Sero-prevalence of brucellosis in ruminants and awareness of stakeholders on the disease in wet markets in Maswa district, Tanzania

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SUMMARY

Brucellosis is a zoonotic disease with economic drawbacks worldwide. Livestock wet-markets are known premises for human-animal interaction, livestock products consumption and live animal trades in village setups. However, the contribution of wet-market procedures and the knowledge of stakeholders towards zoonotic diseases are not well documented. The present study assessed the sero-prevalence of brucellosis in on-sale ruminants, knowledge of stakeholders on the disease and practices favoring disease transmission so as to generate evidence-based disease transmission risk at wet-markets. A cross sectional study involved collection of 496 blood samples from cattle, goats and sheep in wet-markets in Maswa district, Tanzania. Sera were harvested and tested for brucellosis using fluorescent polarization assay. Structured questionnaire about the epidemiology and control of brucellosis was administered to 400 wet-market stakeholders. Data were analyzed by computing descriptive statistics. The sero-prevalences of 11.2% (95% CI: 7.6 – 15.8) in cattle, 3.92% (95% CI: 1.1 – 9.7) in sheep and 1.39% (95% CI: 0.2 – 4.9) in goats were recorded. Un-screened ruminants from different herds were mixed during auction. Sold animals moved to different destinations while un-sold ones returned home. Interview results revealed that 91% of respondents had low knowledge about brucellosis. The mean knowledge score on index-summated scale was 18.2%. The results imply that wet markets are a risk epicenter for transmission of brucellosis and stakeholders are not informed about it. It is recommended that wet-markets be brucellosis surveillance points and strategies for brucellosis control should consider an awareness and training package to the community.

Keywords: *Brucellosis, Fluorescent polarization assay, Maswa, Mnada, Sero-prevalence, wet-market*

INTRODUCTION

Brucellosis is still among the major widest spreading zoonotic diseases of public health concern worldwide, caused by a number of bacteria species in the genus Brucella affecting human, livestock and wildlife animals (Corbel, 2006). The disease is persistent in many areas of Africa, including Tanzania, despite researches and intervention efforts (John *et al.*, 2010; Assenga *et al.*, 2015). The disease affects the livelihood of livestock keeping communities by denying them anticipated services from livestock such as daily family financial requirement, agricultural inputs and power and socio-cultural benefits (Engida *et al.*, 2015). The center of most of these benefits is the sale of livestock in local wet markets.

Wet market or *mnada* (in Swahili) is a place where selling of live animals, fish, fresh meat, fresh crops, fast foods, roast meat, fried meat and other traditional foods takes place at cheap retail prices (Webster, 2004). Wet markets are accompanied by gathering of large number of people, the buyers, sellers and recreation seekers. These wet markets, which are worldwide in distribution, play important role in food security, financial transactions and tourism (Kogan *et al.*, 2019). However, they can pose community health risk due to foodborne and airborne diseases and associated economic losses (Woo *et al.*, 2006; Wu *et al.*, 2017; Kogan *et al.*, 2019).

In Tanzania, wet markets are linked to primary livestock markets and are dominated by selling and buying of cattle, goats, sheep and poultry (Rupindo, 2009). Wet markets are also useful in acquisition of home needs, and as refreshment places. Most rural dwellers attend these markets which seem to play an important role of economic exchanges among them (Herrero *et al.*, 2013; Engida *et al.*, 2015).

The actors of the livestock section of the wet markets include the livestock keepers, small livestock traders, big traders or exporters of livestock, processors and rural and peri-urban consumers. The small livestock traders buy animals from livestock keepers at primary markets and sell them to big traders, who will then transport them to secondary market for resell to either exporters, meat processors and small-scale butchers or they may directly export the animals to neighboring countries (URT, 2017a). Huge gatherings of these animals and people at the wet markets could lead to transmission of pathogens between animals and humans (Webster, 2004; Woo *et al.*, 2006; Michael *et al.*, 2018). Maswa District of Simiyu region has four live animal wet markets that are operating at least once in a week where, on average 1,500 cattle and 1,600 goats and sheep are sold. It is among major sources of the live animals and animal products for major cities of Tanzania and export (Maswa District Livestock market report, 2019).

