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Seroprevalence and molecular detection of *Brucella* infection in livestock in the United Arab Emirates

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ABSTRACT

Small ruminants and camels are important livestock species in the United Arab Emirates (UAE), although *Brucella* infection can limit their productivity. This study aimed to investigate the seroprevalence of *Brucella* infection and its associated risk factors in small ruminants and camels in the Emirate of Abu Dhabi. Additionally, seropositive animals were tested for the DNA of *Brucella*. Multispecies competitive enzyme-linked immunosorbent assay (c-ELISA) and multispecies indirect (i-ELISA) were used to test 3,086 animals from 2022 to 2023. *Brucella* cell surface 31 kDa protein (bcsp31) gene-based real-time polymerase chain reaction (q-PCR) was used to detect *Brucella* DNA. Multivariate logistic regression was used to assess the association between seroprevalence and potential risk factors. The overall seroprevalences of *Brucella* infection were 1.7% (95% confidence interval [CI], 1.2%–2.2%) and 5.8% (95% CI, 5.0%–6.7%) based on serial and parallel testing, respectively. The DNA of *Brucella* was detected in 13 of the 51 seropositive animals. The overall seroprevalence of *Brucella* infection was associated with the region, type of animal holding, species, and age of the animals. In conclusion, this study documented *Brucella* infection in small ruminants and camels in the Emirate of Abu Dhabi, warranting necessary intervention strategies to eliminate *Brucella* infections in livestock populations.

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1. Introduction

Brucellosis is a bacterial disease in animals and humans caused by different species of *Brucella* and is characterized by bacteraemia following infection [1]. The most common *Brucella* species which cause brucellosis in animal are *Brucella abortus* (*B. abortus*), *B. melitensis* and *B. suis* [2]. *B. abortus* is the major cause of brucellosis in cattle while *B. melitensis* is the main causative agent of brucellosis in sheep and goats. Pigs are infected with *B. suis* biovars 1–3 while camels are infected with *B. melitensis* and *B. abortus* [2].

Bucella infection in animals causes abortion, infertility, and retained placenta in female animals while it causes orchitis and epididymitis in male animals. Furthermore, *B. abortus*, *B. melitensis* and *B. suis* are highly pathogenic to humans [2]. Humans acquire infection through the oral, respiratory, or conjunctival routes [1,2]. The infection causes acute febrile illness, which could progresses to a more chronic form affecting the musculoskeletal, cardiovascular, and central nervous systems [2,3]. Ingestion of raw milk products constitutes the main risk to the general public while there is an occupational risk to veterinarians, abattoir workers and farmers [2,3].

Although the disease has been controlled in Europe, the United States of America (USA), Australia, and New Zealand, it is still responsible for

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significant economic losses and public health impacts in the Middle East, central and southwest Asian countries, sub-Saharan Africa, Latin America ,the Caribbean countries, and the Mediterranean region [1,2]. Unfortunately, *Brucella* infection is also re-emerging in countries where it has been controlled for 50 years because of wildlife reservoirs, changes in ecosystems owing to changing climatic and geographic conditions, increased human-assisted movement of animals, increased frequency of travel, wildlife-associated microbes entering intensive livestock-based agricultural systems, and genetic changes or mutations in the pathogens themselves [3].

Thus, *Brucella* infection is a bottleneck in animal production in various endemic countries. A review published on the economic loss caused by brucellosis in animals indicated an average economic loss of 6%–10% per animal [1]. Regarding the zoonotic burden of *Brucella* infection, it is estimated that >500,000 new human cases of brucellosis are occured annually worldwide [4]. The highest incidence of human brucellosis occurs in Middle Eastern countries [4,5]. According to a previous study [4], the incidence of human brucellosis in the United Arab Emirates (UAE) is estimated to be 41 cases per million people per year.

The UAE livestock industry is largely based on raising dairy cattle, dromedary camels, and small ruminants. These livestock species are among the primary risk groups for *Brucella* infection owing to their susceptibility to the *Brucella* species and intensive husbandry practices. Thus, *Brucella* infections in the UAE are regularly reported to the World Organisation for Animal Health (WOAH) [6]. However, comprehensive epidemiological data regarding the status of *Brucella* infections in small ruminants and camels in the UAE is lacking. Therefore, this study aimed to investigate the seroprevalence and associated risk factors of *Brucella* infection in small ruminants and dromedary camels in the Emirate of Abu Dhabi, UAE. Seropositive animals were further tested for the DNA of *Brucella* using real-time polymerase chain reaction (qPCR).

