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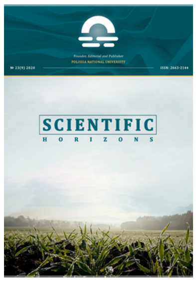

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Regional epidemiology of brucellosis infection in modern conditions of animal husbandry technology in Kazakhstan (by the degree of spread and incidence)

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Abstract. The research relevance is determined by the prevalence and impact of brucellosis in the developing livestock landscape of the Republic of Kazakhstan, which requires immediate assessment to understand the current state due to dynamic changes in animal breeding technologies. The study aims to implement various diagnostic programmes and compare the data obtained with information provided by other organisations. To achieve this goal, the "gold standard" research methods were used,

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a set of classical serological methods, which included the Rose-Bengal test, agglutination reaction, complement binding reaction, enzyme-linked immunosorbent assay, as well as the analysis method and graph analytical method. The results showed that the most infected with brucellosis were epizootic units in Aktobe, Kostanay, Mangistau, Atyrau, Akmola and West Kazakhstan regions, with infection rates exceeding 23.4%. At the same time, Almaty, Turkestan, and Karaganda regions were the least vulnerable, with infection rates not exceeding 3.1%. The largest number of animals with brucellosis was registered in West Kazakhstan Region and the smallest – in Zhambyl Region. This is due to the peculiarities of keeping and geographical locations of the regions of Kazakhstan. Thus, we can classify the situation in Almaty, Pavlodar, Karaganda and Zhambyl regions as class A, as having a low degree of infection. Kostanay, Akmola, Kyzylorda and Atyrau regions are considered to be zones with a medium degree of infection, belonging to class B. In turn, all other regions are characterised by a high degree of infection and are assigned to class C. The practical significance of the study is due to the contribution of valuable information to the scientific understanding of the epidemiology of brucellosis in the Republic of Kazakhstan. The findings provide a basis for the development of targeted intervention strategies and policy recommendations to mitigate the impact of brucellosis on livestock

Keywords: epidemic; regions; diagnostics; statistics; cattle; biotypes

INTRODUCTION

Brucellosis infection poses a serious threat to livestock and human health, resulting in significant economic losses in agriculture and health care costs. In the context of modern livestock production technologies, where highly organised housing systems can facilitate the rapid spread of infection, understanding the current epizootic situation becomes key to effective control and prevention.

A. Shevtsov *et al.* (2023) and A.A. Taipova *et al.* (2023) determined that in modern microbial taxonomy, *Brucella* occupies its place in the domain Bacteria, belonging to the type *Proteobacteria*, class *Alphaproteobacteria*, order *Rhizobiales*, family *Brucellaceae* and genus *Brucella*. This genus includes 12 different species, each characterised by variations in genetic, biochemical, antigenic and virulence traits. *B.suis* – represented by 5 biotypes, main host – pigs, *B. vulpis* (common fox *Vulpesvulpes*), *B. inopinata* (main host not identified), *B. ceti* (cetaceans), *B. neotomae* (desert – bush rats), *B. abortus* – 7 biotypes, main host – cattle, *B. microti* (grey vole), *B. ovis* (sheep), *B. pinnipedialis* (pinnipeds), *B. papionis* (*Papiospp.* baboons), *B. canis* (dogs), *B. meliensis* – represented by 5 biotypes, main host – goats and sheep. This diverse set of Brucella species demonstrates their adaptation to different hosts with different biotypes and characteristics in terms of their ecological niches and relationships with different animal species (Yespembetov *et al.*, 2019).

Some domesticated and free-living wild animals may inadvertently become hosts of Brucella species of epidemiological importance. As noted by N.S. Syrym *et al.* (2019), the brucellosis pathogen exhibits general resistance to environmental factors typical of non-spore-forming bacteria, persisting for long periods in various substrates. In a humid environment at 60°C, the brucellosis pathogen dies in 45 minutes; at 70°C, it dies in 25 minutes; at 75°C, in 15 minutes and instantly at boiling temperature. Dry heat (90-95°C) is fatal to brucellosis after one hour. When exposed to sunlight, brucellae die within a period ranging from a few minutes to 6-9 days, depending on factors such as insolation intensity, atmospheric conditions, and other variables. This resistance to a variety of environmental conditions contributes to the ability of the pathogen to persist and poses challenges to effective eradication measures (Storozhuk *et al.*, 2022).

A. Raushan *et al.* (2023) estimate that Kazakhstan, located in Central Eurasia and a former Soviet republic is among the twenty-five countries in the world with the highest incidence of brucellosis. Despite the implementation of several brucellosis eradication programmes over the past eight decades, epidemiological data for this period are scarce. This deficit makes it difficult to draw definitive conclusions regarding the effectiveness of these measures and the dynamic changes in brucellosis prevalence in both animals and humans over time. In addition, accurate and up-to-date data on specific genotypes of circulating brucellosis strains are lacking, further complicating a comprehensive understanding of the disease situation in the region.