Brucellosis is an endemic zoonotic disease in Tanzania with high impact in public health and widely spreading among multiple species of animals and humans (Ntirandekura *et al.*, 2018). It is prevalent in most agro-pastoral communities due to constant contact of humans with live animals and animal products (Tumwine *et al.*, 2015). Wet markets provide such contact and as such, it could be a potential source of pathogen transmission to animals and humans in surrounding localities and also outside the country (Corbel, 2006). Different studies on brucellosis in Tanzania have reported evidence of infection in ruminants in pastoral herds (Ukita *et al.*, 2021), dairy herds (Mathew *et al.*, 2015), abattoirs (Luwumba et al., 2019), milk (Swai and Schoonman, 2011) and humans (Bodenham et al., 2020; Bouley et al., 2012; Katandukila et al., 2021; Luwumba et al., 2019); and some of the associated risk factors in ruminants (Sagamiko *et al.*, 2018; Ukita *et al.*, 2021) and humans (John *et al.*, 2010) have also been pointed out. However, wet markets have not been highlighted as potential epicenter for brucellosis and other infectious diseases. Therefore, the current study aimed at determination of brucellosis infection in cattle, goats and sheep and level of knowledge of the disease among different stakeholders in wet markets in Maswa district, Simiyu Tanzania. The findings of this study suggest a need for intervention options at wet markets to prevent transmission of brucellosis within and outside the country.

MATERIAL AND METHODS

Study area

The study was conducted in Maswa district council which is among the five districts in Simiyu region, Eastern Lake Victoria Zone. The Ethical permission was granted by Sokoine University of Agriculture (Ref. No. DPRTC/R/186/25) and Maswa District Council (Ref. No. MDC/ADM/Vol 2/009). Verbal consent was sought from all participants. Animal handling and blood collections considered and adhered to Animal welfare ethics as well as the code of veterinary ethics and conduct. Maswa district has 36 administrative wards and 120 villages. It is located along Latitude 3.2 to 3° 12' 0" North and Longitude 33.786 to 33° 47' East. Maswa district is bordered to the north by Magu district and Itilima district, to the East by Meatu district, to the South by the Kishapu district, and to the West by the Kwimba district. According to the 2012 Tanzania National Census, the population of Maswa district was 344 125 of whom 167,382 were female and 176,723 male and the average annual population growth rate is 1.8% (URT, 2013). Therefore, it was estimated by the end of 2019 the human population in Maswa to be 396 898. The major economic activities of communities in Maswa District are agriculture and livestock keeping. The major livestock resource base of the council includes 389,834 cattle, 363,949 goats and 195,960 sheep. Livestock sector has a significant contribution to the economy of farmers, the district and central government. For instance, in 2016/17

livestock keepers earned an income of TZS 16 billion, the Council obtained TZS 423,538,570/= and the Central government obtained TZS 88,639,600/= from livestock trade (URT, 2017b). Most of this income was collected through livestock trade in the local wet markets.

Study design and sample size determination

A cross – sectional study was conducted between August and October, 2020 to determine the prevalence of brucella antibodies by random sampling of indigenous cattle, sheep and goats. Sample size was estimated by using formula for infinite population as described by Charan and Biswas (Charan and Biswas, 2013) which states that; Sample size (n) = Z_α^2 x $p(1-p)/d^2$. Whereby Z_α is standard normal variate at 95% confidence level (1.96), p is expected prevalence and d is absolute error (0.05).

The overall prevalence of brucellosis in ruminants was set at 11.3% (Sagamiko *et al.*, 2018). Computation gave a sample size of 154 for cattle and 154 for sheep and goats. However, the researchers took an advantage of available resources to observe animal welfare and improve the precision and minimize type I error by increasing the sample size (Thrusfield, 2007) to 250 cattle and 246 sheep and goats. Simple random selection was done from the auction registry on every wet market day with the aid of table of random numbers.

