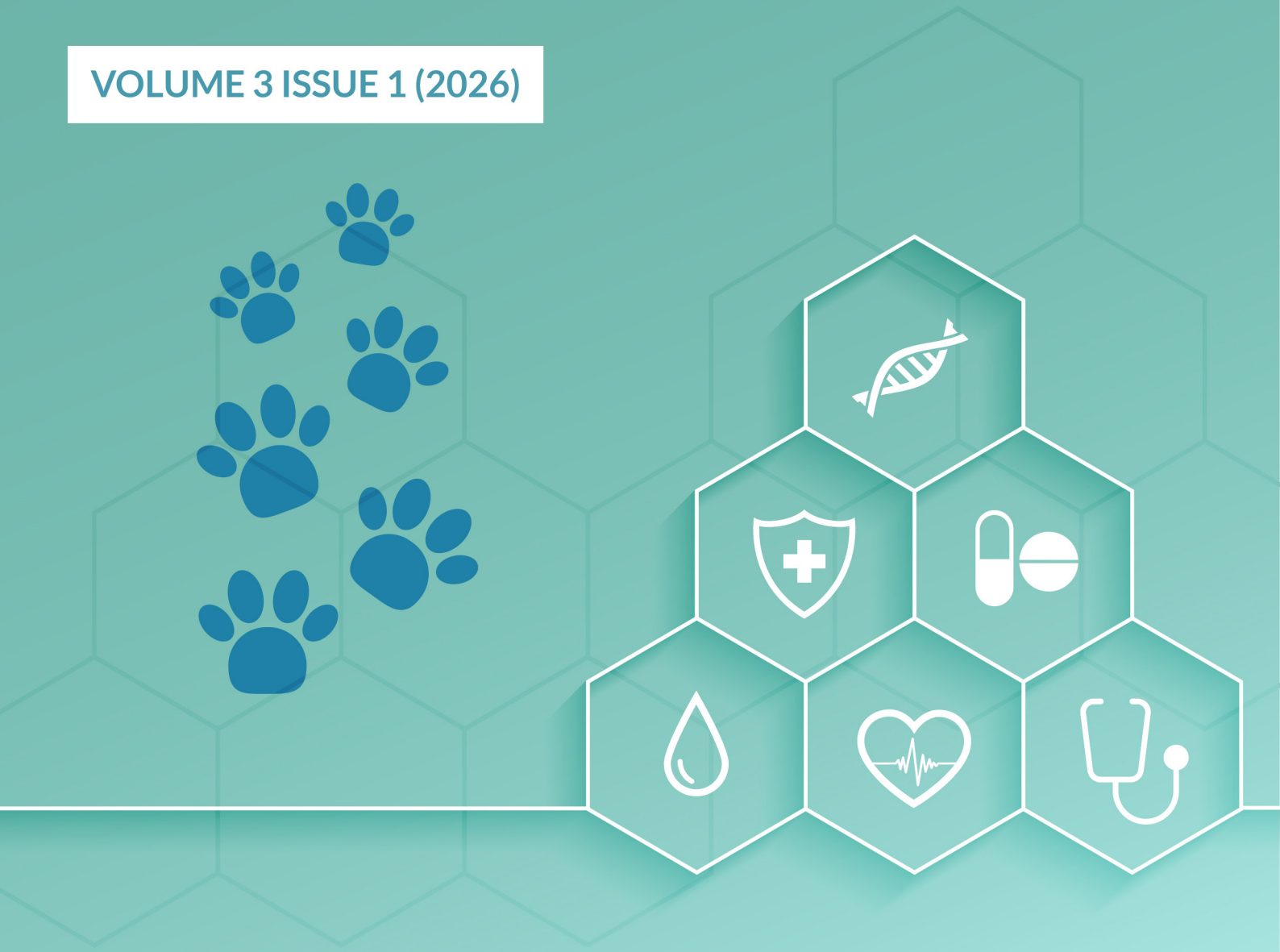
International Journal of Veterinary Medicine and Animal Science (IJVMAS)

ISSN: 3064-8041 (ONLINE)

VOLUME 3 ISSUE 1 (2026)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

International Journal of Veterinary Medicine and Animal Science (IJVMAS)

Volume 3 Issue 1, Year 2026
ISSN: 3064-8041 (Online)
DOI: https://doi.org/10.54536/ijvmas.v3i1.6924
https://journals.e-palli.com/home/index.php/ijvmas

Seroprevalence and Associated Risk Factors of Camel Brucellosis in Niger

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Article Information

Received: November 26, 2025

Accepted: February 05, 2026

Published: July 03, 2026

Keywords

Brucellosis, Camelids, Niger, Seroprevalence, Risk Factors

ABSTRACT

A cross-sectional study was conducted in the Tahoua region (Niger) to estimate the seroprevalence of camel brucellosis and identify the risk factors associated with its occurrence. A total of 332 serum samples were collected from dromedaries of various sexes and ages from 32 farms in four departments of the region. Serological analyses were performed using two tests: the Rose Bengal test (RBT) and the indirect ELISA (iELISA). The results revealed a positivity rate of 0.3 % for each of the two tests, corresponding to two different animals. Parallel interpretation allowed an overall seroprevalence of 0.6 % to be estimated. However, no statistically significant association ($P > 0.05$) was observed between seroprevalence and the variables studied, such as age, sex, farming method, contact with other ruminants, herd size or breed. Furthermore, the survey revealed a low level of knowledge about the disease among farmers. The most significant practices identified as likely to promote disease transmission in the study area were the consumption of raw milk, the handling of aborted foetuses and placentas with bare hands, the cohabitation of dromedaries with other domestic animal species, and poor livestock management. Although the prevalence observed is low, the circulation of Brucella spp. cannot be ruled out in the region. Given the zoonotic potential of the disease, it is necessary to strengthen prevention, awareness and surveillance measures.