2. Materials and methods

2.1. Description of the study area

This study was conducted in the Emirate of Abu Dhabi, which is one of the seven Emirates of the UAE. According to the WOAH, livestock production has increased sharply in the UAE in recent years [7]. The Emirate of Abu Dhabi represents 87% of the mainland area of the UAE [7] and is divided into three regions: Abu Dhabi, Eastern, and Al-Dhafra (Figure 1). The climate of the UAE, reflecting that of the Emirate of Abu Dhabi, is arid, with very high summer temperatures from June to September. The coastal area has a hot and humid climate in the summer, with the temperature and relative humidity reaching 46°C and 100%, respectively [7]. Winter temperatures, from December to March, range between 14°C and 23°C, while the mean annual rainfall is about

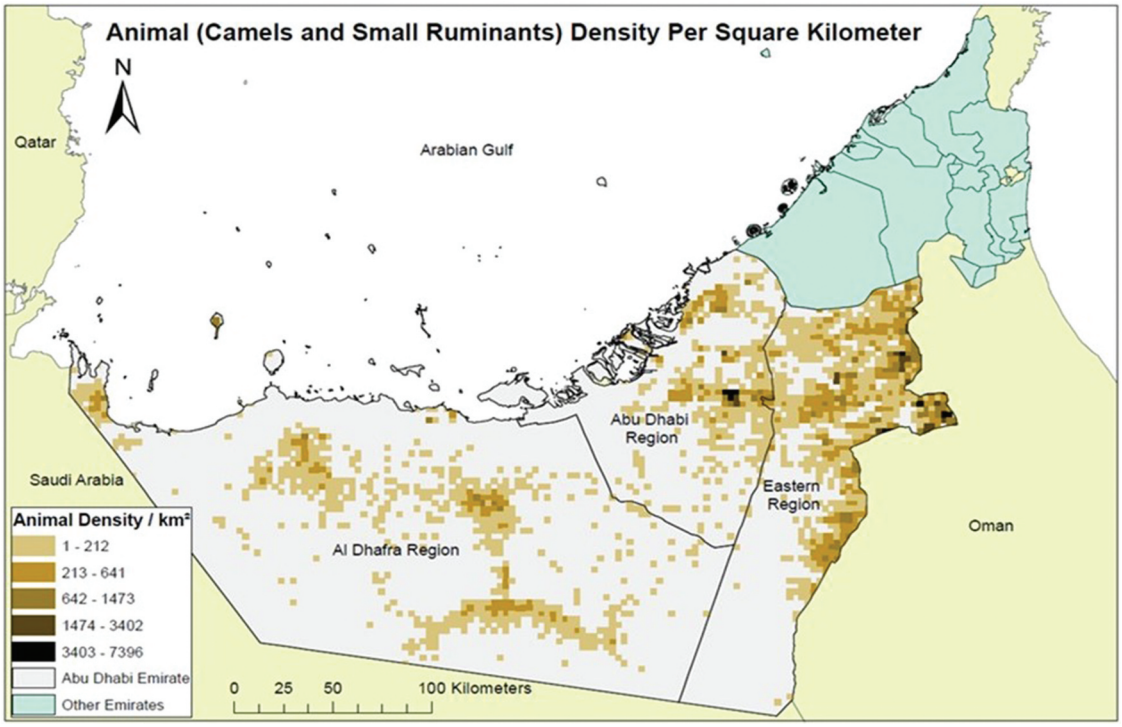

Figure 1. Density of camel and small ruminant populations in the three regions of the emirate of Abu Dhabi. The Emirate of Abu Dhabi is subdivided into three regions, namely the Abu Dhabi, the Eastern and the Al Dhafra regions. The density of camel and small ruminant populations is higher in the Abu Dhabi and Eastern regions as compared to the Al Dhafra region.

78 mm, and over 80% of the annual rain occurs during winter [7]. The densities of camels and small ruminants per square kilometre are shown in Figure 1.

2.2. Study design, sample size estimation, sampling method, and distribution of samples across the three regions

In this cross-sectional study, animals were tested for antibodies against *Brucella* infection, and seropositive animals were cross-sectionally tested for the presence of the DNA of the *Brucella* genus. The predetermined sample size was calculated based on a 2% margin of error. Accordingly, the minimum calculated sample was 2,397 animals. In total, 3,086 animals (356 camels, 1,298 goats, and 1,432 sheep) were recruited for this study from 2022 to 2023. The sample size calculation employed a stratified sampling method, in which proportional allocation was used to recruit the study animals. This approach involved dividing the livestock population in the Emirate into three regional strata: region (Abu Dhabi, Eastern, and Al Dhafra), holding type (farm, regular izba, and random izba), species (goat, sheep, and cattle), and veterinary clinics across the Emirate of Abu Dhabi. Holding types included izbas and farms. The regular and random izba types are licenced and have holding numbers; however, they do not have commercial practices (milk or meat). In contrast, farms have commercial practices. This study used a simple random sample of animals from each clinic based on the number of animals held in the clinics. Veterinary clinics located in the three regions were used as sample collection foci for this study. Veterinarians working in clinics travelled to the farms and izbas located in the surrounding areas to collect the samples.

2.3. Blood collection and extraction of sera

First, 10 mL of jugular blood were collected into plain vacutainers and kept at room temperature overnight for serum separation. Sera were removed from the clotted blood, added into cryovials, labelled, and stored at – 80°C until they were screened for antibodies against *Brucella* using two different enzyme-linked immunosorbent assays (ELISAs).

