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Assessment of knowledge, attitudes and practices relating to brucellosis among cattle farmers, meat handlers and medical professionals in Namibia

Oscar Madzingira[1,2] | Charles Byaruhanga[2] | Folorunso Oludayo Fasina[3] | Henriette van Heerden[2]

[1]Faculty of Agriculture and Natural Resources, School of Veterinary Medicine, University of Namibia, Windhoek, Namibia

[2]Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, South Africa

[3]Emergency Centre for Transboundary Animal Diseases-Food and Agriculture Organisation of the United Nations (ECTAD-FAO), Dar es Salaam, Tanzania

Correspondence
Oscar Madzingira, Faculty of Agriculture and Natural Resources, School of Veterinary Medicine, University of Namibia, Windhoek, Namibia.
Email: omuzembe@gmail.com

Impacts: This study assessed knowledge, attitudes and practices regarding brucellosis among cattle farmers, meat handlers and medical professionals. Respondents had a low level of awareness and knowledge of brucellosis, and showed attitudes that can expose them to infection. Raw milk consumption, assisting cow delivery with bare hands and lack of vaccination of cattle against brucellosis are some of the practices that were identified as promoting human and bovine brucellosis. Low level of surveillance of the disease in medical facilities was identified despite a high level of awareness among medical professionals.

Results of the study can be used to inform brucellosis control programmes in both humans and cattle in Namibia.

Abstract

Background: Brucellosis is a re-emerging zoonosis of significant socio-economic, animal and public health importance. It is principally a foodborne or occupation-associated infection of humans, whose effective control depends on maximum cooperation of high-risk populations.

Objectives: The study assessed knowledge, attitudes and practices relating to brucellosis among cattle farmers (communal and commercial), meat handlers (abattoir and butchery workers) and medical professionals (nurses and doctors) in Namibia.

Methods: Between June 2019 and September 2020, self-administered questionnaires and questionnaire interviews were carried out in cattle farmers (n = 264), meat handlers (n = 143) and medical professionals (n = 124) in Namibia.

Results: Overall, 43.50% (231/531) of respondents were aware of brucellosis, with the highest awareness among medical professionals (73.39%, 91/124) and the least in meat handlers (13.99%, 20/143). Awareness of brucellosis was associated with tertiary education ($p < 0.001$) and the medical profession ($p < 0.001$). However, most medical professionals (98.39%, 122/124) did not consider brucellosis as a differential diagnosis in cases of persistent febrile illness. A proportion of communal (85.60%) and commercial (71.00%) farmers; abattoir workers (44.40%); butchers (53.50%); nurses (55.60%); and medical doctors (28.00%) consumed raw milk.

Conclusions: The study identified the purchase of animals of unknown health status; assisting cow delivery; handling of aborted fetuses with no protective wear; consumption of raw milk, homemade cheese, cattle testes and undercooked livers, as risk factors for Brucella infection in cattle and humans. Thus, intensified risk communication, including public health education, is recommended, in particular, among meat handlers and communal farmers, to promote awareness and discourage risky practices.

KEYWORDS
brucellosis, farmers, knowledge, meat handlers, medical professionals, practices

1 | INTRODUCTION

Brucellosis is a re-emerging zoonosis of significant animal and public health importance (Franc et al., 2018). *Brucella abortus*, *B. melitensis*, *B. suis* and *B. canis* are the species that preferentially infect cattle, small ruminants, pigs and dogs, respectively, and cause disease in humans (Moreno et al., 2002). Human brucellosis is principally acquired through the ingestion of infected animal products, especially unpasteurized dairy products or by accidental occupational exposure to infected animal material (Corbel, 1997; Ibironke et al., 2008). Therefore, persons who come into regular contact with livestock and livestock products, such as farmers and meat handlers, are at greater risk of *Brucella* infection (Corbel, 2006). Often, occupationally exposed individuals have limited knowledge of the disease (DAFF, 2017). In animals, infection is transmitted through ingestion, or direct contact with infected aborted material (Garin-Bastuji et al., 1998). Due to the similarity of clinical manifestation between brucellosis and other human febrile diseases (such as malaria, Q fever and leptospirosis), misdiagnosis often occurs, leading to inappropriate treatment.

In Namibia, brucellosis is an endemic and notifiable disease in both humans and animals. Control of the disease in cattle is based on compulsory vaccination of heifers of 3–8 months of age with *Brucella* S19, or RB51 vaccine in cattle older than 8 months; routine serological testing (Rose Bengal test and complement fixation test) at the state laboratory; and culling of positive reactors (AHR, 2018). In humans, suspected clinical cases are confirmed at the state laboratory using the standard tube agglutination test or the IgG enzyme-linked immunosorbent assay and treated using a standard 6-week treatment protocol of doxycycline and rifampicin. No measures are specified for active surveillance or prevention of infection in the human population. The continued detection of cases in the human population in Namibia (Madzingira et al., 2020) points to the need to improve disease prevention and control measures in both animal and human populations.

Previous studies have linked accurate knowledge of the cause, methods of transmission, clinical manifestation, attitudes and practices with effective control of brucellosis in populations (Howyida et al., 2012; Lindahl et al., 2015). Studies in South Africa (Cloete et al., 2019), Uganda (Kansiime et al., 2014; Nabirye et al., 2017), Kenya (Obonyo & Gufu, 2015), Jordan (Musallam et al., 2015), Nigeria (Buhari et al., 2015) and Tajikistan (Lindahl et al., 2015) among others demonstrate the varying levels of brucellosis knowledge and awareness among countries, and highlight the need to base human brucellosis control measures on identified country-specific knowledge, attitude and practice gaps. Therefore, the current study aimed to assess knowledge, attitudes and practices relating to brucellosis among cattle farmers, meat handlers and medical personnel so as to recommend prevention and control measures that are relevant to the country.