INTRODUCTION

In Niger, livestock farming is a key pillar of the national economy and people's livelihoods. It is practised by more than 87 % of the working population, either as their main activity (20 % of the population live exclusively from livestock farming) or as a secondary activity after agriculture (Niger-MAG/EL, 2024). This age-old activity has long occupied a prominent place in both the national and family economies. Indeed, livestock farming, for which Niger has an undeniable comparative advantage in the West African sub-region, contributes more than 11 % to the national gross domestic product and more than 25 % to household budgets. This significant contribution makes this sub-sector an effective weapon in the fight against poverty and food insecurity, not only because of its contribution in terms of highly nutritious animal products (milk, meat and eggs), but also and above all because of the creation of jobs and substantial income in rural areas (Niger-MAG/EL, 2024).

Despite its many strengths and prominent role in the national economy, the livestock sub-sector in Niger continues to face multiple major challenges. These include the persistence of certain transmissible animal diseases, inadequate livestock feed, low herd productivity, and still very limited public and private investment. These constraints seriously compromise the sector's sustainable development. Among the most worrying animal diseases, brucellosis occupies an important place due to its zoonotic nature, its silent spread and its economic and health repercussions.

Brucellosis is an infectious, contagious disease common to many animal species as well as humans. It is caused by bacteria of the genus Brucella, Gram-negative, facultative intracellular, non-motile and non-spore-forming coccobacilli, ranging in size from 0.5 to 0.7 µm in diameter and 0.5 to 1.5 µm in length (Wernery, 2016; Boukary, 2013). This zoonosis can affect virtually all domestic animal species, with the possibility of cross-transmission between cattle, sheep, goats, camelids and other susceptible species (Ghanem *et al.,* 2009; Agab *et al.,* 1994).

In humans, contamination occurs mainly through the consumption of unpasteurised dairy products or through direct contact with infected animals, particularly when handling abortion products. This bacterial disease is not only debilitating, but also causes significant economic losses due to its impact on human health (time lost by patients in their normal daily activities) and animal health (abortion, infertility, reduced productivity) (Dean *et al.,* 2013).

Globally, brucellosis is recognised as a major public health problem, particularly in developing countries where it remains endemic (Suresh *et al.,* 2022; Radostits *et al.,* 2007).

Although the disease has been extensively studied in cattle and small ruminants, its importance in camelids remains poorly documented, despite their essential role in pastoral

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systems in arid and semi-arid areas of Africa and Asia (Gwida *et al.,* 2012).

In sub-Saharan Africa, and more particularly in Niger, studies on brucellosis have mainly focused on cattle and small ruminants, highlighting the circulation of the disease throughout livestock systems (Musallam *et al.,* 2019; Boukary *et al.,* 2014; Akakpo *et al.,* 1986). However, data on dromedaries remain limited, even in Niger, which ranks sixth in the world for its camel population (FAOSTAT, 2023).

Camels play a strategic role in the food supply, economy and resilience of pastoral communities in Niger. Nevertheless, they can be a potential reservoir for various pathogens, contributing to the persistence of zoonotic diseases in the environment (Fekadu and Juhar, 2019). In this context, reliable epidemiological data on camel brucellosis is essential for assessing health risks and developing appropriate prevention and control strategies. With this in mind, the present cross-sectional study was conducted to estimate the seroprevalence of brucellosis in camels, assess the level of knowledge of dromedary herders with this zoonosis, and to identify behaviours and practices that pose a risk of exposure at the animal-human interface in the Tahoua region.

MATERIALS AND METHODS

Study Period and Area

This study is based on a cross-sectional survey conducted from December 2023 to June 2024 in the pastoral and agro-pastoral areas of the Tahoua region, chosen for its high density of camel livestock. Covering an area of 113,371 km², the region is bordered to the north by the Agadez region, to the south by the Federal Republic of Nigeria, to the east by the Maradi region and to the west by the Dosso and Tillabéry regions and the Republic of Mali (Figure 1). Its centre point is located between 13°42' and 18°30' north latitude and 3°53' and 6°42' east longitude. It is crossed by the sub-Saharan zone and a savannah zone between the 300 and 600 mm isohyets. The terrain is a vast plateau cut by wide valleys running east-west (Ille, 2022). According to the general population and housing census (RGP/H) (Niger-INS, 2012), the Tahoua region has a population of approximately 3,983,172. Administratively, it comprises twelve departments subdivided into seven urban municipalities and thirty-five rural municipalities, with the exception of the city of Tahoua, which has two municipal districts. Socio-economically, livestock farming is the second most important activity after agriculture.

The region is characterised by an extensive livestock farming system and a pastoral lifestyle based on the mobility of herds in search of water and pasture. Approximately 90 % of the population is involved in livestock farming, either sedentary (52 %), transhumant (31 %) or nomadic (17 %), with an estimated total of 9,919,148 head of all species combined (Niger-DREL Tahoua, 2018). At the national level, the camel population is estimated at 1,907,440 head, including 583,179 in the Tahoua region, representing 31 % of Niger's camel population (Niger-MAG/EL, 2022).