Effective control of brucellosis requires comprehensive planning at the national level. D. Charypkhan and S.R. Rüegg (2022) recommend the promotion of increased cooperation between the veterinary and health sectors, adequate financial resources and health education programmes for health professionals, veterinarians, and the general public. In Kazakhstan, new efforts to control animal brucellosis were initiated in 2001. These efforts were mainly based on a screening and slaughter method involving serological testing to detect asymptomatic cases in livestock, followed by culling of the animals (Korotetsky *et al.*, 2010). However, this approach proved costly and produced unsatisfactory results.

Additions by K. Turgenbayev *et al.* (2023) include the following information: "Alternatively, a transition to a mass vaccination programme for sheep and goats was implemented as of 10 March 2019. Evaluation of the effectiveness of this new programme requires additional time and data analysis". Analysis of primary studies of other authors concludes that there is a lack of accurate data and extensive research in each region and comparison with geographical components in different content systems. Therefore, the study aims to conduct different diagnostic programmes and compare them with the data provided by other frameworks.

MATERIALS AND METHODS

The study, conducted in 2021-2023 in 14 regions of Kazakhstan to investigate the epizootic situation of bovine brucellosis, provides an overview of the number of livestock, including cattle, small cattle, pigs, and horses, in different geographical units such as districts, rural districts (RD), settlements and each epizootological unit (EU) for 2023. According to the data presented in Table 1, there are a total of 2479 rural districts in the Republic of Kazakhstan. Among them, the largest number is observed in Almaty Region with 268 rural districts, while the smallest number is observed in Mangystau Region with 52 rural districts.

***Table 1**. Census of cattle, pigs and horses by region, rural districts, and epizootic foci of the Republic of Kazakhstan for 2023*

Regions	Overall RD number	Counts of EU	Number of animals			
			Cattle	Small cattle	Horses	Pigs
Atyrau	65	384	234,538	729,988	998	112
Akmola	231	1,398	400,106	512,332	160,365	91,819
Mangistau	52	273	23,568	431,425	81,474	64
Kostanay	257	1,199	413,142	410,057	120,477	169,201
Jambyl	155	2,402	432,741	3,000,425	124,011	15,504
Kyzylorda	139	1,786	331,289	626,681	149,551	4,679
Almaty	268	5,550	1,018,467	3,578,598	130,007	8,324
Turkestan	192	2,741	1,001,764	3,989,416	318,255	9,178
Pavlodar	131	2,268	402,342	476,316	154,433	40,652
East Kazakhstan	257	2,512	987,465	1,722,687	335,035	87,728
Aktobe	171	2,497	491,858	987,652	136,026	45,378
North Kazakhstan	201	1,347	349,657	441,842	131,713	140,327
West Kazakhstan	149	3,527	618,427	1,235,611	180,321	18,795
Karaganda	211	4,145	572,984	9,455,743	314,655	89,137
Total in Kazakhstan	2,479	32,029	7,854,528	24,407,622	2,493,193	607,237

***Source:** compiled by the authors based on the Ministry of Agriculture of the Republic of Kazakhstan (2023)*

Identification of Brucella species and biovars in specific regions and foci of infection has important epidemiological significance for categorisation of foci, assessment of the status of the epizootic process and confirmation of cases of Brucella migration between animal species. Differentiation procedures were carried out under the conditions of the brucellosis laboratory of the Kazakh Veterinary Research Institute. The following parameters considered the "gold standard" of Brucella differentiation, were investigated: dependence on elevated carbon dioxide (CO_2) concentrations in the growth medium, ability to generate hydrogen sulphide (H_2S), ability to reduce the activity of dyes such as thionine and basic fuchsin, agglutination potential with monospecific brucellosis sera, including anti-abortion and anti-melitensis sera, and sensitivity to the diagnostic brucellosis bacteriophages Tb, Wb, Fi and Bk2. These criteria are fundamental for the accurate classification of brucellosis strains, allowing a thorough assessment of the epidemiological situation and an understanding of the dynamics of brucellosis transmission among different animal species.

Classical serological methods including the Rose-Bengal test, agglutination reaction, complement binding reaction and enzyme immunoassay were used in the diagnostic study. The Rose-Bengal antigen test was used as the initial screening test, detecting antibodies against Brucella by agglutination with specific antigens. The agglutination test further confirmed and characterised the serological response by observing the accumulation of anti-Brucella antibodies in the serum of infected animals. The complement binding test quantifies antibody levels in serum, providing accurate titres and helping to quantify the immune response. The diagnostic repertoire has been enriched by enzyme-linked immunosorbent assay (ELISA), a sensitive and specific assay that uses antibody-binding enzymes to detect and quantify Brucella-specific antibodies. This multifaceted serological approach has provided a comprehensive assessment of Brucella infection, combining traditional and advanced techniques for a detailed understanding of the immune response.

The evolution of the brucellosis epizootic situation over time has been studied by analysing the data provided and the main epizootic indicators. The risk assessment focused on the prevalence of brucellosis-infected animals in certain areas, using this information to assess the potential impact and severity of the disease in these regions. Most of the data used in this study were obtained from annual official reports that focus on brucellosis, a registered epizootic disease in the Republic of Kazakhstan. To summarise the relevant information, some data were extracted from the official statistical reports of the Veterinary Control and Surveillance Committee and the Ministry of Agriculture. These reports provided information on the absolute number of farm animals that had serological tests positive for brucellosis during the relevant period.

