, not absence of brucellosis in the national saiga population. If the 20 examined animals were treated as a simple random sample and the diagnostic system as perfect, zero positives would still correspond to an approximate upper 95% binomial prevalence bound of 13.9%. In reality, the animals were not selected through a population-representative design and tests are not perfectly sensitive; therefore, the inference must be narrower. The result is a useful baseline for the sampled places and period, but it does not rule out low-prevalence, focal or seasonally variable infection. This is why population, geographic area, season, age, sex and contact history must be recorded for every sample.

Comparison with recent wildlife studies reinforces this interpretation. A 2024 survey of 312 apparently healthy wild ruminants in Slovenia found no antibodies to *Brucella* spp., yet the authors still emphasized continuous surveillance at the wildlife-livestock interface [16, p. 1]. Conversely, contemporary European data document *Brucella* circulation in selected wildlife hosts and show that risk is spatially heterogeneous rather than uniform across species or territories [15, p. 1; 17, p. 1]. For saigas, this supports stratified sampling focused on migration bottlenecks, shared watering places, livestock grazing overlap, mortality events, reproductive material and animals obtained during population regulation. Horns and wool alone are diagnostically weak matrices; blood, lymph nodes, spleen, liver, bone marrow and reproductive tissues provide a more biologically justified combination. The proposed risk-based algorithm for brucellosis monitoring in saigas is presented in Table 3.

Table 3 – Proposed risk-based algorithm for brucellosis monitoring in saigas

Situation	Material	Methods	Aim
Intravital examination/capture	Blood, blood serum	RBT, AT, CFT/PCFT, ELISA	Detection of seroreactive animals
Planned sampling after shooting/population regulation	Serum, blood, lymph nodes, liver, spleen, bone marrow	Serology, bacterioscopy, culture method and, where possible, PCR	Detection of active or past infection
Mortality, abortions, suspicion of infection	Aborted fetus, uterus/reproductive organs, lymph nodes, parenchymal organs	Bacteriology, PCR, serology using available samples	Confirmation/exclusion of brucellosis and differentiation of causes of mortality
Areas of contact with domestic livestock	Material from saigas and parallel samples from domestic animals	Synchronous serological and bacteriological monitoring	Assessment of interspecific exchange of infection and targeting of preventive measures

One Health, physical transmission pathways and economic implications

An increase in saiga numbers does not mechanically cause brucellosis. The physical mechanism of risk is contact-mediated: overlap of migration routes with livestock pastures and watering places can connect host populations, while infected reproductive discharges, aborted material and contaminated soil or water can provide an indirect pathway through mucous membranes or damaged skin. Recent wildlife and livestock studies similarly identify grazing overlap, reproductive materials and environmental persistence as the critical interface variables [15, p. 1; 17, p. 1; 18, p. 1]. Consequently, population size should be treated as a modifier of encounter opportunities, not as evidence that saigas are an established source of infection.

The economic pathway is also indirect but important. If infection crosses into livestock, losses may arise from abortion, infertility, reduced production, diagnostic testing, vaccination, movement restrictions and compulsory removal of infected animals; Kazakhstan-specific analyses have already documented substantial health and economic burden from brucellosis [19, p. 1]. During saiga population regulation or mortality response, additional costs concern safe sampling, laboratory testing, carcass handling and occupational protection. Recent Kazakhstan data further show persistent gaps between knowledge and risk-related practices among livestock keepers, while international experience supports territorially targeted One Health measures rather than uniform control [13, p. 1; 18, p. 1]. These mechanisms justify an integrated database and synchronized surveillance of saigas, domestic ruminants and environmental risk sites without prematurely labelling the saiga as the principal reservoir.

Study limitations

The main limitation of the research is the retrospective nature of part of the experimental data and the small number of animals used in the experiments, which was due to the biological characteristics of the saiga, the difficulty of keeping it in captivity and the limited availability of material. The 2023 monitoring also covered a limited sample of 20 animals; therefore, negative results cannot be extrapolated to the entire population. At the same time, the combination of experimental, serological, bacteriological and current monitoring data makes it possible to formulate scientifically grounded proposals for subsequent studies.