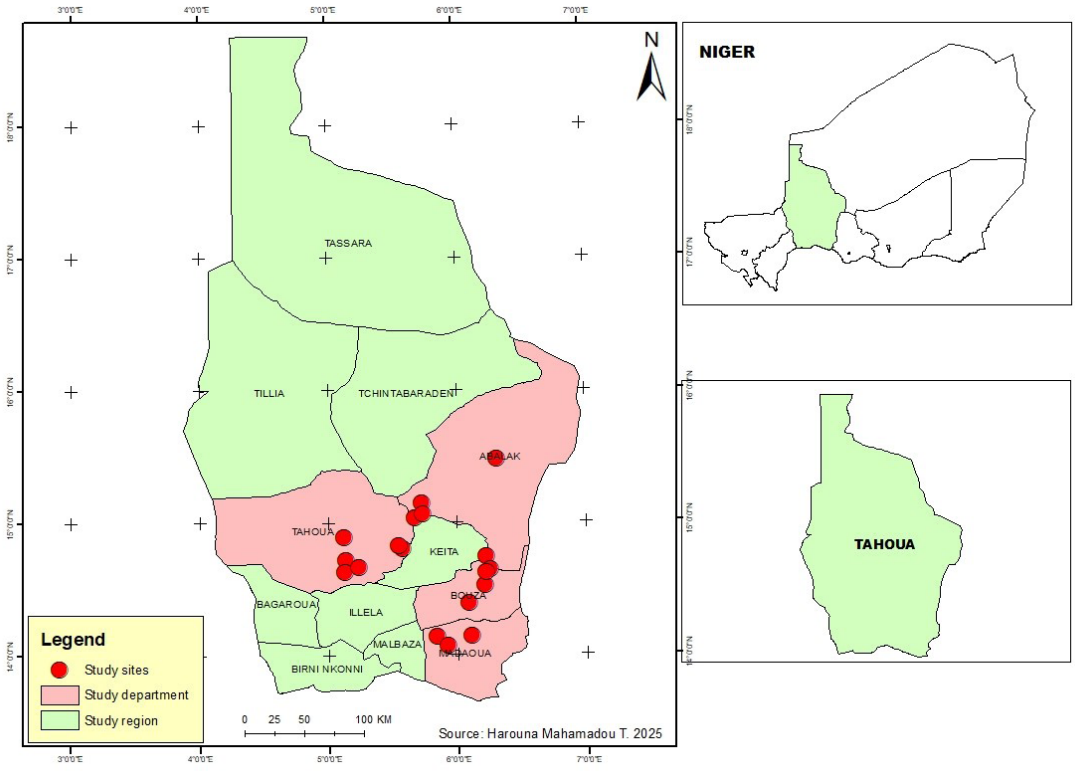

Figure 1: Geographical distribution of study sites in the Tahoua region
Source: Harouna Mahamadou Tanimoun

Study Population

The study population consisted of local breed camels. All farms with local breed camels, male or female, aged at least one year old, were included. However, farms without camels were excluded from the study.

Sampling Method

A simple random sampling method was used to select the farms. The study was conducted in two complementary phases.

Preparation and Farm Census Phase

This consisted of obtaining up-to-date data on camel numbers in Niger from the Statistics Department of the Ministry of Livestock. Steps were then taken with the regional and departmental livestock departments to identify camel farms located in the study area and draw up an exhaustive list of them. To refine the identification of collection sites, collaboration was established with key local actors, including local private veterinary services (SVPP), livestock breeders' associations and groups, non-governmental organisations (NGOs) working in pastoral development, and milk collectors and traders operating in the target area. This approach aimed to identify as comprehensively as possible all farms with dromedaries, including small family units with only a limited number of animals.

Field Phase

This second phase of the study consisted of visiting the selected farms to take blood samples for serological analysis. In parallel with these samples, questionnaires were administered to farmers to assess their knowledge, attitudes and practices relating to camel brucellosis, and to identify risky behaviours and practices that could promote the transmission of the disease between animals and humans.

Sample Size

The serological sample size was determined using the formula: $N = z^2 \times p\,(1-p)\,/d^2$ (Thrusfield, 2007) where N = estimated sample size; z^2 = confidence level (for a confidence level of 99 %, z=2.576); d = absolute precision or margin of error is 5 %; p = estimated or expected prevalence.

For this study, an expected prevalence of 4 % was used, based on data from the only recent study conducted in dromedaries in Niger (Harouna *et al.,* 2021). Applying these parameters, the theoretical sample size was 102 sera. However, a total of 332 serum samples were ultimately collected to enhance the reliability of the results. In addition, 80 camel breeders agreed to participate in the KAP survey conducted in parallel with the serological study.

Blood Sampling

Blood samples were taken after obtaining prior consent from the camel owners, in strict compliance with animal welfare principles.

On each farm, blood samples were taken by puncturing the jugular vein, after the animal had been adequately restrained (in a lying or standing position), with the assistance of two people. Between 5 and 10 ml of blood was collected aseptically using Vacutainer vacuum tubes.

After collection, the tubes were kept in an upright or slightly inclined position to facilitate clot retraction (start of coagulation), avoiding any agitation so as not to alter the quality of the samples. The samples were then kept cool in a cooler containing dry ice and transported to the laboratory.

Upon arrival, the samples were centrifuged at 3000 rpm for 5 minutes. The sera obtained were transferred to microplates (Micronics) using a 1 ml micropipette and stored in a freezer at -20°C until analysis.

Survey Questionnaire

A questionnaire that had been designed, tested and adjusted was administered to camel breeders in order to assess their level of knowledge about camel brucellosis and identify risky behaviours and practices likely to promote transmission of the disease at the animal-human interface. Data were collected using printed copies of the questionnaire, which comprised several main sections: (a) the socio-demographic characteristics of the participants, (b) the breeding system and management, (c) the health status of the camel herd, (d) knowledge of camel brucellosis, and (e) practices and behaviours that pose a risk of transmission between animals, as well as factors of exposure at the human-animal interface.

For ethical reasons, verbal informed consent was obtained from the dromedary owners before the interviews were conducted. The confidentiality of the data collected was ensured, and the anonymity of the participants was scrupulously respected during the data analysis.

Sample Analysis

Serological analyses were performed at the Niger Central Livestock Laboratory (LABOCEL) using the Rose Bengal test (RBT) with Brucella abortus antigen supplied by IDEXX (Montpellier, France) and the indirect ELISA test (iELISA) produced by ID. Vet (France) (ID Screen® Brucellosis Serum Indirect Multi-species kit, with cups sensitised with Brucella abortus LPS). All analysis steps for these two tests were performed in accordance with the protocols provided by their manufacturers.