2 | MATERIALS AND METHODS

2.1 | Study area

Namibia is located in the southwestern part of Africa. It is divided into 14 administrative regions. The northern part of the country comprises communal land on which cattle are raised on shared grazing, while the southern part of the country has predominantly commercial livestock farmers who raise cattle on private land. Both communal and commercial cattle farmers can access government veterinary services and private veterinary services at a fee.

2.2 | Study design

This cross-sectional survey was conducted between June 2019 and September 2020 in both northern communal and southern commercial cattle farming areas of the Zambezi, Kavango East, Hardap, Khomas and Omaheke (Figure 1) regions using a pretested semi-structured questionnaire. The five study regions were selected from the 14 regions of Namibia using stratified random sampling, with production system (communal or commercial) and location (north or south of the country) as strata. Commercial cattle farmers in Hardap, Khomas and Omaheke region, and communal cattle farmers in the Zambezi, Kavango East and Omaheke regions were selected for the study. In each region, participating farmers were selected using systematic random sampling at state veterinary offices, animal auctions and during routine farm inspections. Abattoir workers at a major beef export abattoir located in the Khomas region, and butchery employees in urban areas of Divundu (Kavango East), Katima Mulilo (Zambezi), Windhoek (Khomas) and Gobabis (Omaheke) who consented to the study were targeted. Due to the limited number of meat handlers and butcheries in the urban areas of Divundu, Katima Mulilo and Gobabis, all butcheries and meat handlers were enrolled in the study. In the larger city of Windhoek, workers at all butcheries in two low-income residential areas where the majority of the population lived were targeted. Medical professionals were from major private and state medical facilities located in the towns or cities of Mariental, Windhoek, Gobabis, Rundu and Katima Mulilo. Respondents 18 years of age and above, of any gender, who gave consent were included in the study. In butchery and abattoir workers, working with or handling meat or cattle was a criterion for inclusion in the study. All nurses and medical doctors at selected health facilities were included in the study.

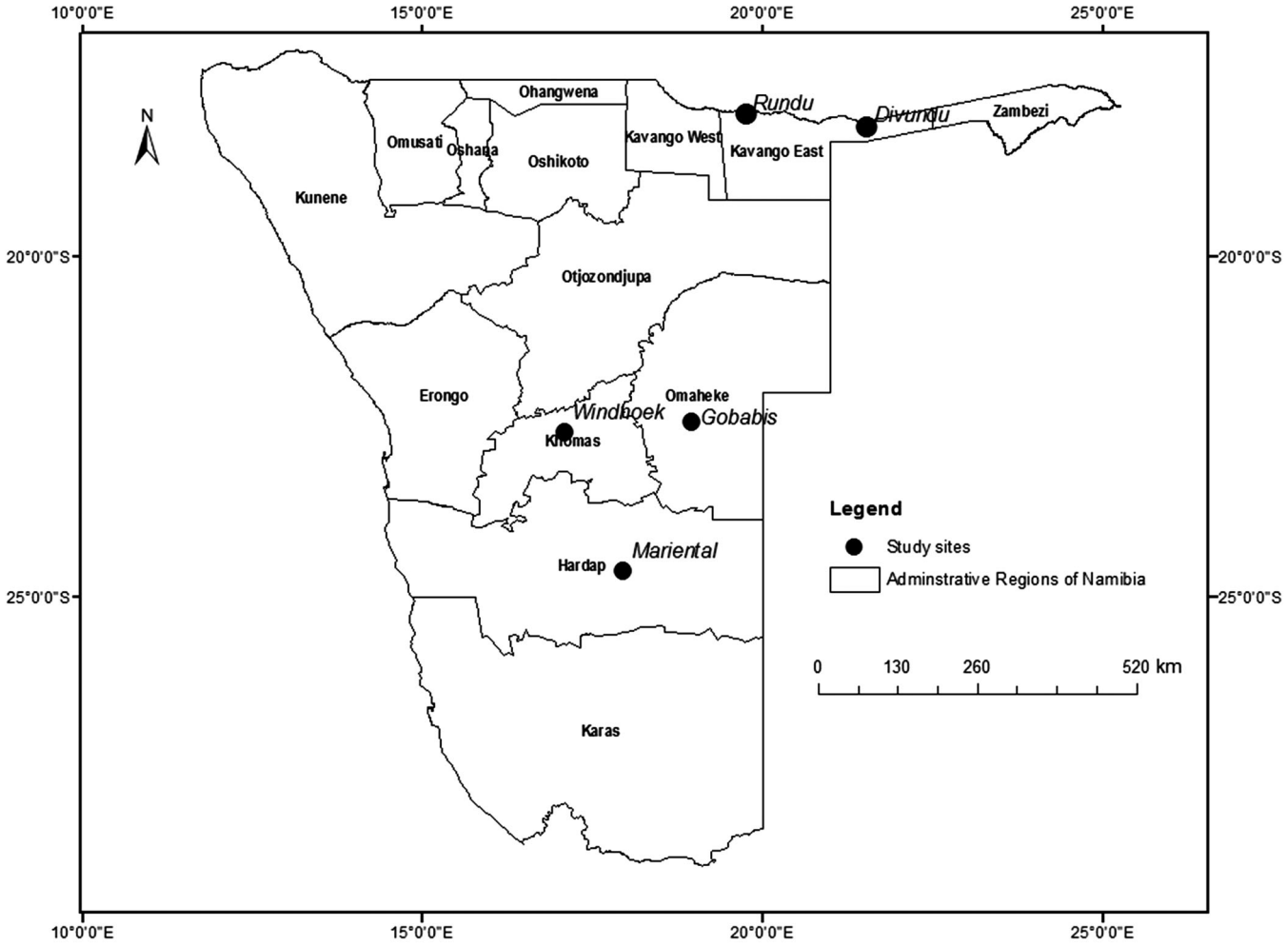

FIGURE 1 Administrative regions of Namibia ($n = 14$). The study was carried out in Hardap, Khomas, Omaheke, Kavango East and Zambezi regions

2.3 | Sample size

The sample size estimated for this study was 385. This was determined using Epitools (https://epitools.ausvet.com.au), assuming an estimated true proportion of 50%, and a precision of 0.05 at a 95% level of confidence. However, 531 participants were enrolled in the study to account for any possible clustering effects.