The graph-analytical method involves maps with smaller mapping units and annual data. These maps are vital in identifying 'hot spots' by determining areas that may serve as potential sources of disease spread, as well as 'cold spots' that require in-depth research for disease control. The analysis includes surveillance of regions with increased incidence, assessment of their recovery and identification of new areas susceptible to the disease. This advanced research approach helps to understand the causes of animal brucellosis in the Republic of Kazakhstan, providing valuable information for the development of targeted prevention and control strategies.

RESULTS

Extensive research has established that Brucella species such as *B. melitensis* and *B. suis* are anaerobes. It is worth noting that the initial generations of *B. ovis* and *B. abortus* cultures can only be isolated in a 6-12% carbon dioxide environment. However, with subsequent reseeding, *B. abortus* cultures lose this requirement and feel perfectly well under normal atmospheric conditions. Furthermore, the hydrogen sulphide (H_2S) production capacity varies among Brucella species. Notably, *B. suis* (biotype 1) has the most pronounced ability to produce hydrogen sulphide, whereas *B. neotomae*, and *B. abortus* (biotypes 1-3, 7) show this trait to a lesser extent. These results shed light on the diverse physiological characteristics of different Brucella species, highlighting their ability to adapt to different environmental conditions (Table 2).

Table 2. *Distinctive characteristics of different bacterial species and biological variants of brucellae*

Type	Biotype	Comparison strains	CO_2-dependency	H_2S formation
B. melitensis	I	14-T	-	-
	II	3/15	-	-
	III	Bart	-	-
B. abortus	I	633	(+)	+
	II	91/3/62	(+)	+
	III	Theon	(+)	+
	IV	194	(+)	+
	V	W-4387	-	-
	VI	957	-	(+)
	VII	A-32	-	+
B. suis	I	2,950	-	+
	II	Virat 34	-	-
	III	752	-	-
	IV	39	-	-
	V	483	-	-
B. ovis			+	-
B. canis			-	-

Type	Growth on media with dyes		Agglutination reaction with sera			Sensitivity to bacteriophages				Animal carriers
	Fuchsin	Tionine	R	A	M	Wb	Tb	Bk2	Fi	
B. melitensis	+	+	-	-	+	(-)	-	+	-	Sheep, goats
	+	+	-	+	-	(-)	-	+	-	
	+	+	-	+	+	(-)	-	+	-	
B. abortus	+	-	-	+	-	+	+	+	+	Cattle
	-	-	-	+	-	+	+	+	+	
	+	+	-	+	-	+	+	+	+	
	(+)	-	-	-	+	+	+	+	+	
	+	+	-	-	+	+	+	+	+	
	+	+	-	+	-	+	+	+	+	
	+	+	-	-	+	+	+	+	+	

Table 2. Continued

Type	Growth on media with dyes		Agglutination reaction with sera			Sensitivity to bacteriophages				Animal carriers
	Fuchsin	Tionine	R	A	M	Wb	Tb	Bk2	Fi	
B. suis	(-)	+	-	+	-	+	-	±	+	Pigs
	-	+	-	+	-	+	-	±	+	Pigs, rabbits
	+	+	-	+	-	+	-	±	+	Pigs
	(-)	+	-	+	+	+	-	±	+	Reindeer
	-	+	-	-	+	+	-	±	+	Mice rodents
B. ovis	(-)	+	+	-	-	-	-	-	-	Sheep
B. canis	-	+	+	-	-	-	-	-	-	Dogs

Note: *+ – the trait is detected in all representatives; (-) – the trait is absent in most cultures; – the trait is absent in all representatives, ± – the trait is detected in some strains that are not sensitive; (+) – the majority of cultures have this trait*
Source: *compiled by the authors*

Some strains of *B. abortus* (biotype 6) demonstrated hydrogen sulphide generation ability. At the same time, cultures of *B. abortus* (biovar 5), *B. melitensis*, *B. canis*, and *B. ovis* show notable reducing activity against dyes. In particular, cultures of *B. abortus* biotype 1 grow on media containing fuchsin but do not grow on media containing thionine. Conversely, cultures of biotype 1 *B. suis* grow on media containing thionine but show no growth on media containing fuchsin. In contrast, cultures of *B. melitensis* species show growth on media containing both dyes, demonstrating their unique dye staining characteristics.