Rose Bengale Test (RBT)

The RBT was performed according to the standard protocol below :

- Bring the Rose Bengal antigen (Ag RB) to room temperature (20°±3°C) before use (approximately 15 min);
- Bring the positive and negative controls and samples to room temperature;
- Gently homogenise the reagent, i.e. Ag RB, samples and controls, by briefly vortexing;
- Distribute 30 µl of the antigen suspension (Ag RB) onto the plate according to the number of samples.

- Vortex the samples and controls (positive and negative) and distribute 30 µl next to the Ag RB according to the plate layout.

- Using a comb, gently mix the Ag RB with the sera using an oval motion.

- Gently shake the plate using circular motions for 4 minutes, while reading every minute using a magnifying glass to determine the degree of positivity.

Samples are considered positive when visible agglutination is observed or as soon as any agglutination, even very fine, is formed. The degree of positivity was assessed according to the intensity of agglutination. This was monitored for 4 minutes, after which the results were interpreted according to the intensity of the agglutination observed.

++++ : 1 minute → Intense agglutination with lightening of the liquid, thick edge ;

+++ : 2 minutes → Moderate agglutination with lightening of the liquid, clear edge ;

++ : 3 minutes → Fine agglutination, clear edge ;

+ : 4 minutes → Very fine agglutination, invisible edge.

Samples are considered negative if there is no visible agglutination.

- : > 4 minutes → No agglutination, the pink colour is uniform.

iELISA Test

The test was performed in accordance with the manufacturer's recommendations.

The results are expressed as optical density (OD), measured at a wavelength of 450 nm using a Thermo Scientific Multiskan spectrophotometer (ELISA reader).

The interpretation of the results is based on the percentage of the sample/positive ratio (S/P%), calculated using the following formula:

S/P % = (sample OD – DOCN) / (DOCP – DOCN) x 100

The interpretation thresholds were defined as follows:

- Positive: S/P % ≥ 120%
- Doubtful: 110% < S/P% < 120%
- Negative: S/P% ≤ 110%

S/P: S = Sample (OD of the sample) and P = Positive (OD of the positive control)

OD: Optical Density; NC: Negative Control; PC: Positive Control.

Statistical Analyses

All data collected from serological tests (RBT and iELISA) were carefully entered into Microsoft Excel version 2013 and then imported into SPSS software (IBM SPSS Statistics version 20) for statistical analysis. Seroprevalence was calculated by dividing the number of animals seropositive for Brucella spp. (RBT and iELISA) to the total number of camel sera tested. Descriptive statistics and the chi-square (χ^2) test were used to compare the proportions and frequencies of qualitative variables, as well as to assess the association between seroprevalence and categorical variables or the various risk factors associated with seroprevalence. The strength of this association was measured using the p-value and the odds ratio (OR), with a 95 % confidence interval.

For all analyses, a p-value of less than 0.05 ($p < 0.05$) was considered statistically significant. In addition, the data from the survey forms were entered into SPHINX software (version 5.1.0.5) and then exported to Microsoft Excel 2013 for further processing. Finally, thematic maps were generated using ArcGIS® software version 10.3.

RESULTS AND DISCUSSION

Seroprevalence of camel brucellosis in the Tahoua region

A total of 332 serum samples from 32 farms were collected and analysed, including 181 females and 151 males from the departments of Tahoua, Bouza, Madaoua and Abalak. Of all the sera analysed, only one sample was positive for Rose Bengal (0.3 %; 1/332) and another for indirect ELISA (0.3 %; 1/332). Parallel interpretation, considering any sample that tested positive in either of the two tests as positive, estimated an overall seroprevalence of 0.6 % (2/332) (Table I). Both positive samples came from the department of Tahoua. However, no statistically significant difference was observed between departments ($p > 0.05$). The seroprevalence at herd level was 3.1 % (1/32) for each of the two tests (RBT and iELISA), corresponding to two different herds. Parallel interpretation increased this seroprevalence to 6.2 % (2/32). However, no statistically significant association was found between Brucella spp. seropositivity and herd ($\chi2 = 7.226$; $p=0.61$).

Table 1: Positive sera detected by both serological methods (RBT and iELISA)

locality	Number of sera tested	RBT positive (%)	ELISA positive (%)	RBT/ELISA positive (%)	χ2	p-value
Abalak	72	0(0 %)	0(0 %)	0(0 %)	6.338	0.09 (p>0.05)
Bouza	80	0(0 %)	0(0 %)	0(0 %)		
Madaoua	100	0(0 %)	0(0 %)	0(0 %)		
Tahoua	80	1 (0.3 %)	1 (0.3 %)	2(0.6 %)		
Total	332	1 (0.3 %)	1 (0.3 %)	2(0.6 %)		

χ2 : Chi Square

Factors Influencing the Seroprevalence of Camel Brucellosis

The results of the analysis of risk factors associated with seroprevalence of camel brucellosis in the study area

are presented in Table II. Individual seroprevalence was higher in females (1.10 %; 2/181) than in males, with no statistically significant difference ($p > 0.05$). Based on age, the highest rate was observed in dromedaries aged 5 to 10 years (1.21 %; 2/164), while no animals under 5 years of age were seropositive; however, this association was not significant ($p > 0.05$). According to herd size, seroprevalence was higher in small and medium-sized herds (1-20) than in large herds, but without significant difference ($p > 0.05$). Regarding breed, the highest seroprevalence was recorded in Azawak dromedaries (0.65 %; 2/306), with no significant difference ($p > 0.05$). Finally, the seroprevalence of brucellosis was higher in dromedaries raised with other domestic ruminants (cattle and small ruminants) than in those raised alone, but this difference was not statistically significant ($p > 0.05$).