2.4 | Data collection

Questionnaire interviews were carried out by trained veterinary officials at state veterinary offices, animal auctions and during routine farm inspections, while some questionnaires were distributed to farmers through the national farmers' organization. In the communal areas of the Zambezi, Kavango East, and the commercial areas of Omaheke, interviews were carried out during farmers' meetings, auctions and at systematically selected households in the villages. In meat handlers and communal farmers, questionnaire interviews were performed by veterinary paraprofessionals who were trained by the principal investigator. Questions were translated into the local language during interviews as needed. For medical professionals, questionnaires were distributed to medical doctors and nurses at medical facilities in towns located in the five study regions with the permission of the Chief Medical Officer of the area.

The questionnaires for farmers, meat handlers and medical professionals were divided into sections A to E; A to D; and A to B, respectively. Section A was designed to gather the socio-demographic information (age, sex, education level, job title and the number of years on the job of respondents), while section B gathered information on brucellosis awareness and knowledge, including cause, transmission, clinical manifestation and control in both humans and cattle. For medical professionals, information on predisposing practices, and disease cases and their management were captured under section B. Sections C, D and E gathered information on attitudes and predisposing practices for *Brucella* infection.

TABLE 1 Socio-demographic features of the survey respondents ($n = 531$) from five regions of Namibia

Variable	Category	Communal farmers ($n = 195$)%	Commercial farmers ($n = 69$)%	Abattoir employees ($n = 72$)%	Butchers ($n = 71$)%	Nurses ($n = 99$)%	Medical doctors ($n = 25$)%
Age	18–30	9.7	7.3	38.9	32.4	49.5	24.0
	31–50	53.9	55.1	58.3	62.0	42.4	60.0
	>50	36.4	37.7	2.8	5.6	8.1	16.0
Gender	Male	73.9	91.3	72.2	78.9	33.3	68.0
	Female	26.2	8.7	27.8	21.1	66.7	32.0
Education level	No formal education	12.3	2.9	0.0	16.9	0.0	0.0
	Primary	14.9	14.5	6.9	25.4	0.0	0.0
	Secondary	36.4	46.4	80.6	46.5	0.0	0.0
	Tertiary	36.4	36.2	12.5	11.3	100.0	100.0
Region	Hardap	0.0	46.4	0.0	0.0	22.2	12.0
	Omaheke	21.5	53.6	0.0	11.3	13.1	0.0
	Kavango East	13.3	0.0	0.0	53.5	19.2	16.0
	Zambezi	65.1	0.0	0.0	16.9	24.2	20.0
	Khomas	0.0	0.0	100.0	18.3	21.2	52.0

2.5 | Statistical analysis

Data were coded manually in Microsoft Excel and uploaded into the statistical software IBM SPSS version 22 (SPSS, Inc., Chicago, IL, USA) for analysis. Data from close-ended responses were presented as frequencies and percentages per question, while open-ended responses were categorized into themes and subjected to content analysis. The chi-square or Fisher's exact tests were used to determine the significance of differences between proportions of respondents for each variable: between communal and commercial farmers, between nurses and doctors, and between abattoir and butchery workers.

For multi-variable analysis, seven variables that were common to all participant categories (farmers, medical workers and meat handlers), and considered to be of importance in exposure to brucellosis were considered. The multiple correspondence analysis (MCA) was performed to determine patterns in the dataset, whereby different categories of each column and row variables, and the relations between them, were depicted as 'clouds' of points in a multidimensional Euclidean space. The variables were: the age of the respondent (18–30, 31–50, >50 years), gender, education level (no formal education, primary, secondary, tertiary), profession (nurse, doctor, commercial farmer, communal farmer, butcher worker, abattoir worker), number of years at work (<2 years, 2–5 years, >5 years), awareness about brucellosis (yes, no), and consumption of raw milk and its products (yes, no). Interpretation of the results was made on basis of the relative distribution and position of points across the dimensions. The number of MCA dimensions to retain was determined using the eigenvalue criteria. The coordinates (*coord*), quality of representation (*cos2*) and contribution (*contrib*, %) of each variable to the dimensions on the factor map were determined. Data analysis was performed using R packages 'FactoMineR', 'ggplot2' and 'Factoextra' in R Console version 4.0.3 (R Core Team, 2020) at a 5% level of significance.

3 | RESULTS

3.1 | Socio-demographic characteristics of respondents

A total of 531 respondents: 264 cattle farmers (communal = 195, commercial = 69), 143 meat handlers (abattoir employees = 72, butchers = 71) and 124 medical professionals (nurses = 99, medical doctors = 25) from the Hardap ($n = 57$), Khomas ($n = 119$), Omaheke ($n = 100$), Kavango East ($n = 87$) and Zambezi ($n = 168$) regions of Namibia took part in the survey. There were more male (68.74%, $n = 365$) than female (31.26%, $n = 166$) respondents. The demographic features of the study groups are shown in Table 1.