2.4. Detection of Brucella antibodies in serum samples using c-ELISA and i-ELISA kits

Frozen serum samples were thawed and tested for *Brucella* antibodies using the INgezim *Brucella* Compac 2.0 multispecies competitive ELISA (c-ELISA) and IDvet multispecies indirect ELISA (i-ELISA). Two ELISA kits were used to determine the seroprevalence of *Brucella* infection by increasing the sensitivity of the test by parallel testing and also to determine the seroprevalence by increasing the specificity of the test by serial testing. In both assays, the microplates were pre-coated with purified lipopolysaccharide (LPS) antigen, although the principles of the two assays differed. For c-ELISA, the procedure described by the manufacturer (INgezim *Brucella* Compac 2.0 multispecies ELISA, Prod. Ref: 10.BRU. K3, Spain) was used. After the assay was completed, optical density (OD) was measured at 450 nm using a plate reader (BioTek Instrument Inc., Highland Park, US). The validity of the results was evaluated based on the kit recommendations. Accordingly, the results for each plate were considered valid when the mean OD value of the negative control (OD_{NC}) was > 1.0 and when the mean OD value of the positive control (OD_{PC}) was < 0.35. The results were interpreted based on the percentage of inhibition (PI) for each sample. As indicated in the kit, PI was calculated as follows: $PI = 100 \times [1\text{-}] \ (OD_{sample}/OD_{NC})]$. Then, samples with PIs of ≥ 40% were considered positive for *Brucella* antibodies, while samples with PIs of < 40% were considered negative for *Brucella* antibodies.

Similarly, i-ELISA was conducted following the procedure described by the manufacturer (Innovative Diagnostics, ID Vet, France). OD values were measured at 450 nm (BioTek Instruments Inc., Highland Park, US). As described by the manufacturer of the kit, the test is considered valid when the mean OD_{PC} was > 0.35 and when the ratio of mean OD_{PC} and mean OD_{NC} was > 3 (i.e. OD_{PC}/OD_{NC} >3). The results were interpreted according to the manufacturer's instructions. Accordingly, the sample percentage was calculated as follows: $(S/P\%) = OD_{sample} - OD_{NC}/OD_{PC} - OD_{NC} \times 100$. When S/P% was ≤ 110%, the sample was considered negative. When S/P% was > 110%, the sample was considered positive.

2.5. Detection of Brucella in the sera of seropositive animals using qPCR

DNA samples were extracted from 51 animals that were deemed seropositive by serial testing, and they were further tested for the DNA of the *Brucella* genus using qPCR. The extraction of the DNA from the sera samples was performed using the NucleoSpin® Tissue kit (MACHEREY-NAGEL GmbH & Co.KG, Germany, www.mn-net.com) following the manufacturer's instructions. The concentration of the extracted DNA samples was measured using a NanoDrop spectrophotometer (Thermo Fisher Scientific, Waltham, MA, USA). Primers previously described by other researchers [8,9] were used for the detection of the target gene, *Brucella* cell surface 31 kDa protein (bcsp31), which is highly conserved in the *Brucella* genus and found in all biovars of the *Brucella* species [8,10]. The primers used for the amplification of bcsp31 were forward-5′-

GCTCGGTTGCCAATATCAATGC-3′ and reverse-5′-GGGTAAAGCGTCGCCAGAAG-3′. The sequences of these primers have been published previously [9] and were supplied by Gene Link (www.genelink.com). The glyceraldehyde 3-phosphate dehydrogenase (GAPDH) gene was amplified along with DNA samples as an internal control using a previously described procedure [9]. The primers used for the amplification of GAPDH were forward-5′-CCACCCATGGCAAATTCC-3′ and reverse-5′-TCGCTCCTGGAAGATGGTG-3′. The HOT FIREPol EvaGreen qPCR Supermix 5× ready-to-use solution was supplied by Solis BioDyne (www.solisbiodyne.com) and was used to detect the amplified product. The reaction mixture had a total volume of 12 L, and the mixture consisted of 0.4 L (10 LM) of each primer, 4 L (1×) of HOT FIREPol EvaGreen q-PCR Supermix, 3 L of DNA template or GAPDH, and 4.2 L of PCR grade water. Two-step qPCR was used in this study. The reaction mixture was heated at 95°C for 10 min and then subjected to 44 cycles of denaturation at 95°C for 15 s and annealing at 60°C for 30 s. The CFX-96 real-time system (Bio-Rad, Hercules, CA, USA) was used for the assay, and the results were captured with the FAM channel, whereas the internal control was read with the HEX channel. The result of qPCR was considered positive when the quantification cycle (Cq) (i.e. cycle threshold [Ct]) value was ≤ 40 [9,11].

2.6. Data analysis

Statistical analyses were performed using SPSS version 21. The seroprevalences of *Brucella* infection were presented as percentages and 95% confidence intervals (CIs). Associations between seroprevalence and potential risk factors were evaluated using Pearson's chi-square test or Fisher's exact test. Person chi-square test was used to assess the association between risk factors and the seroprevalence of *Brucella* infection. However, when more than about one fifth of the cells have expected values of less than 5 or when any cell has an expected value of less than 1, Fisher's Exact test was used as an alternative to Person chi-square test to identify the potential risk factors. Univariate and multivariate logistic regression analyses were used to calculate the odds ratio (OR) for each potential risk factor. Variables with p values of <0.20 in univariate logistic regression analysis were considered in the multivariate regression analysis [12]. In all cases, a confidence level of 95% and a significance level of 5% were used to define statistical significance. In the case of qPCR, since bcsp31 was used as a target, a Ct value of ≤ 40 was considered positive for DNA of the *Brucella* genus.