The agglutination reaction with monospecific (R-, A-, M-) sera varies between Brucella cultures. In addition, agglutination of Brucella cultures with monospecific sera against *melitensis* (M) and against *abortus* (A) depends on the respective biotypes. In the case of cultures of *B. ovis* and *B. canis* as well as other Brucella species and biotypes in the R-form, monospecific antisera are used in the agglutination reaction. In addition, the sensitivity to the brucellosis diagnostic bacteriophages Wb, Tb, Bk2 and Fi varies among brucellosis species. B. abortus is lysed by all four bacteriophages, whereas *B. melitensis* is sensitive only to bacteriophage Bk2. *B. suis* is sensitive to Bk2 and Wb. It is noteworthy that *B. Abortus* and partially *B. suis* are lysed by bacteriophage Fi. However, cultures of *B. ovis* and *B. canis* are resistant and are not lysed by these phages. These observations highlight the diverse and subtle characteristics of different Brucella strains in response to different diagnostic tests and conditions.

According to the data presented in Tables 3 and 4, among 2,479 rural districts, brucellosis-positive animals were detected in 1,634, which is 56.4% of the total. Brucellosis was most prevalent in West Kazakhstan Region, where out of 149 rural districts, brucellosis-positive animals were recorded in 137, or 91.9% of the total. Similarly, a significant prevalence of brucellosis infection among rural districts was observed in Akmola (83.9%), Kyzylorda (70%), East Kazakhstan (75.8%) and North Kazakhstan (75.6%) regions. The obtained data indicate that brucellosis is widespread in some regions, which requires special attention and measures to reduce the spread of the disease among livestock.

Table 3*. Brucellosis incidence and animal infection rates by RD and EU in 2023*

Regions	RD amount	RDs with infected animals/%	EU amount	EUs with infected animals/%
Atyrau	65	38/58.4	384	123/32
Akmola	231	194/83.9	1,398	365/26.1
Mangystau	52	28/53.8	273	67/24.5
Kostanay	257	157/61	1,199	297/24.7
Jambyl	155	102/65.8	2,402	308/12.8
Kyzylorda	139	98/70	1,786	158/8.8
Almaty	268	81/30	5,550	157/2.8
Turkistan	192	113/58.8	2,741	56/2
Pavlodar	131	89/67.9	2,268	361/15.9
East Kazakhstan	257	195/75.8	2,512	409/16.2
Aktobe	171	107/62.5	2,497	1,273/50.9
North Kazakhstan	201	152/75.6	1,347	176/13
West Kazakhstan	149	137/91.9	3,527	827/23.4
Karaganda	211	68/32.2	4,145	129/3.1
Total	**2,479**	**1,634/56.4**	**32,029**	**4,976/17.4**

Source: *ccompiled by the authors*

Table 4. *Number of infected animals by species*

Regions	Cattle		Small cattle		Pigs		Horses	
	Total	Infected/%	Total	Infected/%	Total	Infected/%	Total	Infected/%
Atyrau	175,905	1,327/0.7	44,453	468/0.1	34,024	312/0.9	1,196	3/0.02
Akmola	300,080	1,422/0.5	549,836	1,976/0.3	80	4/5	372	0
Mangystau	17,676	521/2.9	329,173	399/0.1	30,034	68/0.2	447	0
Kostanay	309,857	1,693/0.5	233,921	108/0.05	50	0	146	0
Jambyl	324,556	398/0.1	2,281,051	1,934/0.08	4,529	18/0.3	770	0
Kyzylorda	248,467	1,224/0.4	2,504,441	2,667/0.1	2,396	5/0.2	14,387	5/0.003
Almaty	763,850	968/0.1	566,449	201/0.03	622	0	620	0
Turkistan	751,323	10,512/1.3	3,237,266	1,097/0.03	2,461	0	1,221	2/0.1
Pavlodar	301,757	420/0.1	1,856,900	2,237/0.1	2,312	11/0.4	9,265	7/0.007
East Kazakhstan	740,599	4,381/0.6	443,273	694/0.02	22,028	23/0.1	550	0
Aktobe	368,893	3,079/0.8	770,866	1,327/0.1	5,068	0	533	0/0
North Kazakhstan	262,243	4,512/1.7	1,133,192	2,733/0.2	8,546	0	2,272	2/0.008
West Kazakhstan	463,820	8,647/1.8	1,088,723	4,502/0.4	6,133	0	671	1/0.1
Karaganda	429,738	795/0.2	390,325	204/0.005	24,996	37/0.1	552	0
Total	**5,890,896**	**39,899/0.7**	**15,082,168**	**20,547/0.1**	**142,008**	**478/0.3**	**33,001**	**13/0.03**