3.2 | Awareness of brucellosis among respondents

Overall awareness of brucellosis among participants was 43.5% (231/531). The highest frequency of brucellosis awareness was recorded among medical professionals (73.4%, 91/124) (all medical doctors, $n = 25$; most nurses, 67.0%, 66/99), followed by cattle farmers (45.5%, 120/264) (commercial farmers, 84.1%, 58/69; communal farmers, 31.8%, 62/195) and meat handlers (14.0%, 20/143) (butchers, 8.5%, 6/71; abattoir workers, 19.4%, 14/72) in descending order. Evaluation of education levels showed an association between disease awareness and tertiary education ($p < 0.001$). Thus, most nurses

TABLE 2 Knowledge of brucellosis among communal and commercial farmers in selected regions in Namibia

	Communal farmers ($n = 195$)		Commercial farmers ($n = 69$)		
	Frequency		Frequency		
Variable	*N*	%	*N*	%	*p* value
Species affected	54	27.7	55	79.7	<0.001*
Mode of transmission to humans	20	10.3	35	50.7	<0.001*
Mode of transmission to cattle	21	10.8	37	53.6	<0.001*
Symptoms in humans	15	7.7	30	43.5	<0.001*
Clinical signs in cattle	27	13.9	20	29.0	0.005*
Prevention in humans	15	7.7	23	33.3	<0.001*
Prevention in cattle	42	21.5	52	75.4	<0.001*

Note: The participating farmers were selected from Gobabis, Hardap, Kavango, Khomas and Zambezi regions in Namibia. *N* = number of respondents. Proportions were compared using the chi-square test of association.
* Statistically significant at 5% level of significance.

(67.0%, 66/99) and all medical doctors ($n = 25$) with tertiary education were aware of brucellosis ($p < 0.001$). Individuals who had worked for more than 5 years were more aware of brucellosis than those who had worked for less than 2 years or 2–5 years.

3.3 | Specific knowledge of brucellosis in communal and commercial farmers

Brucellosis knowledge was higher in commercial than communal cattle farmers ($p < 0.05$) (Table 2). More than 70.0% (range: 72.3–92.3%) of communal farmers lacked knowledge about the animal species affected by brucellosis; its transmission; zoonotic nature; symptoms or clinical signs; prevention and management approaches in both humans and animals (Table 2). In contrast, more than half of commercial farmers had knowledge of most aspects of brucellosis (Table 2).

3.4 | Specific knowledge of brucellosis among meat handlers

The majority of abattoir (83.3–97.2%) and butchery (94.4–100%) workers lacked knowledge of brucellosis (species affected, transmission, symptoms and prevention) (Table 3), with most meat handlers unable to state one zoonotic disease (88.1%) or cause of abortion in cattle (91.6%).

3.5 | Specific knowledge of brucellosis among medical professionals

All medical doctors (25/25) and the majority of the nurses (68.7%, 68/99) had knowledge of the mode of transmission of brucellosis to humans. A higher proportion of medical doctors (92.0%) than nurses (71.7%) gave correct advice regarding the prevention of *Brucella* infection in humans ($p = 0.04$). Although the majority of medical doctors (96.0%) and nurses (82.8%) had encountered cases of persistent fever in patients, only 1.6% of medical professionals (two medical doctors) listed brucellosis as part of the differential diagnosis. Other differential diagnoses listed were malaria, tuberculosis, urinary tract infection, respiratory tract infection, meningitis, HIV/AIDS, influenza (H1N1), COVID-19 and typhoid fever in descending order (data not shown).

3.6 | Farmers' attitude towards brucellosis

The majority of communal (96.4%) and commercial (82.6%) cattle farmers did not consider themselves at risk of *Brucella* infection (Table 4). More commercial (53.6%) than communal (30.3%) farmers considered raw milk to be of the same health status as pasteurized milk ($p < 0.05$) (Table 4). However, a high proportion of communal (85.6%) and commercial (68.1%) farmers boiled raw milk prior to consumption. Abortions in cattle were considered as a serious to very serious occurrence in cattle herds by communal (96.9%) and commercial farmers (89.8%). However, a high proportion of communal (75.4%) and commercial (82.6%) farmers did not consult a veterinarian when faced with a diseased animal.

3.7 | Meat handlers' attitude towards brucellosis

More abattoir than butchery workers considered the handling of abortion material (43.1% vs. 19.7%) as unsafe with regard to *Brucella* infection ($p < 0.001$) (Table 5). Overall, a high proportion of meat handlers were averse to handling (67.1%) or drinking cattle blood (90.2%), and to the opening of a cow's uterus without protective gear (76.9%). About 45.5% ($n = 65$) of meat handlers regarded raw cow's milk and homemade cheese as having the same health status as pasteurized products sold in the shops.

TABLE 3 Knowledge of brucellosis among meat handlers (abattoir and butchery workers) ($n = 143$) in selected regions of Namibia

	Abattoir workers ($n = 72$)		Butchery workers ($n = 71$)		
	Frequency		Frequency		
Variable	*N*	%	*N*	%	*p* value
Species affected	10	13.9	4	5.6	0.16
Mode of transmission to humans	4	5.6	3	4.2	0.72
Mode of transmission to cattle	4	5.6	3	4.2	1.0
Symptoms in humans	5	6.9	0	0	0.06
Clinical signs in cattle	2	2.8	2	2.8	1.00
Prevention in humans	11	15.3	2	2.8	0.02*
Prevention in cattle	12	16.7	3	4.2	0.03*

Note: The participating meat handlers were selected from one abattoir and 35 butchers in four regions (Gobabis, Khomas, Kavango East and Zambezi) in Namibia. *N* = number of respondents. Proportions were compared using the Fisher's exact test of association.
* Statistically significant at 5% level of significance.