3. Results

3.1. Seroprevalence of Brucella infection in small ruminants and camels on the basis of serial testing

Of the 3,086 animals tested by c-ELISA and i-ELISA, 51 tested positive for *Brucella* infection in both tests. Thus, the overall seroprevalence of *Brucella* infection was 1.7% (95% CI, 1.2%–2.2%), based on serial testing. The results of the analysis of the association between the seroprevalence of *Brucella* infection and potential risk factors are presented in Table 1. Based on serial testing, the overall seroprevalence of *Brucella* infection was associated with the region ($\chi^2 = 20.5$; $p < 0.0001$) (Figure 2), type of holding ($\chi^2 = 9.8$; $p < 0.01$), and species of animals ($\chi^2 = 10.9$; $p < 0.01$).

Further analysis of the association between the seroprevalence of *Brucella* infection using multivariable logistic regression showed that the odds of seroprevalence of *Brucella* infection in animals raised in the Abu Dhabi and Eastern regions were 13.8 (95% CI, 1.82–104.66) and 14.4 (95% CI, 1.95–106.65) times higher than those in animals

Table 1. Serial testing-based association of seroprevalence of *Brucella* infection with potential risk factors in small ruminants and camels as analysed by univariate binary logistic regression.

		Serial testing						
Risk factor		Negative	Positive	Total	Prevalence (%)	Odd ratio (95%CI)	χ^2	P value
Region	Abu Dhabi	804	21	825	2.5	19.72 (2.65–146.96)	20.5*	0.000
	Eastern	1476	29	1505	1.9	14.83 (2.02–109.12)		
	Al Dhafra	755	1	756	0.1	1		
Type of holding	Farm	657	15	672	2.2	2.37 (1.15–4.88)	9.8	0.008
	Random izba	1557	15	1572	1.0	2.66 (1.36–5.18)		
	Regular izba	821	21	842	2.5	1		
Species	Camel	345	11	356	3.1	3.73 (1.60–8.68)	10.9	0.004
	Sheep	1287	11	1298	0.8	2.42 (1.20–4.86)		
	Goat	1403	29	1432	2.0	1		
Age	Young	710	10	720	1.4	1	0.40	0.53
	Adult	2325	41	2366	1.7	1.25 (0.62–2.51)		
Body condition	Good	63	0	63	–	0	1.8*	0.35
	Moderate	771	17	788	2.2	1.43 (0.79–2.57)		
	Poor	2201	34	2235	1.5	1		
Reproductive status	Dry	1193	15	1208	1.2	1	3.5*	0.31
	Pregnant	683	16	699	2.3	1.86 (0.92–3.79)		
	Lactating	924	15	939	1.6	1.29 (0.63–2.66)		
	Others	235	5	240	2.1	1.69 (0.61–4.70)		

*Fisher's exact test.