In summary, none of the factors studied (sex, age, livestock production system, herd size, breed and contact with other ruminants) showed a significant association with Brucella spp. seropositivity in dromedaries. Consequently, the strength of the association was not quantified (OR), as chi-square tests revealed no significant association between the variables analysed. Furthermore, multiple logistic regression analysis was not feasible due to the small number of seropositive animals.

Table 2: Risk factors associated with Brucella seroprevalence

Variables	Category	Number of sera tested	RBT positive (%)	ELISA positive (%)	RBT/ ELISA positive (%)	χ2	p-value
Sex	Female	181	1 (0.5%)	1 (0.5%)	2 (1.10%)	1.658	0.198 (p>0.05)
	Male	151	0 (0%)	0 (0%)	0 (0%)		
Age	(1-4)	84	0(0%)	0(0%)	0(0%)	2.061	0.357 (p>0.05)
	(5-10)	164	1(0.60%)	1(0.60%)	2(1.21%)		
	(11-15)	84	0(0%)	0(0%)	0(0%)		
Livestock production system	Nomadic	16	0(0%)	0(0%)	0(0%)	1.598	0.449 (p>0.05)
	Sedentary	185	1(0.54)	1(0.54)	2(1.10)		
	Transhumance	131	0(0%)	0(0%)	0(0%)		
Herd size	(1-20)	125	1(0.83%)	1(0.83%)	2(1.60%)	2.725	0.189 (p>0.05)
	(21-50)	105	0(0%)	0(0%)	0(0%)		
	(> 50)	102	0(0%)	0(0%)	0(0%)		
Camel Breed	Azarghaf	22	0(0%)	0(0%)	0(0%)	0.170	0.918 (p>0.05)
	Azawak	306	1(0.32%)	1(0.32%)	2(0.65%)		
	Manga	4	0(0%)	0(0%)	0(0%)		
Contact ruminants	Yes	328	1(0.3%)	1(0.3%)	2(0.6%)	0.024	0.875 (p>0.05)
	No	4	0(0%)	0(0%)	0(0%)		

χ2 : Chi-Square

Knowledge, Attitudes and Practices of Camel Breeders Regarding Brucellosis

Analysis of Participants' Socio-Demographic Data

The survey covered 80 camel breeders in four departments in the Tahoua region. All respondents were male and mainly Tuareg (51 %; 41/80). The majority worked as breeders (56/80), i.e. 70 %, while 30 % (24/80) were camel herders. Furthermore, in 79 % of cases, the herds belonged to a single owner (63/80).

Assessment of Camel Breeders' Knowledge of Brucellosis

With regard to knowledge of the disease, it appears that no farmers were aware of camel brucellosis, susceptible species, clinical signs or modes of transmission.

Consequently, farmers were unaware of the potential for transmission of camel brucellosis from animals to humans via dromedaries, reflecting a marked lack of knowledge about the zoonotic nature of this disease.

Behaviors and Practices Posing a Risk of Exposure at the Animal–Human Interface

All of the breeders surveyed reported consuming raw camel milk or selling it unpasteurised. None of them reported boiling the milk before consumption or sale.

Furthermore, almost all farmers (99 %; 79/80) indicated that their camels cohabited or came into regular contact with other domestic species, particularly small ruminants, cattle, or sometimes donkeys. Newly acquired animals were generally introduced directly into the herd without prior quarantine, and isolation of sick animals was rarely observed, according to 86 % of farmers (69/80).

In the event of abortion, more than half of the breeders (45/80), or 56 %, reported handling the placenta and foetus with their bare hands, while contaminated waste or rejects were most often left in the open air. With regard to the management of breeding animals, the majority of respondents (69/80), or 86 %, did not lend or borrow breeding males. It also appeared that not

all of the breeders surveyed vaccinated their camels against brucellosis, and that the majority (66 %; 53/80) vaccinated against pasteurellosis. A cause for concern is that none of the breeders had received prior awareness training on this disease, nor training on good milk hygiene practices (milking or milk handling) or modern livestock management techniques.

Discussion

In recent years, brucellosis in camels has attracted growing interest, particularly in regions where camels play a major economic and cultural role, such as the Persian Gulf countries, Africa and parts of Asia (Yasmin and Remya, 2011). However, despite the importance of camel herds in Niger, epidemiological data on brucellosis in this species remain fragmentary, unlike those available for cattle and small ruminants, in which the disease is recognised as endemic throughout the country's livestock systems.

The overall seroprevalence of 0.6 % observed in this study highlights the circulation of Brucella spp. among dromedaries in the study area. This result is comparable to the low prevalences reported in the pastoral areas of south-eastern Ethiopia, where rates between 0.4 % and 0.9 % have been described (Bekele, 2004; Gumi *et al.,* 2013; Gessese *et al.,* 2014).

However, this seroprevalence is lower than the 4 % reported by Harouna *et al.* (2021) in the peri-urban dairy basin of Niamey (Niger), as well as those reported in other countries: 18.3 % in Egypt (Hussein *et al.,* 2025), 4.8 % in Ethiopia (Mohomed *et al.,* 2024), 5.3 % in Algeria (Benfodil *et al.,* 2022), 10.5 % in Nigeria (Salisu *et al.,* 2018), 5.7 % in Libya (Al-griw *et al.,* 2017) and 1.4 % in Chad (Schelling *et al.,* 2004).

In Ethiopia, several studies have also reported higher rates: 2.9 % (Ahad *et al.,* 2024), 2 % (Waktole *et al.,* 2022), 1.53 % (Robayo and Esubalew, 2017), 4.1 % (Hadush *et al.,* 2013), 5.4 % (Bekele *et al.,* 2013) and 7.6 % (Zewolda and Haileselassie, 2012).