TABLE 4 Frequency of responses from communal and commercial farmers ($n = 264$) showing their attitudes towards brucellosis and possible sources of infection in Namibia

Variable	Communal farmers ($n = 195$)		Commercial farmers ($n = 69$)		
	Frequency		Frequency		
	N	%	*N*	%	*p* value
Raw milk or homemade cheese is as healthy as similar products sold in retail shops					
Yes	59	30.3	37	53.6	<0.001*
No	134	68.7	28	40.6	
Don't know	2	1.0	4	5.8	
It is necessary to boil raw milk before drinking it					
Yes	167	85.6	47	68.1	0.001*
No	26	13.3	17	24.6	
Don't know	2	1.0	5	7.2	
Seriousness of cattle abortions					
Very serious	125	64.1	53	76.8	0.001*
Serious	64	32.8	9	13.0	
Not important	6	3.1	7	10.1	
Handling of diseased cattle					
Treat myself	159	81.5	57	82.6	<0.001*
Seek veterinary help	68	34.9	19	27.5	
Slaughter for meat	4	22.1	2	2.9	
Do nothing	0	0	2	2.9	
Risk of *Brucella* infection					
Yes	60	30.8	10	14.5	0.006*
No	120	61.5	47	68.1	
Don't know	15	7.7	12	17.4	
Need for brucellosis information					
Yes	188	96.4	57	82.6	<0.001*
No	7	3.6	12	17.4	

Note: The survey was conducted in five of the 14 regions in Namibia. *N* = number of participants. Proportions compared using the chi-square or Fisher's exact tests of association.
* Statistically significant at 5% level of significance.

TABLE 5 Responses of abattoir and butchery workers ($n = 143$) showing their attitudes towards sources of *Brucella* infection at home and the work place in selected regions of Namibia

	Abattoir workers ($n = 72$)		Butchery workers ($n = 71$)		
	Frequency		Frequency		
Variable	*N*	%	*N*	%	*p* value
Raw milk or homemade cheese is as healthy as similar products sold in retail shops					
Yes	44	61.1	21	29.6	<0.001*
No	28	38.9	50	70.4	
Handling aborted or stillborn calves with no protection can result in *Brucella* infection					
Yes	31	43.1	14	19.7	<0.001*
No	19	26.4	12	16.9	
Don't know	22	30.6	45	63.4	
It is safe to handle blood from slaughtered cattle with unprotected hands					
Yes	13	18.1	23	32.4	0.004*
No	57	79.2	39	54.9	
Don't know	2	2.8	9	12.7	
It is safe to drink blood from slaughtered cattle					
Yes	13	18.1	2	2.8	0.003*
No	57	79.2	63	88.7	
Don't know	2	2.8	6	8.5	
Risk of *Brucella* infection at work					
Yes	20	27.8	27	38.0	0.037*
No	44	61.1	43	60.6	
Don't know	8	11.1	1	1.4	

Note: The survey was conducted in three of the 14 regions in Namibia. *N* = number of respondents. Proportions were compared using the chi-square or Fisher's exact tests of association.
*Statistically significant at 5% level of significance.

3.8 | Attitude of medical professionals towards brucellosis

Although the majority of nurses (64.6%) and doctors (84.0%) did not think that they were at risk of *Brucella* infection, a high proportion (94.9% and 88.0%, respectively) indicated that they needed more information on the disease.

3.9 | Practices that promote *Brucella* infection among farmers

A higher proportion of communal than commercial cattle farmers engaged in practices that promote *Brucella* infection ($p < 0.05$) (Table 6), including raw milk consumption, assisting cow delivery, frequent mixing of herds, use of communal bulls, grazing of cattle with other species, such as sheep and goats, and purchasing of replacement stock from other farmers and auctions (Table 6). The proportion of farmers who vaccinated cattle against brucellosis (using *Brucella* S19 or RB51 vaccines) in commercial areas (87.0%, $n = 60$) was higher than the vaccination rate for communal areas (19.5%, $n = 38$). No *Brucella*-positive cattle were reported by commercial cattle farmers. However, one communal cattle farmer reported a case of a seropositive cow that remained in the herd. Both communal and commercial cattle farmers disposed of aborted fetuses and membranes on pastures (29.9%, 79/264), by feeding to dogs (28.8%, 76/264), burying (29.9%, 79/264) or burning to ashes (6.4%, 27/264).

3.10 | Meat handlers' practices that promote *Brucella* infection

Practices that promote *Brucella* infection among abattoir and butchery workers were splashing of blood into the eyes, eating undercooked or raw meat/viscera, drinking raw milk, assisting cows to deliver with bare hands and eating homemade cheese (Table 7). Abattoir workers were

TABLE 6 Practices that promote *Brucella* infection in humans among communal and commercial farmers in Namibia

	Communal farmers ($n = 195$)		Commercial farmers ($n = 69$)		
	Frequency		Frequency		
Variable	*N*	%	*N*	%	*p* value
Raw milk consumption					
Yes	167	85.6	49	71.0	0.007*
No	28	14.4	20	29.0	
Handling of aborted fetuses with bare hands					
Yes	62	31.8	22	31.9	0.99
No	133	68.2	47	68.1	
Assisting cows to deliver					
Yes	127	65.1	34	49.3	0.035*
No	68	34.9	35	50.7	
Raising cattle with other animal species (e.g. goats or sheep)					
Yes	72	36.9	58	84.1	<0.001*
No	123	63.1	11	15.9	
Purchase of replacement cattle from outside (e.g. other farmers and auctions)					
Yes	166	85.1	51	73.9	0.036*
No	29	15.9	18	26.1	
Veterinary health checks on replacement animals					
Yes	149	84.2	39	56.5	0.003*
No	28	15.8	14	20.3	
Frequency of contact with other herds					
Always	147	75.4	0	0	<0.001*
Sometimes	42	21.5	3	4.3	
Rarely	1	0.5	8	11.6	
Don't mix at all	5	2.6	58	84.1	
Breeding method					
Own bull	161	82.6	69	100.0	<0.001*
Communal bull	34	17.4	0	0	

Note: Survey conducted in five of the 14 regions in Namibia. Proportions were compared using the chi-square and Fisher's exact tests of association.
*Statistically significant at 5% level of significance.

not permitted to handle meat or animals with bruised or injured hands (Table 7) as they were provided with full protective gear, while 7.0% ($n = 5$) and 38.0% ($n = 27$) of the butchers handled meat using bare hands and had no protective gear, respectively (Table 7).