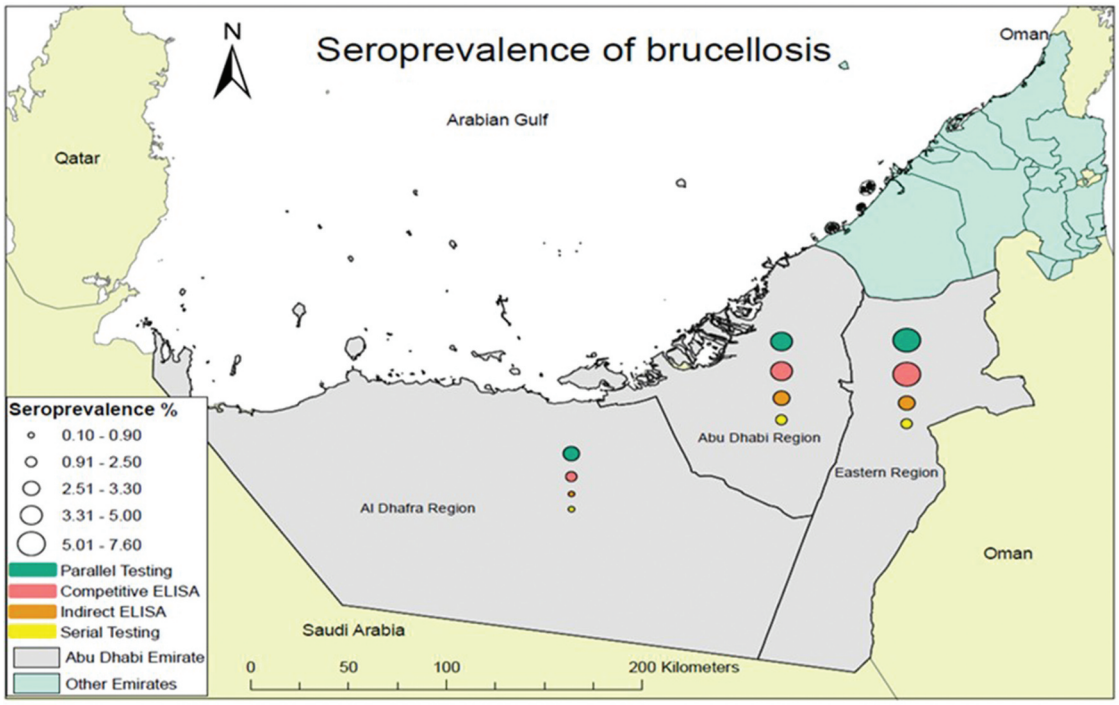

Figure 2. Seroprevalence of *Brucella* infections in small ruminants and dromedary camels in the three regions of Abu Dhabi. Four different testing approaches were used and the seroprevalence values derived thereof are indicated by circles with different colours and sizes. Green-, red-, orange- and yellow-coloured circles indicate seroprevalence values estimated on the basis of parallel testing, competitive ELISA, indirect ELISA and serial testing, respectively. The sizes of the circles indicate the ranges of seroprevalence values; the smallest circle represents seroprevalence ranging from 0.10–0.9% while the largest circle represents seroprevalence ranging from 5.01–7.60%.

raised in the Al Dhafra region(Figure 2). Additionally, the odds of seroprevalence of *Brucella* infection in animals kept in farms and regular izbas were 2.5 (95% CI, 1.14–5.62) and 2.3 (95% CI, 1.12–4.52) times higher than those in animals kept in random izbas (Table 2). Similarly, the odds of seroprevalence of *Brucella* infection in camels and sheep were 5 (95% CI, 2.07–11.83) and 2.3 (95% CI, 1.15–4.67) times higher than that in goats.

3.2. Seroprevalence of Brucella infection in small ruminants and camels on the basis of parallel testing

The overall seroprevalence of *Brucella* infection was 5.8% (95% CI, 5.0%–6.7%) based on parallel testing and was associated with the region ($\chi^2 = 19.3$; $p < 0.0001$) (Figure 2), type of holding ($\chi^2 = 19.1$; $p < 0.0001$), and age of the animals ($\chi^2 = 4.6$; $p < 0.05$). The associations between the seroprevalence of *Brucella* infection and potential risk factors based on univariate binary logistic regression and multivariate logistic regression analyses are presented in Tables 3 and 4, respectively. Accordingly, the odds of seroprevalence of *Brucella* infection in animals raised in the Eastern region were 2.3 (95% CI, 1.43–3.66) times higher than those in animals raised in the Al Dhafra region (Figure 2 and Table 4). The odds of seroprevalence of *Brucella* infection in animals kept in farms and regular izbas were 1.9 (95% CI, 1.23–2.84) and 2.1 (95% CI, 1.48–3.02) times higher than those in animals kept in random izbas.

Table 2. Serial testing-based association of seroprevalence of *Brucella* infection with potential risk factors in small ruminants and camels as analysed on multivariate binary logistic regression analysis.

Risk factor	Category	Odd ratio (95%CI)	Wald test	df	P value
Region		–	6.861	2	0.032
	Abu Dhabi	13.79 (1.82–104.66)	6.434	1	0.011
	Eastern	14.43(1.95–106.65)	6.843	1	0.009
	Al Dhafra	1	–	–	–
Type of holding			6.573	2	0.037
	Farm	2.53 (1.14–5.62)	5.173	1	0.023
	Regular izba	2.26 (1.12–4.53)	5.213	1	0.022
	Random izba	1	–	–	–
Species			13.068	2	0.001
	Camel	4.95 (2.07–11.83)	12.98	1	0.0001
	Sheep	2.31 (1.15–4.67)	5.477	1	0.019
	Goat	1	–	–	–

Table 3. Parallel testing-based association of seroprevalence of *Brucella* infection with potential risk factors in small ruminants and camels as analysed by univariate binary logistic regression analysis.

		Parallel testing						
Risk factors		Negative	Positive	Total	Prevalence (%)	Odd ratio (95% CI)	χ^2	P value
Region	Abu Dhabi	784	41	825	5.0	1.60 (0.95–2.67)	19.3	0.000
	Eastern	1391	114	1505	7.6	2.50 (1.60–3.92)		
	Al dhafra	732	24	756	3.2	1		
Type of holding	Farm	629	43	672	6.4	1.59 (1.07–2.36)	19.1	0.000
	Random izba	1507	65	1572	4.1	2.14 (1.51–3.02)		
	Regular izba	771	71	842	8.4	1		
Species	Camel	333	23	356	6.5	1.16 (0.71–1.88)	0.4	0.84
	Sheep	1225	73	1298	5.6	1.03 (0.75–1.43)		
	Goat	1349	83	1432	5.8	1		
Age	Young	690	30	720	4.2	1	4.6	0.04
	Adult	2217	149	2366	6.3	1.55 (1.04–2.31)		
Body condition	good	60	3	63	4.8	1	3.2	0.20
	moderate	732	56	788	7.1	1.53 (0.47–5.03)		
	poor	2115	120	2235	5.4	1.14 (0.35–3.67)		
Reproductive status	Dry	1138	70	1208	5.8	0.99 (0.55–1.79)	0.1	1.0
	Pregnant	659	40	699	5.7	0.98 (0.52–1.83)		
	Lactating	884	55	939	5.9	1.0 (0.55–1.84)		
	Others	226	14	240	5.8	1		

Table 4. Parallel testing-based association of seroprevalence of *Brucella* infection with potential risk factors in small ruminants and camels as analysed by multivariate binary logistic regression analysis.