Furthermore, this result is slightly higher than the zero seroprevalence (0 %) recorded by Madu *et al.* (2015) in Nigeria, Lounes *et al.* (2011) in Algeria, and El-Ansary *et al.* (2001) in Sudan.

The differences in seroprevalence observed in this study compared to those reported in other studies could be explained by several factors. These include agroecological variations between study areas, sample sizes, differences in herd management, herd composition (presence of other species), and the presence or absence of nearby infectious foci (Radostits *et al.,* 2007). Other factors may also influence these variations, such as the sensitivity of the diagnostic methods used, the nutritional and immune status of the animals, sampling bias, or livestock farming practices and the movements of livestock farmers.

In addition, climatic conditions could play a significant role. According to Akakpo and Bornarel (1987) and Saegerman *et al.* (2010), Brucella survives longer in cool, humid environments, while it is quickly destroyed in hot, dry climates, as is the case in the arid and semi-arid areas covered by this study. This factor could explain the low seroprevalence recorded. Nevertheless, this low prevalence should not be interpreted as an absence of risk. The detection of apparently healthy seropositive animals suggests the existence of asymptomatic carriers, which are likely to spread the pathogen within herds and represent a potential source of infection for humans, particularly through unprocessed animal products.

From a methodological point of view, it should be noted that no serological test is currently officially validated for the diagnosis of brucellosis in camelids. Although some studies have used combinations of serological tests to improve diagnostic sensitivity, such as cELISA, the modified Rose Bengal test (mRBPT) or the complement fixation test (CFT), interpreting the results remains difficult. The combination of the standard Rose Bengal test and iELISA used in this study nevertheless complies with generally accepted recommendations for seroepidemiological surveys in this species (Wernery, 2014).

Regarding the influence of sex on brucellosis seroprevalence in dromedaries, the present study found a slightly higher individual prevalence in females (1.10 %) than in males (0 %). However, this difference was not statistically significant ($\chi^2 = 1.658$; $p = 0.198$).

This finding is consistent with the results reported by several previous studies, notably those by Almuzaini *et al.* (2025) in Saudi Arabia, as well as Waktole *et al.* (2022), Wakjira *et al.* (2021), Gumi *et al.* (2013) and Hadush *et al.* (2013) in Ethiopia, and those of Madu *et al.* (2015) and Junaidu *et al.* (2006) in Nigeria. Nevertheless, data on the relationship between animal sex and brucellosis prevalence remain contradictory. Indeed, some authors have reported significantly higher seroprevalence in females, notably Mohomed *et al.* (2024), Benfodil *et al.* (2022), Salisu *et al.* (2018), El-Sayed *et al.* (2017), Warsame *et al.* (2012), Omer *et al.* (2010), Teshome *et al.* (2003) and Agab *et al.* (1994). According to Salisu *et al.* (2018), female camels are more susceptible to brucellosis infection than males. This vulnerability could be explained by the weakening of the immune system during gestation, lactation and physiological stress associated with reproduction (Salisu *et al.,* 2018; Gyles *et al.,* 2008). In addition, the presence of erythritol in females, a sugar that promotes the multiplication of Brucella, in high concentrations in the pregnant uterus, is thought to be a major biological factor explaining the greater susceptibility of females (Walker, 2004; Smith *et al.,* 1962). According to Hirsh and Zee (1999), male animals are less susceptible to Brucella infection due to the absence of erythritol sugar in their reproductive tissues. In addition, concentrations of erythritol and sex hormones increase with age and sexual maturity, which may also contribute to higher seroprevalence in females (Radostits *et al.,* 2007; Gyles *et al.,* 2008).

Furthermore, females are kept longer in herds for breeding purposes, unlike males, which are fattened and sold, with the exception of a few individuals that are kept

for breeding, pulling and transport (Salisu *et al.,* 2018). This longer exposure time could also increase the risk of infection in females.

Conversely, some authors have reported a higher seroprevalence of brucella antibodies in male dromedaries than in females (Hussein *et al.,* 2025; Admasu *et al.,* 2017; Tassew and Kassahun, 2014; Bekele *et al.,* 2013; Tilahun *et al.,* 2013). However, other researchers believe that there is no significant association between sex and the presence of anti-Brucella antibodies (Bayasgalan *et al.,* 2018; Fatima *et al.,* 2016; Ullah, 2015; Muma *et al.,* 2006; Musa and Shigidi, 2001; Akakpo *et al.,* 1986), suggesting equal susceptibility between the two sexes.

With regard to the distribution of seroprevalence by age group, a higher prevalence of brucellosis was observed in adult camels, aged 5 to 10 years (1.2 %), compared to young camels, in which no seropositive cases were detected (0% in animals under 5 years of age). However, this difference is not statistically significant ($\chi^2 = 2.061$; $p = 0.357$). These results are consistent with those reported by Hussein *et al.* (2025), Waktole *et al.* (2022), Wakjira *et al.* (2021), Hadush *et al.* (2013), Bekele *et al.* (2013). In the literature, opinions differ as to the influence of age on the seroprevalence of brucellosis. Several authors point to increased susceptibility in adult animals, with a significantly higher prevalence compared to young dromedaries (Mohomed *et al.,* 2024; Alatabi *et al.,* 2020; Alrawahi *et al.,* 2019; Admasu *et al.,* 2017; Madu *et al.,* 2015; Zewolda and Haileselassie, 2012; Warsame *et al.,* 2012; Dawood, 2008; Musa and Shigidi, 2001; Akakpo *et al.,* 1986). Indeed, age is considered one of the intrinsic factors associated with brucellosis in animals. According to Bekele *et al.* (2011), brucellosis is traditionally considered a disease of adult animals, as susceptibility increases after sexual maturity and pregnancy. This is because Brucella spp. has a tropism for the reproductive tract due to the production of the sugar erythritol in foetal tissues (Paridah *et al.,* 2016). According to Radostits *et al.* (2007), sexually mature animals are more susceptible to Brucella infection than sexually immature animals of both sexes. This can be explained by the fact that sex hormones and erythritol, which stimulate the growth and multiplication of Brucella, tend to increase in concentration with age and sexual maturity (Radostits *et al.,* 2007). In addition, the disease occurs more frequently in older animals because it is chronic in nature and the likelihood of exposure to infection increases with age (Acha and Szyfres, 2005). Furthermore, prolonged contact with infected animals or with an infected or contaminated environment also contributes to a higher prevalence of infection in adult animals; this is observed in herds where positive animals have not been removed from the herd (Megersa *et al.,* 2011). It is also true that younger animals tend not to show signs of infection and frequently clear or shed an established infection, although some latent infections may occur (Quinn *et al.,* 2004; Walker, 1999).