Source: *compiled by the authors*

On the territory of the Republic of Kazakhstan, 32,029 epizootological units were registered. Of these, in 4,976 epizootological units, or 17.4%, animals positive for brucellosis were detected. The spread of brucellosis is particularly pronounced in some regions. It is noteworthy that the Aktobe Region has the highest prevalence rate: 50.9% of epizootological units were affected, followed by Kostanay Region – 24.7%, Mangistau Region – 24.5%, Atyrau Region – 32%, Akmola Region – 26.1% and West Kazakhstan Region – 23.4%. In 2023, a comprehensive testing of the cattle population of the Republic of Kazakhstan was carried out. A total of 5,890,896 cattle were tested, as a result of which 39,899 cattle, representing only 0.7%, were identified as brucellosis-positive. In parallel, 15,082,168 sheep were tested, of which 20,547 (0.1%) tested positive for brucellosis. Among 142,008 pigs tested, only 478 were positive, representing 0.3%. In addition, 33,001 horses were tested and only 13 (0.03%) tested positive for brucellosis. According to Tables 3 and 4, the highest incidence of brucellosis in cattle was observed in West Kazakhstan (8,647 heads), North Kazakhstan (4,512 heads), East Kazakhstan (4,381 heads) and Turkestan (10,512 heads) regions. On the contrary, Zhambyl (398 heads) and Pavlodar (420 heads) regions registered the smallest number of cattle with brucellosis positive status. Regional analysis of the epizootic situation places Almaty, Pavlodar, Karaganda and Zhambyl regions in class "A" (areas with a low degree of infection) in terms of bovine brucellosis incidence. Kostanay, Akmola, Kyzylorda and Atyrau regions are classified as class "B" (zones with medium degree of infection). Conversely, all other regions have the status of class "C" (zones with a high contamination degree).

According to the data presented in Table 5, the analysis of the results of diagnostic tests shows that in recent years, from 2021 to 2023, Mangistau Region has consistently had the highest level of infestation among cattle. In particular, a rate of 2.3% was recorded in 2021. Subsequently, a slight increase was noted in 2022, where 2.9% of animals had reactions indicative of brucellosis and this indicator remained stable in 2023.

Table 5. *Results of diagnostics of brucellosis of cattle in Kazakhstan: analysis 2021-2023*

Regions	2021			2022			2023		
	Study groups	Pos. reactions	%	Study groups	Pos. reactions	%	Study groups	Pos. reactions	%
Atyrau	204,590	1,454	0.7	188,706	1,440	0.8	175,905	1,327	0.7
Akmola	358,120	1,420	0.3	327,138	1,347	0.4	300,080	1,422	0.5
Mangystau	20,481	487	2.3	187,740	549	2.9	17,676	521	2.9
Kostanay	355,555	2,181	0.6	330,762	1,902	0.6	309,857	1,693	0.5
Jambyl	381,528	389	0.1	349,999	342	0.1	324,556	398	0.1
Kyzylorda	283,457	1,155	0.4	261,761	1,346	0.5	248,467	1,224	0.4
Almaty	886,620	1,117	0.1	808,989	1,084	0.2	763,850	968	0.1
Turkistan	878,755	9,662	1.0	820,754	9,961	1.2	751,323	10,512	1.3
Pavlodar	348,450	359	0.1	323,309	402	0.1	301,757	420	0.1
East Kazakhstan	844,161	5,274	0.6	778,610	4,829	0.6	740,599	4,381	0.6

Table 1. Continued

Regions	2021			2022			2023		
	Study groups	Pos. reactions	%	Study groups	Pos. reactions	%	Study groups	Pos. reactions	%
Aktobe	434,924	2,467	0.5	402,322	2,703	0.7	368,893	3,079	0.8
North Kazakhstan	308,263	4,605	1.4	282,691	4,833	1.7	262,243	4,512	1.7
West Kazakhstan	542,383	9,526	1.7	493,553	8,660	1.8	463,820	8,647	1.8
Karaganda	489,711	935	0.1	455,439	894	0.2	429,738	795	0.2
Total	**6,841,464**	**41,031**	**0.6**	**6,266,917**	**40,292**	**0.5**	**5,890,896**	**39,899**	**0.7**

Note: *Pos. reactions – positive reactions*
Source: *compiled by the authors*

In recent years, West Kazakhstan and North Kazakhstan regions experienced a high incidence of brucellosis in cattle. In West Kazakhstan, incidence rates were 1.7% in 2021, 1.8% in 2022, and 1.8% in 2023. Atyrau Region also had a relatively high incidence of brucellosis in cattle from 2021 to 2023 with relatively stable rates of 0.7%, 0.8% and 0.7%, respectively. On the contrary, in the Zhambyl Region, the situation of cattle brucellosis is more stable, nevertheless, for several years in a row there have been up to 400 positive animals. In Almaty and Pavlodar regions there are single cases, where the incidence of cattle brucellosis does not exceed 0.1% during annual routine diagnostic tests. These differences in brucellosis morbidity highlight the diverse regional dynamics and emphasise the need for targeted measures to control and treat the disease in specific regions. Comparing these data with the physical map of the Republic of Kazakhstan reveals a remarkable observation: cattle and small ruminant breeding is concentrated mainly in hilly and flat areas where arable land development is less prominent (National Atlas of…, 2023).

By studying the atlas maps illustrating the features of Kazakhstani land and Tables 1, 3 and 4, it is possible to estimate the prevalence of the disease in different regions of Kazakhstan. A marked correlation is evident when comparing the table data, which respectively represent the number of cattle and the number of infected cattle. This correlation is more obvious for small ruminants. This means that the farming approach is not strongly tied to the type of animals being farmed. However, an interesting pattern emerges when assessing the incidence of brucellosis in cattle compared to small ruminants. Geographical factors play an important role in this respect, as small ruminants are predominantly reared in mountainous and more arid areas, whereas cattle are reared in the highlands. This conclusion is supported by a similar comparison in the case of cattle and small ruminant livestock (sheep and goats), allowing an assessment of the scale of agricultural activity in the study area. Moreover, these data indicate the perceived presence of natural conditions and economic viability favouring this particular agricultural activity in different regions of Kazakhstan.