3.11 | Practices that promote *Brucella* infection among medical professionals

More nurses (55.6%, 55/99) than medical doctors (28.0%, 7/25) ($p = 0.014$) consumed raw milk and/or other dairy products. One medical doctor and six nurses assisted cows to deliver without hand protection.

3.12 | Human brucellosis cases observed by respondents

Among the respondents, only commercial cattle farmers ($n = 4$), nurses ($n = 3$) and medical doctors ($n = 2$) had seen a total of 13 hospital (laboratory) confirmed cases of the disease in their lifetime. The source of infection in the observed cases was reported as raw milk consumption and contact with live or dead cattle. The clinical signs described were fever, body weakness, poor appetite, vomiting, abdominal pain, diarrhoea, weight loss, back pain, joint pain, general body aches, skin rashes, headaches, night sweats, swollen liver and lymph nodes. All 13 cases are reported to have recovered following treatment at the hospital.

TABLE 7 Practices that may promote *Brucella* infection as mentioned by abattoir and butchery workers in Namibia

	Abattoir workers ($n = 72$)		Butchery workers ($n = 71$)		
	Frequency		Frequency		
Variable	*N*	%	*N*	%	*p* value
Consumption of raw milk or homemade cheese					
Yes	32	44.4	38	53.5	0.32
No	40	55.6	33	46.5	
Handle cattle fetuses during carcass dressing					
Yes	8	11.1	13	18.3	0.25
No	64	88.9	58	81.7	
Frequency of blood splash into the eyes					
Always	3	4.2	3	4.2	0.89
Sometimes	17	23.6	16	22.5	
Rarely	17	23.6	13	18.3	
Never	35	48.6	39	54.9	
Eat cattle testicles, uteri, undercooked or raw meat					
Yes	35	48.6	26	36.6	0.18
No	37	51.4	45	63.4	
Handle meat with bare hands following injury					
Yes	0	0	5	7.0	0.03*
No	72	100	66	93.0	

Note: The survey was conducted in five of the 14 regions of Namibia, using semi-structured questionnaires. *N* = number of respondents. Proportions were compared using chi-square and Fisher's exact test.
*Statistically significant at 5% level of significance.

3.13 | Consumption of raw milk and milk products

MCA found no association between awareness of brucellosis and consumption of raw milk ($p = 0.62$) (Figure 2). Therefore, despite a high level of awareness of brucellosis among commercial cattle farmers (84.0%, 58/69), a large proportion (71.0%, 49/69) consumed raw milk and/or milk products (Figure 2). Consumption of raw milk and milk products was associated more with older age categories, >50 years (72.2%, 83/115) and 31–50 years (68.2%, 195/286), than with the younger category, 18–30 years (53.8%, 70/130) ($p = 0.004$) (Figure 2). Results showed a decline in raw milk consumption with increasing level of education, but the differences were not significant ($p = 0.23$). Results showed that longer duration in an occupation (>5 years) (71.3%, 238/334) was linked to consumption of raw milk and its products (Figure 2). Raw milk consumption was more prevalent among males (69.9%, 255/365) than females (56.0%, 93/166) ($p = 0.002$) (Figure 2).

4 | DISCUSSION

Brucellosis has been confirmed in humans (Magwedere et al., 2011) and domestic ruminants (Madzingira et al., 2014, 2015, 2016, 2020) in Namibia. Hence, a method 'One Health' approach was used to assess knowledge, attitudes and practices in farmers, meat handlers and medical professionals with a view to provide evidence-based guidance to brucellosis control programmes and public health interventions in the country.

The study determined a brucellosis awareness level of 43.5% among the respondents, which is lower than awareness levels of greater than 80% reported in similar populations in other African countries (Buhari et al., 2015; Kansiime et al., 2014; Safaan & Mohsen, 2016). Low awareness levels as recorded in the current study expose the population to *Brucella* infection; negatively impact compliance with brucellosis control measures; and can lead to under-reporting of disease incidence in the country (Ruano & Aguayo, 2017). In agreement with studies by Lindahl et al. (2015), and Ruano and Aguayo (2017), our results showed low awareness of the disease among groups with lower education levels (communal cattle farmers, abattoir workers and butchers). This finding highlights the need to focus public health education and risk communication strategies on such groups in order to raise awareness. High awareness of brucellosis among medical professionals is confirmation that formal training on disease risks can raise awareness in specific groups. The observation that brucellosis increased with the number of years spent in an occupation is evidence that experiential learning is an important component of brucellosis knowledge acquisition (Govindaraj et al., 2016). Other studies documented causes of low