Risk factor	Category	Odd ratio (95%CI)	Wald test	df	P value
Region			17.186	2	0.0001
	Abu Dhabi	1.29 (1.43–3.66)	0.696	1	0.404
	Eastern	2.29 (1.43–3.66)	11.899	1	0.001
	Al Dhafra	1	–	–	–
Type of holding		–	18.105	2	0.0001
	Farm	1.87 (1.23–2.84)	8.587	1	0.003
	Regular izba	2.11 (1.48–3.02)	17.741	1	0.0001
	Random izba	1	–	–	–
Age	Young	1	–	–	–
	Adult	1.35 (0.88–2.07)	1.922	1	0.166
Body condition			6.554	2	0.038
	Good	1	–	–	–
	Moderate	1.71 (0.51–5.73)	0.751	1	0.386
	Poor	1.10 (0.33–3.64)	0.026	1	0.873

3.3. Seroprevalence of Brucella infection in small ruminants and dromedary camels in farms surrounding veterinary clinics (hospitals)

The seroprevalences of *Brucella* infection at the clinics (hospitals) serving as focal points for sample collection from the farms and izbas ranged from 0.0%–15.7% (Figure 3). In the Abu Dhabi region, the highest seroprevalence of *Brucella* infection was recorded for farms and izbas situated around the Samha veterinary clinic. In the Eastern region, the highest seroprevalence was recorded for farms surrounding the Wagan veterinary clinic, followed by those surrounding the Al Qattara veterinary hospital. Lastly, the seroprevalence values were low for all farms and izbas in the Al Dhafra region (Figure 3). However, a relatively high seroprevalence was recorded for farms and izbas located near the Selaa veterinary clinic.

3.4. Detection of the DNA of Brucella in the sera of seropositive animals

The results of qPCR are shown in Figure 4(a,b). In total, 51 serum samples that were positive for *Brucella* antibodies based on serial testing were used for DNA extraction and subsequent amplification with qPCR. The DNA of the *Brucella* genus was detected in 25.5% (13/51) of seropositive samples when considering a Ct (Cq) cut-off value of ≤ 40 (Figure 4). The mean ± standard error of the mean (SEM) of the Cq values of samples was 38.47 ± 0.35 (95% CI, 37.71–39.24), while the mean ± SEM of the internal control (GAPDH) was 32.38 ± 0.36 (95% CI, 31.49–33.27). No significant difference was observed between the mean Cq values of the samples and those of the internal controls (two-tailed t test = 11.04; $p > 0.05$) (Figure 4(b)).

4. Discussion

This observational study was conducted to examine *Brucella* infection in small ruminants and dromedary camels using serological and qPCR tests in the three regions of the Emirate of Abu Dhabi. The study involved 3,086 animals from 2022 to 2023. The seroprevalence of *Brucella* infection was estimated using two ELISA tests with serial and parallel testing approaches. The results of this study fill the paucity