Mangystau Region is the least developed in terms of cattle production in comparison with other oblasts. Among other less productive regions, Kyzylorda and Atyrau regions are 10 times ahead of the Mangystau Region ($p \leq 0.05$), and Kostanay and Zhambyl regions surpass it even more significantly. Karaganda, Aktobe, Akmola and West Kazakhstan regions belong to the category of medium producers. The most favourable agricultural conditions are observed in three regions – East Kazakhstan, Almaty, and Turkestan regions – where livestock production is three times higher than in North Kazakhstan oblast ($p < 0.05$). Thus, six regions of Kazakhstan can boast a medium to high level of livestock development, which exceeds the number of less favourable regions. The resulting Pearson correlation coefficients indicate significant associations within the dataset. In particular, there is a strong positive correlation of 0.71 ($p \leq 0.005$) between the total headcount and the number of cases, suggesting that as the total herd size increases, the number of reported cases also increases. In addition, there is a moderate positive correlation of 0.44 ($p < 0.01$) between the total population and the proportion of infected animals, indicating a tendency for a higher proportion of infected animals in areas with larger populations. In addition, a remarkable correlation of 0.91 ($p \leq 0.0001$) was observed between the number of animals and the proportion of infected animals. This finding emphasises that as the number of animals in a given area increases, the probability of brucellosis infection among them increases. These results are consistent with the broader patterns observed in the elevation sector and rainfall map, confirming a consistent trend in the relationship between population factors and brucellosis prevalence.

The prevalence of infected animals is often correlated with herd size. As the number of animals in a herd increases, the number of infected animals increases accordingly. Conversely, this trend may reverse, indicating a potential decrease in the number of infected animals as herd size increases, allowing more attention to be paid to animal health. To effectively capture and visualise this dynamic, it is useful to calculate the percentage of infected animals to total herd size within an administrative unit. This ratio, chosen as a cartographic indicator, indicates disease patterns. A similar analytical approach is valid when comparing data on the number of infested animals with the percentage of the total animal population. It is noteworthy that the data obtained show a strong correlation with maps showing agricultural land, especially areas labelled as pastures. This correlation is important, especially in the Republic of Kazakhstan, where pastures dominate the landscape, emphasising their role in sustainable livestock production.

The increased prevalence of sheep and goat diseases in the south-western regions is primarily due to the proximity to the border with Kyrgyzstan, where there are similarly high levels of animal infections. Poor control at the border checkpoint, combined with shared pastures and evacuation routes, exacerbates the incidence of the disease in these areas. In contrast, addressing the data obtained for the number of hectares of pasture per sheep shows a different trend: a constant pasture size reduces the probability of contracting the disease. This suggests that management and optimisation of pasture allocation can play a key role in mitigating the spread of disease. In addition, factors such as farm size, equipment and transport accessibility can influence disease incidence. Ensuring good sanitation and hygiene, providing adequate water sources, and promoting controlled grazing are additional key elements affecting disease prevalence. The complex interplay of these factors emphasises the multifaceted nature of disease dynamics, which requires an integrated approach to effectively address and manage the associated risks.

DISCUSSION

The study results obtained show a marked correlation between geographical location and the extent of brucellosis infection. The correlation between geographical location and the extent of brucellosis infection was also important. Nevertheless, for greater objectivity and relevance of the data, it is important to compare these figures with similar works by other authors.

A study by M. Pal *et al.* (2020) a study of 131 *B. abortus* strains from animals in two specific regions of Mexico revealed limited genetic diversity, indicated by a TYND-22 genetic diversity index of 0.512. However, the discriminatory power of the study was considered insufficient for reliable epidemiological monitoring, a limitation possibly related to the limited sampling area. To address this limitation, scaling up the study would have entailed expanding both the sampling area and time frame, including samples from repositories dating as far back as 1952. To overcome these limitations, an alternative approach was adopted in Kazakhstan, where more extensive diagnostic methods and statistical analyses were used in a comprehensive study. This approach yielded accurate results in determining the genetic diversity and extent of brucellosis infection throughout the country. The comparative effectiveness of this broader methodology in Kazakhstan highlights the importance of methodological considerations and the need for a thorough approach to provide reliable epidemiological data.

The observations of D. Tulu (2022) and J.M. Blasco *et al.* (2023), show that the main factors contributing to the spread of this disease among animals are the disregard of strict veterinary and sanitary regulations, the shortage of veterinary specialists and the insufficient coverage of diagnostic tests for animals, especially breeding bulls. Other key factors were untimely isolation and transport of sick livestock to slaughter, irregularities related to prophylactic and continuous forced disinfections with inadequate quality control, and sub-optimal housing and proper feeding conditions.