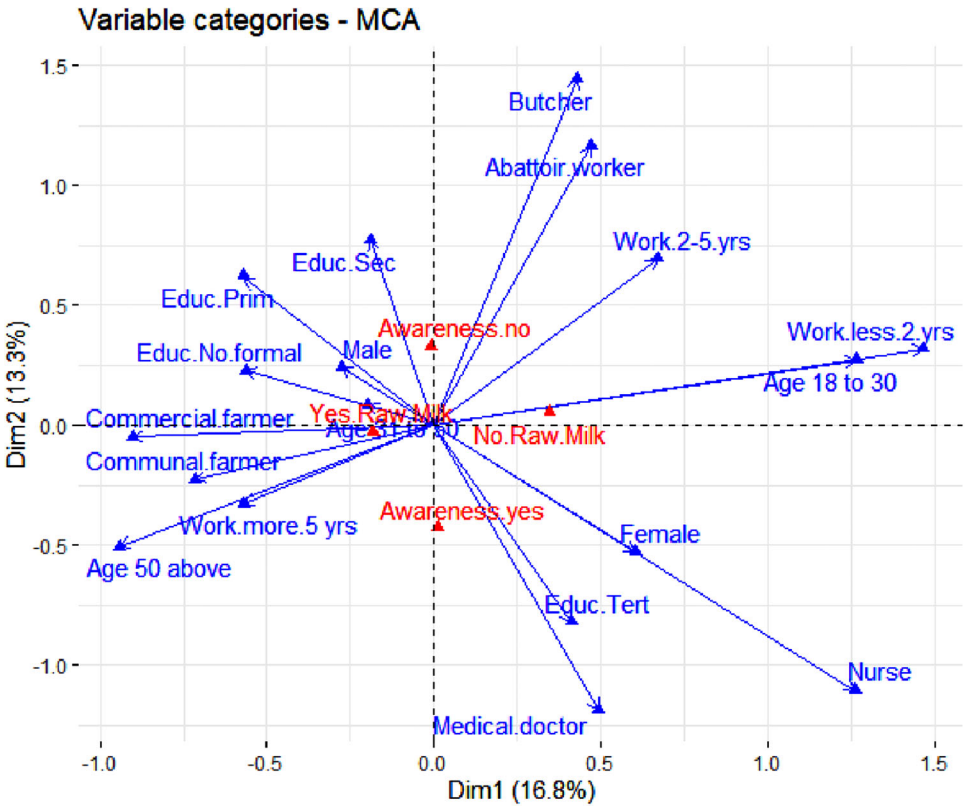

FIGURE 2 A symmetric biplot of the first two axes of a multiple correspondence analysis showing the association between potential risk factors related to human brucellosis in Namibia. The variables included were: education level, occupation, gender, age, duration at work, consumption of raw milk/milk products and awareness of brucellosis. A total of 531 participants (195 communal farmers, 69 commercial farmers, 71 butchery workers, 72 abattoir workers, 99 nurses and 25 medical doctors) were interviewed from five regions, namely Hardap, Khomas, Kavango East, Omaheke and Zambezi

brucellosis awareness in populations as lack of health education programmes, limited training on animal handling and rearing procedures, limited extension services, absence of health facilities and the remote location of participants (Munyeme et al., 2010).

Communal cattle farmer awareness and knowledge of brucellosis was significantly lower than that of commercial cattle farmers, which may be a reflection of the differences in access to information between the two groups. Awareness among communal cattle farmers (31.8%) in the current study was about half the level (60.0%) reported in communal cattle farmers in South Africa (Cloete et al., 2019). Poor knowledge of the disease was responsible for the risky practices observed among communal farmers in the current study. Previous studies have implicated limited access to animal health resources and services (FAO, 2001; Grace et al., 2017) as causes of low animal disease awareness and knowledge among communal farmers. In Namibia, commercial cattle farmers have access to both private and state veterinary services, while communal farmers have limited access to state veterinary services and cannot afford private veterinary services (Haakuria et al., 2020). This may explain why the majority of farmers treated animals without consulting veterinary personnel for a diagnosis. Although a high proportion of commercial farmers (84.1%) were aware of brucellosis, they lacked in-depth knowledge of the clinical manifestation of the disease in cattle, and the prevention of the disease in humans, perhaps due to ineffective or lack of information transfer to the farmers. As a result, a large proportion underplayed the risk of infection with brucellosis by consuming raw milk. In contrast to a report by Cloete et al. (2019), the current study showed a minor role for state veterinary services (14.3%) in promoting brucellosis awareness, with the workplace (46.3%) and training institutions (26.0%) playing a major role.

Brucellosis awareness and knowledge was low among meat handlers. As expected, awareness was higher at the highly regulated export abattoir than at the less regulated urban butcheries. The frequency of brucellosis awareness among butchers was comparable to findings of a similar study in India (11.0%) (Singh & Jindal, 2017), while awareness levels in abattoirs workers were lower than the level (76.0%) reported in Tanzania (Luwumba et al., 2019). Despite the apparent lack of brucellosis knowledge, it was encouraging that only ≤7.0% of meat handlers handled carcasses without protection or with bruised or injured hands. Although most abattoir and butchery operators provided protective gear to workers, training on zoonotic diseases was found to be lacking.

Knowledge of the mode of transmission and prevention of brucellosis in humans was more frequent among medical professionals (more than two-thirds) than in other participant categories, as has also been reported in Uganda (Nabirye et al., 2017). However, brucellosis was rarely considered during the diagnosis of febrile illnesses among

patients, with only two medical doctors considering it. The multiplicity of diseases that present with similar non-specific clinical symptoms in Namibia, such as malaria and typhoid, may have played a confounding role. Therefore, as has also been observed in Tanzania (Zhang et al., 2018), active surveillance for human brucellosis at medical facilities around the country was low. With about a third (33.3%) of the nurses lacking brucellosis knowledge, misdiagnosis of brucellosis within the population and the subsequent development of the severe chronic disease in patients due to delayed or no treatment cannot be ruled out (Kunda et al., 2007; Kunda et al., 2008; Dean et al., 2012; Nabirye et al., 2017). Misdiagnosis of brucellosis is likely to be prevalent in remote areas of the country where health facilities are manned by nurses. With a contribution of only 0.43% to awareness among the respondents, the Ministry of Health and Social Services needs to play an increased role in the dissemination of zoonotic disease information to the Namibian population.

The majority of farmers (91.3%), meat handlers (67.8%) and medical professionals (68.5%) did not perceive that they were at risk of *Brucella* infection, and were, therefore, likely to engage in practices that are a risk for *Brucella* infection, such as drinking raw milk, assisting cow parturition and disposal of aborted fetuses without putting on protective gloves (Ruano & Aguayo, 2017).