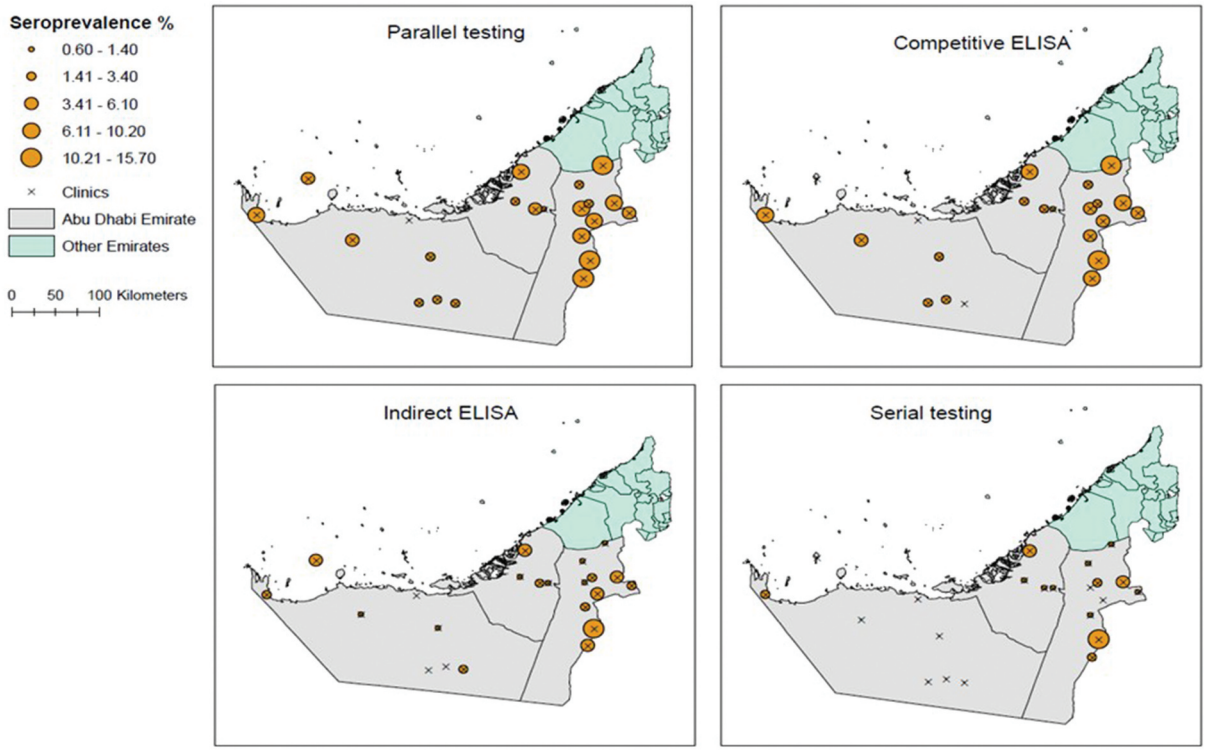

Figure 3. Seroprevalence of *Brucella* infection in small ruminants and dromedary camels in the areas surrounding veterinary clinics of the three regions of Abu Dhabi. Four different testing approaches were used (c-ELISA, i-ELISA, parallel and serial testing) and the four maps represent the seroprevalence values of four different tests. The seroprevalence values at the areas surrounding the different clinics are indicated by circles with different sizes while the clinics are indicated by x. The sizes of the circles indicate the ranges of seroprevalence values; the smallest circle representing seroprevalence ranging from 0.60–1.4% while the largest circle represents seroprevalence ranging from 10.21–15.70%.

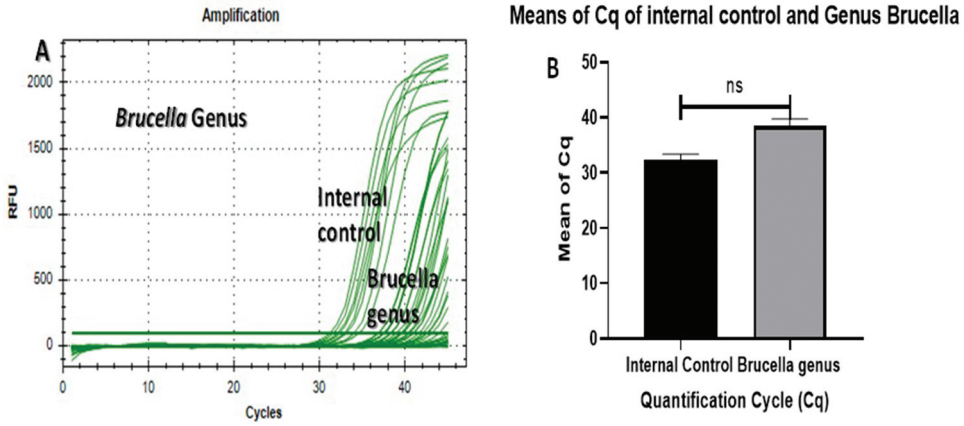

Figure 4. Amplification curve of real-time PCR of for the detection of 51 DNA of *Brucella* genus extracted from sera samples of seropositive animals. of the 51 seropositive sera, 13 (25.5%) were positive by q-PCR (panel a) with mean quantification cycle (cq) or cycle threshold (ct) value of 38.47 ± 0.35 (95% CI: 37.71, 39.24, panel b).

of scientific data on *Brucella* infection in livestock in the UAE and complement the few serological studies reported previously [13–17].

The overall seroprevalence of *Brucella* infection was determined to be 1.7% based on serial testing and 5.8% based on parallel testing. Furthermore, it was 2.5% and 5.0% based on i-ELISA and c-ELISA, respectively. Thus, the overall seroprevalence was highest based on parallel testing and lowest based on serial testing. The true seroprevalence could be the average of these two seroprevalence values, which is 3.8%, lower than that reported earlier in countries of the Middle East, North Africa, and East Africa [14,18–27]. The lower seroprevalence recorded in this study could be attributed to the implementation of the test-and-slaughter strategy by the UAE [28]. A previous review [19] indicated that the test-and-slaughter strategy was used in the Middle East to eradicate brucellosis.

However, the test-and-slaughter method has not been successful in eradicating brucellosis in Iran, as it is not complemented by vaccination [19]. Similar to the present study, another group of researchers conducted a seroprevalence study on 6,126 small ruminants and camels in three regions of the Emirate of Abu Dhabi between January 2009 and December 2010 [14]. These researchers employed a serial testing approach using the Rose Bengal Plate Test (RBPT) and c-ELISA as screening and confirmatory tests, respectively. These authors reported overall seroprevalences of 8.0% and 7.0% based on RBPT and c-ELISA, respectively, which were higher than the seroprevalence values recorded using both serial (1.7%) and parallel (5.8%) tests.