Practical recommendations

- Include the saiga in regular risk-based monitoring of brucellosis in the territories of the Ural, Betpakdala and Ustyurt populations.
- Conduct parallel monitoring of domestic animals in areas where pastures, watering places and saiga migration routes intersect.
- During shooting, population regulation or mortality events, collect not only horns and wool, but also blood, lymph nodes, liver, spleen, bone marrow and, where available, reproductive material.
- Use a set of serological methods (RBT, AT, CFT/PCFT, ELISA), taking into account the AT diagnostic titer for saigas of 1:25, tested in the materials of KazRVI [9, p. 14; 12, p. 1].
- When infection is suspected, perform bacteriological confirmation and, where technically possible, molecular-genetic identification of *Brucella spp.*
- Create an electronic database of the results of biomaterial examination from saigas, indicating population, region, season, sex, age, sampling method and laboratory-test results.
- Consider veterinary monitoring of the saiga as part of an interdepartmental One Health system that unites nature-conservation, veterinary, medical and agricultural structures.

Conclusion

The array of experimental and field materials of KazRVI, not previously published in full, shows that the saiga is susceptible to *B. melitensis* and *B. abortus*, and that the serological dynamics in experimentally infected animals correspond to the general patterns of brucellosis infection: early appearance of agglutinins and later detection of complement-fixing antibodies.

The 2023 monitoring, which included 20 saigas and 159 biological-material samples, did not reveal serological or bacteriological signs of brucellosis in the examined sample. These results are favorable, but they do not exclude the need to continue regular surveillance, especially in areas of contact between saigas and domestic ruminants and in territories of mass animal concentration.

The current situation requires a transition from episodic studies to standardized risk-based monitoring that combines serological, bacteriological, molecular and epizootiological methods. Taking into account the scale of saiga population recovery, such monitoring should be integrated into an interdepartmental One Health system.

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Ethical aspects

This article does not contain new experimental infections of animals; it is based on retrospective materials from previously completed scientific work and on a diagnostic study of biological material in 2023.

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Conflict of interest: The authors declare no conflict of interest.

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ВЛИЯНИЕ ТЕХНОЛОГИЧЕСКОГО ПРОЦЕССА ВЫРАЩИВАНИЯ НА БЛАГОПОЛУЧИЕ ЖИВОТНЫХ В УСЛОВИЯХ ЗАМКНУТОГО ЦИКЛА ПРОИЗВОДСТВА

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В статье рассматривается проблема управления качеством мясного сырья в рамках замкнутого технологического цикла «выращивание – предубойная выдержка – первичная переработка». Существующие подходы к оценке предубойного стресса часто не учитывают индивидуальную адаптацию у животных, что снижает точность прогнозирования дефектов туш. В ходе исследования на базе предприятий Костанайской области изучена основная динамика ключевых прижизненных биомаркеров – кортизола, лактатдегидрогеназы (ЛДГ) и креатинфосфокиназы (КФК) – в сопоставлении с послеубойным уровнем pH мышечной ткани в процессе автолиза. Установлена прямая связь между интенсивностью антёмортального стресс-ответа и блокированием послеубойного снижения pH говядины. Выбор экспериментальной площадки обеспечил возможность комплексного мониторинга адаптационных особенностей крупного рогатого скота (КРС) мясного скота в условиях открытого содержания, при их выводе из производства и последующем направлении на убой. Экспериментально доказано, что у критически стрессированных животных (группа III) на фоне пиковой концентрации кортизола ($180,70 \pm 3,59$ нмоль/л) к 24 часам после убоя уровень pH фиксируется на аномально высокой отметке $6,32 \pm 0,06$, что обуславливает развитие дефекта DFD в 24% туш. Доказано, что интеграция экспресс-мониторинга биохимических маркеров и замера pH в сквозную систему контроля позволяет предприятиям оперативно выявлять технологические риски и минимизировать экономические убытки.

Ключевые слова: замкнутый цикл, предубойный стресс, качество мяса, кортизол, DFD.

ТҰЙЫҚ ӨНДІРІСТІК ЦИКЛ ЖАҒДАЙЫНДАҒЫ МАЛ ӨСІРУ ТЕХНОЛОГИЯЛЫҚ ПРОЦЕСІНІҢ ЖАНУАРЛАР ӨЛ-АУҚАТЫНА ӨСЕРІ

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Мақалада «өсіру – сою алдындағы ұстау – бастапқы өңдеу» тұйық технологиялық циклі шеңберінде ет шикізатының сапасын басқару мәселесі қарастырылады. Сою алдындағы күйзелісті