The practice of feeding raw milk and skimmed calf fat to calves was also a major concern for J. Papaparaskevas *et al.* (2023). These animals, which are not identified by commonly accepted standard diagnostic methods, persist in herds as vectors of brucellosis. They are hidden sources of infection, thus supporting the ongoing epizootic process. Addressing these multifaceted issues is crucial for effective control and prevention of brucellosis in animal populations. This information is also very important for the above study; as possible modes of disease transmission are not sufficiently suppressed even under current conditions of animal husbandry technology in the Republic of Kazakhstan.

The main approach to controlling sheep brucellosis in Iran until the early 1990s, as stated by M. Dadar *et al.* (2020), was to test and cull seropositive animals. However, this strategy had limitations as the coverage of the sheep population did not exceed 50%, which consequently had minimal impact on the overall economic situation in the country. Between 1991 and 2003, there was a shift towards brucellosis vaccination using the *B. abortus* R21 vaccine for sheep of all ages, combined with pre-testing and culling of seropositive cattle. This initiative resulted in a significant reduction in the incidence of brucellosis in sheep by 50%.

The additions of R. Al Jindan (2021) are equally important, noting that since 2004, young sheep received the Kov2 vaccine and adults continued to be vaccinated with *the B. abortus* R21 vaccine until 2015. Subsequently, a switch to a single immunisation of young sheep with the Kov2 vaccine was made to coincide with a complex epidemiological scenario where groups of animals of different ages were housed together. This adjustment proved ineffective, leading to a rise in brucellosis incidence between 2015 and 2022, reaching levels equivalent to those observed in 1990. Similar epidemic control methodologies have been applied in Kazakhstan but have also shown variable success in herd recovery.

According to C. Di Bari *et al.* (2022), the prevalence of brucellosis in Venezuela is due to global climate change, in particular general warming, which favours an increase in the incidence of the disease in animals and humans. This phenomenon is aggravated by intensive agricultural development and a lack of compliance with veterinary and sanitary regulations. The uncontrolled movement of infected animals, inadequate indoor hygiene, and the use of semen from untested animals for insemination have contributed to the spread of brucellosis (Busol *et al.*, 2023). This trend is not unique to Venezuela; similar findings were reported for countries such as Brazil, Mexico, Canada, India, Peru, and various Asian countries. Although Kazakhstan is slightly north of these countries, the effects of global warming are also affecting farms in this territory.

Z.G. Liu *et al.* (2020) determined the economic standard of living that forces people to keep farm animals on individual farms unattended. Similar oversight applies to the limited differentiation of pastures where multiple species coexist, favouring cooperative grazing. The relatively modest participation of Central Asian countries in the global division of labour increases unemployment among local populations. As a result, there is a significant share of small private farms characterised by inadequate equipment and a lack of compliance with sanitary norms (Turmagambetova *et al.*, 2017).

Following L. Xu and Y. Deng (2022), these problems are compounded by the impact of unprotected borders and the increased prevalence of animal infections in neighbouring countries, further adding to the complexity of the situation. This complex interplay of economic factors, livestock management practices and regional dynamics emphasises the multifaceted nature of the challenges faced in this context. This indicates that, in addition to Kazakhstan's internal problem with brucellosis infection, this is compounded by the presence of similar situations among its neighbours.

The spread of brucellosis, as observed by K.I. Prahesti *et al.* (2020), is primarily related to economic and geographical factors, which are essentially products of human activities. Contrary to this view, physiographic factors such as climate and weather are believed to have a negligible effect on the incidence of brucellosis due to careful animal care. However, this view overlooks the potential influence of physiographic factors on the type of farming activities that ultimately determine the economic viability of stabling and grazing. This contradiction emphasises the complex interplay between environmental conditions, human habits and wider economic dynamics that influence the prevalence of brucellosis (Koroban *et al.*, 2023). These ideas further emphasise the importance of the above study of the regional epizootiology of brucellosis infection under the current conditions of livestock production technology in the Republic of Kazakhstan.

The study results obtained by A. Shehzad *et al.* (2021) and S.U. Hassan *et al.* (2023) highlighted the significant correlation between total population and number of infected animals, revealing a significant correlation of 0.66 for cows ($p \leq 0.004$) and 0.49 for sheep and goats ($p \leq 0.02$). These results emphasise that regions with a higher prevalence of infection foci have an increased probability of brucellosis. Even though Pakistan has almost twice as many regions favourable for cattle than regions suitable for small ruminants, the correlations of the variables for cattle and small ruminants remain remarkably comparable. The findings from this study prompted S.U. Hassan *et al.* (2023) to advocate a modification of the existing methodology for epidemiological surveillance. The proposed changes include the use of spatial (geographical) analysis techniques to improve the accuracy of disease monitoring. In addition, it is proposed to adapt the cattle and small ruminant breeding process by incorporating additional health guidelines that consider geographical aspects of disease spread. This approach echoes similar observations and correlation values recorded in Kazakhstan. Thus, the recommendations of S.U. Hassan *et al.* (2023) recommendations are valuable for choosing an effective strategy to study and control brucellosis infection, given the similarity of the situations observed in both regions.