As observed in the present study, the seroprevalence of *Brucella* infection was significantly lower in the Al Dhafra region than that in either the Abu Dhabi or the Eastern regions. Similarly, a higher seroprevalence was reported in the Eastern and Abu Dhabi regions, whereas a lower seroprevalence was reported in the Al Dhafra region [14]. The differences in seroprevalence among the three regions could be associated with the densities of animal populations and environmental (climatic) conditions. The density of the animal population was lowest in the Al Dhafra region, highest in the Eastern region, and intermediate in the Abu Dhabi region. In addition, the Al Dhafra region is typically characterized by a vast geographic area and sparsely distributed animal holding establishments (farms and regular and random izbas), which do not favour disease transmission. In addition, the Al Dhafra region is mostly a desert and is not convenient for the survival of reservoir hosts, which could limit the transmission of *Brucella* infection to domestic animals.

Furthermore, variations were observed in the seroprevalence of *Brucella* infection at the clinics (hospitals) that served as focal sites for sample collection. In the Abu Dhabi region, the highest seroprevalence of *Brucella* infection was recorded in the farms and izbas situated around the Samha veterinary clinic, while in the Eastern region, the highest seroprevalence was recorded in the farms surrounding the Wagan veterinary clinic, followed by those surrounding the Al Qattara veterinary hospital. In contrast, in the Al Dhafra region, a relatively high seroprevalence was recorded at farms and izbas surrounding the Selaa veterinary clinic. The reasons for the difference in the seroprevalences of *Brucella* infection at clinics (hospitals) within each region could also be associated with the differences in the densities of animal populations in the areas surrounding these clinics and hospitals.

A comparison of the seroprevalences of *Brucella* infection among the three species of animals indicated that the seroprevalence was highest in camels and lowest in goats based on serial testing, whereas it did not differ among the three species based on parallel testing. The higher seroprevalence in camels, compared with that in small ruminants, could be associated with the application of the test-and-slaughter strategy in small ruminants [28] but not in camels. This difference could also be attributed to the cumulative effect of age, as camels live longer and have a higher chance of being exposed to infection.

The genus *Brucella* was confirmed in 13 of the 51 seropositive animals; 25.5% of the seropositive animals were positive for the genus *Brucella* using qPCR. Several researchers have previously used qPCR for the detection of the DNA of *Brucella* in seropositive animals [9,21,29–32].

A previous study was conducted on 53 seropositive animals using qPCR and detected *Brucella* DNA in 35 (66%) of the animals [29]. In contrast, all 25 serum samples from aborted livestock species were positive for the DNA of *Brucella* using qPCR, which indicated 100% positivity [30] that could be attributed to ongoing active infection. Furthermore, the sensitivities of qPCR were 70.2% and 97.2% in detecting *Brucella* DNA in positive sera and culture-positive blood, respectively [9]. Studies conducted in Egypt [21] and Pakistan [31] reported that 27% (32/118) and 44% (31/71) of seropositive animals, respectively, were also positive for the genus *Brucella* using qPCR. As seen in the results of these studies, the percentage of the DNA of *Brucella* in seropositive sera varies. These differences are mainly associated with the stage of infection of *Brucella*. In the case of active infection and bacteraemia, the chance of detecting bacterial DNA in the serum is higher, whereas in latent infection localized to specific lymph nodes, the chance of detecting bacterial DNA in the serum is less likely.

In addition to reports of its occurrence in livestock, a few studies have reported *Brucella* infection in wild and captive animals in the UAE; for example, a seroprevalence of 67% was reported in a study conducted on 959 captive scimitar-horned oryx [16,17]. Moreover, a large number of studies have reported brucellosis in humans in the UAE [33–38], underlining the significance of the disease [39].

5. Conclusion

The seroprevalence of *Brucella* infection was estimated in 3,086 animals in the Emirate of Abu Dhabi using different serological testing approaches. The results of the study indicated a seroprevalence ranging from 1.7%–5.8% based on the different testing methods used. In addition, *Brucella* infection was confirmed in seropositive animals using qPCR. The overall seroprevalence of *Brucella* infection was associated with the region, type of animal holding, species, and age of the animals. Therefore, implementation of control and preventive measures focusing on areas with high seroprevalence is recommended.

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Author contributions

G.A. conceived and designed the study, and drafted the manuscript. A.Z.; I.A.A.; B.A.D.; B.M.E.; and M.E. H. contributed in the designing of the study. A.Z.; Y.M.E.; M.S.A.; M.M.A.; A.S.A. and R.A.K. contributed in the execution of the study and data acquisition. B.B.; T.S. and G.A. contributed in data analysis and interpretation. G.A.; A.A.A.and N.A. contributed in preparing the maps. K.K.; M. M.A.N.; R.B.; A.L.W.; B.M.E.; M.T.; T.S. and Y.M. E. contributed in the edition of the manuscript.

Data avaialability

Data will be available upon request to the corresponding author.

Ethical approval

The research project was approved by the Animal Research Ethics Committee of the United Arab Emirates University (Ref. No. ERA_2020_6182) on the 2nd of April 2021. In addition, it was by the Ministry of Climate Change and Environment (MOCCAE) of the United Arab Emirates by a letter dated 8 February 2022 (Ref. MOCCEA/EA/2022).

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