In the communal areas, the study identified regular contact between cattle herds (75.4%); low brucellosis vaccination rates (19.5%); and the use of communal bulls (17.4%) as practices that may promote *Brucella* infection and transmission between and within herds. It is difficult to control brucellosis in a pastoral system where regular contact between herds occurs (Sammartino et al., 2005), but vaccination of cattle can be promoted to reduce abortions and disease incidence. Although the majority of communal farmers owned bulls, due to a lack of controlled breeding, the venereal transmission of brucellosis between herds, although limited, cannot be excluded. The low vaccination rate identified in the communal sector (19.5%) compared to the commercial sector (87%) may be due to low awareness of the disease among farmers; a lack of resources to implement the vaccination programme (FAO, 2001); or limited enforcement of the compulsory vaccination of heifers 3–8 months of age using the S19 vaccine by government officials (Madzingira et al., 2020). On commercial farms, the rearing of cattle in a mixed farming system with domestic or wild animal species (85.5%) and the sourcing of replacement cattle from outside the farm by the majority of farmers (82.6%) were identified as practices that can promote the introduction and persistence of infection due to a number of reservoirs. On a positive note, both communal and commercial farmers performed health assessments on replacement cattle (76.4%, 56.5%) before purchase, which though not specific can contribute to brucellosis prevention on farms. The practices implemented by the majority of commercial farmers, including the absence of contact between different cattle herds (84.1%); vaccination of cattle (87.0%); seeking veterinary help in case of suspected brucellosis (60.9%); and the use of own breeding bulls, promote the prevention and control of the disease on farms.

The high level of awareness and knowledge of brucellosis that was observed among medical professionals did not translate into good practices for the prevention of *Brucella* infection, as has been observed by other studies (Arif et al., 2017). For example, some medical doctors consumed partially roasted meat sold by street vendors; came into contact with cattle birth fluids with no protection and consumed raw milk (28.0%). Further, some nurse respondents consumed homemade cheese and yoghurt, undercooked meat, raw meat, such as biltong; handled cattle blood or consumed meat of doubtful health status; and more than half consumed raw milk (55%). Similarly, a large proportion of commercial farmers (71%) drank raw milk, despite being aware that brucellosis can be transmitted to humans through raw dairy products. The results of this study are in agreement with previous reports that high levels of brucellosis awareness and knowledge do not necessarily translate into appropriate behaviours and practices (Cloete et al., 2019) because the perception of risk is influenced by a number of factors, including life experiences and culture (Sjoberg, 2000). The foregoing indicates that creating awareness and imparting knowledge alone may not be adequate to prevent infection in people, but that a shift in behaviour and cultural practices may be necessary (Njenga et al., 2020).

The likelihood of consumption of raw milk and milk products increased with the age of respondents and was more common among males than females. Therefore, old age did not seem to result in a change in eating habits. The fact that more males than females consumed raw milk can be a reflection of the closeness and dependency of male livelihoods on animals in the Namibian society, as has been reported elsewhere (Grahn, 2013; Cleaveland et al., 2017). Multivariable analysis revealed no association between awareness of brucellosis and consumption of raw milk. The absence of an association between participants' knowledge and practices has also been observed by other studies (Mangesho et al., 2021) and explains the following findings from this study: (1) about half of the farmers and meat handlers regarded raw milk and pasteurized milk from shops as of same health status; (2) respondents' education did not affect their attitude towards consuming raw milk and milk products; (3) and individuals with more work experience were more likely to consume raw milk and milk products. Although the consumption of raw milk was linked to farmers, the majority of communal (85.6%) and commercial farmers (68.1%) boiled raw milk before consuming it, which may explain why most farmers did not think that they were at risk of *Brucella* infection. Further good practices were recorded in the majority of farmers and meat handlers with respect to the handling of blood with bare hands; drinking cattle blood; and opening the uterus, which reduce exposure to infection. It was encouraging that the majority of farmers, meat handlers and medical professionals requested for education on brucellosis, an observation that was also made among participants in Uganda (Kansiime et al., 2014) and South Africa (Cloete et al., 2019).

Based on the relatively low brucellosis awareness and knowledge levels determined in this study, public health education and awareness campaigns are recommended as the main strategy for risk mitigation. Such campaigns, led by public health and veterinary officials, and following a One Health approach, should focus on communal farmers, abattoir workers and butchers. In particular, awareness regarding the boiling of raw milk before consumption; the use of protective gear,

such as gloves, when assisting cow delivery or handling aborted animal tissues; and the vaccination of cattle against brucellosis should be emphasized. Medical professionals should be regularly sensitized to consider brucellosis as a differential in the diagnostic workout for febrile conditions. It is also recommended that the Ministry of Health and Social Services develop a strategy for surveillance and control of brucellosis in the country. Future studies to determine the burden of *Brucella* infection in occupationally exposed groups are recommended.

5 | CONCLUSIONS

The study identified brucellosis knowledge, attitude and practice deficiencies that can predispose humans to serious public health effects and reduce cattle production. Awareness and knowledge of the disease were particularly low among communal farmers, abattoir and butchery workers. Practices that were identified as a risk for human infection include the consumption of raw milk, other dairy products and undercooked meat; splashing of blood into the eyes during slaughter; and assisting cows during delivery.

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CONFLICT OF INTERESTS

All authors declared no conflict of interests.

AUTHOR CONTRIBUTIONS

Oscar Madzingira: conceptualization; formal analysis; investigation; methodology; project administration; writing – original draft; writing – review and editing. Folorunso Oludayo Fasina: supervision; writing – original draft; writing – review and editing. Henriette van Heerden: conceptualization; supervision; writing – original draft; writing – review and editing.

ETHICAL APPROVAL

Written permission to carry out interviews at the abattoir was obtained from the abattoir operator. The study protocol was approved by the Ministry of Health and Social Services (Ref: 17/3/3 OM) and the Research Ethics Committees of the University of Pretoria (REC056-20 and HUM026/0620). Data were collected independently from each participant and coded to ensure anonymity and confidentiality at all stages of the study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Oscar Madzingira https://orcid.org/0000-0003-1145-9880

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