According to the statements of S.S.R. Vakamalla *et al.* (2023), established in India at the beginning of the last century, brucellosis has since been reported in almost all states. Numerous publications emphasise the widespread occurrence of brucellosis in the country, affecting various mammalian species including cattle, goats, buffaloes, yaks, camels, horses, and pigs. Five years ago, a nationwide cattle survey revealed that 4% of cattle and 2% of buffaloes in the country were infected with brucellosis. The disease is more common in organised farms (45%) compared to marginal herds (8%), which is primarily due to intensive management practices employed in large livestock enterprises. Data obtained in a study of brucellosis in Kazakhstan regionally confirm the study of colleagues.

CONCLUSIONS

Analysis of data on the prevalence of brucellosis in cattle in the regions of Kazakhstan revealed notable trends emphasising the importance of geographical, climatic, and economic factors in the dynamics of disease incidence. the following key numerical indicators are highlighted based on the information provided. The total number of epizootological units in the Republic of Kazakhstan is 32,029, of which 4,976 (17.4%) were found positive for brucellosis in cattle. In 2023, 5,890,896 cattle were tested, and 39,899 brucellosis cases (0.7%) were detected, and among sheep and goats, out of 15,082,168 tested, 20,547 (0.1%) were positive. Importantly, only 478 out of 142,008 pigs tested (0.3%) tested positive. In 33,001 horses tested, brucellosis was detected in only 13 cases (0.03%).

In the regional context, in the West-Kazakhstan region, 50.9% of epizootological units are affected, in North-Kazakhstan Region – 24.7%, in Akmola Region – 26.1%, in Atyrau Region – 32%, and in Mangistau Region – 24.5%. It is noted that in the Mangistau Region, which is a less developed agricultural region, there is a persistent infection of cattle with brucellosis. Geographical dynamics are also noticeable, with Zhambyl

Region demonstrating a stable and more favourable brucellosis situation. Correlation analyses indicate a relationship between total herd size and the number of brucellosis cases. There is also an influence of herd size on the probability of infection, emphasising the importance of effective herd management. In addition, geographical factors such as pasture availability and climatic patterns have been observed to influence the prevalence of the disease.

Based on these findings, it is reasonable to assume that the adoption of comprehensive measures, including optimisation of herd management, pasture management and sanitary and hygienic practices, could help to reduce the prevalence of brucellosis in different regions of Kazakhstan. Consideration of geographical and climatic specificities in the development of control strategies may also increase the effectiveness of the measures taken. Prospects for further research include genomic analyses for comprehensive strain characterisation, which will provide a better understanding of strain diversity for targeted interventions. Adopting a holistic One Health ("Единое здоровье") approach that integrates human, animal and environmental health data may provide a more complete understanding of disease dynamics, enabling the development of effective control measures.

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CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Крайова епізоотологія бруцельозної інфекції в сучасних умовах технології тваринництва в Республіці Казахстан (за ступенем розповсюдження та рівнем захворюваності)

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Анотація. Актуальність статті обумовлена тим, що в тваринницькому ландшафті Республіки Казахстан, який розвивається, гостра проблема поширеності та впливу бруцельозу вимагає негайної оцінки для розуміння поточного стану, обумовленого динамічними змінами в технологіях розведення тварин. Мета цього дослідження полягає у виконанні різних діагностичних програм і зіставленні отриманих даних з інформацією, наданою іншими організаціями. Для досягнення мети було використано методи дослідження «золотого стандарту», комплекс класичних серологічних методів, до якого входили Роз-Бенгал проба, реакція аглютинації, реакція зв'язування комплементу, імуноферментний аналіз, а також метод аналізу та графоаналітичний метод. Отримані результати продемонстрували, що найзараженішими щодо бруцельозу виявилися епізоотологічні одиниці Актюбінської, Костанайської, Мангістауської, Атирауської, Акмолинської та Західно-Казахстанської областей, показники зараженості яких перевищували 23,4 %. Водночас найменш уразливими були Алматинська, Туркестанська та Карагандинська області, показники яких не перевищували 3,1 %. Найбільша кількість хворих на бруцельоз тварин зареєстрована в Західно-Казахстанській області, а найменша – в Жамбильській. Це пов'язано з особливостями утримання та географічними положеннями регіонів Казахстану. Таким чином, можна віднести ситуацію в Алматинській, Павлодарській, Карагандинській і Жамбилській областях в клас «А», як з низьким ступенем зараження. Костанайська, Акмолинська, Кизилординська і Атирауська області розглядаються як зони із середнім ступенем зараження, відносячись до класу «Б». Своєю чергою, всі інші регіони відзначаються високим ступенем зараження і приписуються класу «С». Практична значущість обумовлюється внесенням цінної інформації в наукове розуміння епідеміології бруцельозу в Республіці Казахстан. Отримані результати слугують підґрунтям для розроблення цільових стратегій втручання та політичних рекомендацій щодо пом'якшення впливу бруцельозу на поголів'я тварин

Ключові слова: епідемія; регіони; діагностика; статистика; велика рогата худоба; біотипи