Some authors have reported that the seroprevalence of brucellosis in dromedaries is not significantly associated with age groups, suggesting that dromedaries of all ages are susceptible to infection (Benfodil *et al.,* 2022; El-Sayed *et al.,* 2017; Bekele *et al.,* 2013). According to El-Sayed *et al.* (2017), brucellosis infection can affect dromedaries from an early age, probably through the ingestion of milk from an infected mother, and persist into adulthood.

In this study, the farming system was not identified as a significant risk factor for brucellosis infection ($\chi^2 = 1.598$; $p = 0.449$), a result consistent with that reported by Benfodil *et al.* (2022) in Algeria. However, several studies have shown a higher seroprevalence of camel brucellosis in intensive farming systems compared to extensive or transhumant systems (Gwida *et al.,* 2012). In intensive farming, high animal density and the permanence of animals in the same space promote contamination of the environment by biological secretions, particularly during abortions, creating conditions conducive to the persistence and transmission of Brucella. Conversely, in nomadic or transhumant pastoral systems, the mobility of herds allows for rapid removal from contaminated areas, thus limiting the risk of superinfection. For example, seroprevalence rates of between 2% and 5% have been reported in countries practising nomadic or transhumant pastoralism, while higher rates, ranging from 8% to 15%, have been observed in intensive systems (Abbas and Agab, 2002; Radwan *et al.,* 1995). These differences are thought to be mainly related to the high animal density and more humid environmental conditions in intensive farming, which favour the survival and spread of brucellae between infected and susceptible animals.

The seroprevalence of brucellosis was higher in small and medium-sized herds than in large herds. However, herd size was not identified as a significant risk factor associated with infection ($\chi^2 = 2.725$; $p = 0.189$). This finding is consistent with the results obtained by Benfodil *et al.* (2022) in Algeria. However, it contradicts several studies that have demonstrated a significant association between herd size and brucellosis seroprevalence (Hussein *et al.,* 2025; Mohomed *et al.,* 2024; Bekele *et al.,* 2013; Hadush *et al.,* 2013; Zewolda and Haileselassie, 2012; Omer *et al.,* 2010), showing that animals belonging to large herds were more likely to be infected. The higher seroprevalence observed in large herds could be attributed to higher animal density and a high frequency of direct contact, favouring bacterial transmission, particularly during calving or abortion, periods during which bacterial shedding is particularly high (Abbas and Agab, 2002; Radostits *et al.,* 2007 Ghanem *et al.,* 2009). Thus, herd size, population density, ambient humidity and management practices play a decisive role in the dynamics of infection (Wernery and Kaaden, 2002; Abu-Eisha, 2000). However, some studies conducted in Ethiopia have found no significant association between herd size and serological prevalence (Waktole *et al.,* 2022; Admasu *et al.,* 2017).

The seroprevalence of brucellosis in dromedaries in contact with other ruminants (cattle, sheep, goats) was higher than in those raised without contact with other animals. However, this difference is not statistically

significant (P > 0.05). These results are consistent with those reported by Admasu *et al.* (2017) in Ethiopia and by Radwan *et al.* (1992) in Saudi Arabia.

On the other hand, several authors have reported a significantly higher seroprevalence in camels raised in association with other ruminants compared to those raised alone (Hussein *et al.,* 2025; Mohomed *et al.,* 2024; Bayasgalan *et al.,* 2018; Fatima *et al.,* 2016; Gessese *et al.,* 2014; Hadush *et al.,* 2013; Zewolda and Haileselassie, 2012; Ghanem *et al.,* 2009). This difference could be attributed to the increased risk of cross-species transmission in mixed livestock systems. Such distribution and diversification of animal species is common in other regions of Niger and has economic and ecological advantages. However, it increases the risk of transmission of brucellosis and other diseases to dromedaries from other infected ruminants. Indeed, the endemic nature of brucellosis in cattle and small ruminants and the lack of an adequate brucellosis control programme, including vaccination, may contribute to an increase in the prevalence of infection in dromedaries in the country, as the infection rate in dromedaries depends on the infection rate in primary host animals in contact with them.

With regard to camel breed, the seroprevalence of brucellosis was higher in the Azawak breed than in other breeds, but did not reach statistical significance (χ^2 = 0.170; p = 0.918). These results are consistent with those of numerous studies that have indicated that breed is not a factor influencing the seroprevalence of brucellosis in camels (Almuzaini *et al.,* 2025; Benfodil *et al.,* 2022; Alrawahi *et al.,* 2019; Radwan *et al.,* 1995; Agab *et al.,* 1994).

The questionnaire survey gathered information on the knowledge, attitudes and practices of camel breeders with regard to brucellosis in Niger.

The results show that the majority of farmers surveyed are unaware of the disease, the animal species susceptible to it, the clinical signs in infected animals, and even less so the modes of transmission from animals to humans. This finding is similar to that reported by Harouna *et al.* (2021) in the Niamey region (Niger), as well as by Gessese *et al.* (2014) and Bekele *et al.* (2013) in the Oromia and Afar regions of Ethiopia, respectively, where the majority of camel herders surveyed were unaware of the existence of camel brucellosis.

This lack of knowledge could be attributed to insufficient or even non-existent awareness campaigns targeting camel breeders. This knowledge gap represents a major obstacle to the adoption of effective prevention and control practices and could also increase the risk of zoonotic transmission of brucellosis within exposed communities. Furthermore, our results contradict those reported by Issaka (2018), who observed, during a survey on bovine brucellosis in Niamey and its surroundings, that all the cattle farmers interviewed had already heard of this disease. This difference could be explained by the fact that camel brucellosis has not received the same attention from local animal health authorities as cattle and small ruminants, particularly in terms of awareness-raising and extension services. This would explain the generally low level of awareness among these farmers regarding the existence of brucellosis in this species.

On these farms, the farming system is mainly traditional and extensive, and most camel farms are mixed, incorporating other animal species. The majority of the farmers interviewed reported that dromedaries live in close proximity to other species, particularly small ruminants and cattle. This finding is consistent with the observations reported by Harouna *et al.* (2021) in Niger, as well as by Gessese *et al.* (2014) and Bekele *et al.* (2013) in the Oromia and Afar regions of Ethiopia, respectively. In extensive mixed systems, frequent contact between camelids, sheep, goats and cattle, species susceptible to B. abortus and B. melitensis, is a major factor in interspecies transmission. Separate rearing of these species would reduce this risk, although this measure remains difficult to implement in pastoral contexts based on free grazing. In this context, dromedaries and other species frequent the same pastures and share the same water points, which are often used simultaneously by several herds from different localities. This situation promotes close contact between potentially infected and healthy animals, thereby increasing the risk of transmission (Harouna *et al.,* 2021). The literature also emphasises that communal grazing and shared water sources are important factors in the spread of disease (Acha and Szyfres, 2005).

According to Musa *et al.* (2008), camels can be infected by both Brucella abortus and Brucella melitensis. Thus, the occurrence of brucellosis in dromedaries depends both on the Brucella species circulating in other animals sharing their habitat and on the farming system practised. Also, the transhumance during the dry season, particularly movements to watering points, encourages the gathering of animals from different geographical origins, creating conditions conducive to the spread of infection (Radostits *et al.,* 2007). Added to this are the mobility practices of livestock farmers, particularly seasonal migrations across departments, regions and sometimes international borders, especially with Nigeria. This mobility, often associated with trade in animals that are not subject to veterinary control, increases the risk of brucellosis being introduced and spread within herds.

In this study, it was observed that farmers frequently consume raw camel milk, a practice also reported by Harouna *et al.* (2021) in Niger, as well as by Gessese *et al.* (2014) and Bekele *et al.* (2013) in Ethiopia. However, the consumption of unpasteurised milk from infected animals is one of the most significant modes of transmission of brucellosis to humans. Human infection can also occur through the ingestion of contaminated fresh cheese, vegetables contaminated with brucellic manure consumed raw, or through the inhalation of dust from infected litter. In addition, farmers often handle placentas and aborted foetuses with their bare hands during abortions, which represents a high risk of exposure to Brucella. Transmission to humans can thus occur through direct contact with infected animals or

through the handling of abortive products, particularly in people who are in close contact with animals (Araita, 2013; Yumuk and O'Callaghan, 2012).

In addition, certain practices such as the loan of breeding males between farmers, the use of the same breeding male for several herds, the retention in the herd of females that have had repeated abortions, and the introduction of new animals without prior quarantine are all factors that promote the transmission and spread of the disease. These findings suggest that, in general, the zoonotic nature of brucellosis remains largely unknown to camel breeders. However, occupational exposure to brucellosis remains high, particularly in countries where traditional livestock farming practices are still in use, as is the case in Niger. This situation is exacerbated by inadequate preventive measures, the lack of effective control programmes, and the uncontrolled movement of animals across often porous borders. These results highlight the urgent need to set up awareness campaigns for camel breeders and to promote greater involvement of veterinary services in pastoral activities.

Veterinarians play a key role in disseminating good hygiene practices, improving herd health management, and contributing to the long-term prevention and control of brucellosis.

CONCLUSION

The study revealed a seroprevalence of 0.6%. Although relatively low, this result confirms the circulation of Brucella spp. in the region and should not be overlooked in view of the local epidemiological context. The identification of major risk practices, in particular the consumption of raw milk, close and repeated contact with animals, and the low perception of the zoonotic nature of the disease by farmers, highlights the persistence of practices that promote the transmission of infection. In light of these findings, it appears essential to carry out awareness-raising activities among livestock farmers. These campaigns should focus on the prevention of zoonotic diseases, the adoption of good hygiene practices, modern farming methods and the dangers associated with the consumption of unpasteurised animal products, particularly raw milk.

Given the zoonotic potential of brucellosis, it is necessary to implement prevention and epidemiological surveillance measures at the national level. This includes identifying circulating strains and establishing a prophylactic strategy tailored to the species concerned, with the aim of protecting both the health of camel herds and that of human populations. Finally, to ensure effective control of this major yet neglected zoonosis, an integrated One Health approach is required. This requires the coordinated commitment of all stakeholders in animal, human and environmental health.

Acknowledgement

The authors express their sincere gratitude to the Regional Centre of Excellence on Pastoral Production (CERPP) Niger, through the Faculty of Agronomy of Abdou Moumouni University in Niamey, for their support in carrying out this research; To the Central Livestock Laboratory (LABOCEL) of Niger for the serological analysis of the samples; The Tahoua Regional Livestock Laboratory for processing samples in the field; The Local Private Veterinary Services (SVPP) of Tahoua, Bouza, Madaoua and the Abalak departmental directorate for their support in the field; The livestock farmers and camel owners for their frank cooperation.

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