Proportionate sampling criteria was used to distribute sample size among wet markets whereby, about 80% of cattle (n=201) samples were collected from Shanwa wet market, 33 from Senani and 16 cattle from Malampaka wet markets. For sheep and goats, 104 were sampled from Shanwa, 76 from Senani, 44 from Lalago and 16 from Malampaka wet markets.

Number of respondents for knowledge assessment was obtained using the same formula, the expected knowledge index was set at 50% for infinite population, therefore minimum sample size of 384 individuals was expected to be interviewed but we managed to interview 400.

Blood Sample collection procedures

A total of 496 blood samples were collected by venipuncture into plain vacutainer tube from the jugular vein from randomly selected cattle, sheep and goats. A total of 250 samples were collected from indigenous cattle and 246 samples from goats and sheep brought to livestock wet market on the day of sample collection. Vacutainers were labeled as per each animal species and source, stored in a cool box with ice packs at slant position, and then transported to veterinary office at Maswa district council for serum separation within 24 hours. Serum was drawn into Eppendorf tubes and stored in a refrigerator at 4°C before transportation to the Tanzania Veterinary Laboratory Agency, Mwanza branch for analysis.

Questionnaire administration

The Pre-tested semi-structured questionnaire was administered to 400 targeted stakeholders who attended the markets by face-to-face interviews. The questionnaire gathered information regarding the demographic characteristics of respondent, knowledge on the definition of the disease, species that are affected, mode of transmission in animals, clinical signs in animals, ways of preventing the disease to animals, knowledge on zoonotic potential of the disease, transmission of the disease to human and control measures in both animals and human beings.

Wet market structures and operations

The interview was done among the wet market officials to assess the structures and operation of the wet markets. Interviews were supplemented by inspection of market attributes by researchers. The market schedules, infrastructures, species and number of animals brought to the markets, place of animal origin and destination, movement permits, animal health check and how selling and buying was conducted and documentation procedures were assessed.

Laboratory blood sample processing

Collected serum samples were tested for presence of brucella antibodies at Tanzania Veterinary Laboratory Agency, Mwanza Centre using Fluorescent Polarization Assay (FPA) technique. FPA was used in this study purposely due to its advantages over other test

procedures as being of low cost to run, gives results in a relatively short time (0.5 minute per sample), is able to give specific antibody for *B. abortus*, *B. melitensis* and *B. suis.* The test has high specificity and sensitivity as compared to i-ELISA, and can be used as screening and confirmatory test (McGiven *et al.*, 2003). The diagnostic test uses OPS extracted from *Brucella abortus* which is the most specific antigenic part of LPS and conjugated with fluorophore (Smirnova *et al.*, 2013) . More so, the assay has a capability to discriminate samples from cattle which were previously vaccinated with *B. abortus* strain 19 from those which are naturally infected with *B. abortus* (Gall *et al.*, 2002).

A total of 496 serum samples were tested using the FPA technique. The test procedure was conducted as recommended by OIE Test Kit guideline. Briefly, 20µl of three negative and one positive control samples were mixed with 1 ml of sample diluent. Also, 20µl and 40µl cattle and small ruminant serum respectively were mixed with 1 ml sample diluent then incubated for 3 minutes. Thereafter blank readings with FPA device were taken then 10µl of tracer was added to every tube and further re-incubated for 3 minutes. The second reading from the FPA device were done for every tube, then the means of negative control, positive control and sample values were recorded in millipolarization (mP) units. The difference between the sample mP and negative control mP values were computed i.e.;

ΔmP = sample ΔmP – negative control ΔmP

Interpretations: If $\Delta mP < 10$ mP the sample is negative, if $10 \leq \Delta mP < 20$ *mP* it means the results are doubtful and if $\Delta mP \geq 20$ *mP* the samples are positive to Brucellosis as per test kit standards.

To distinguish the sample from animals previously vaccinated with S19 or B19 the cut-off point value for ΔmP is adjusted to higher value as per test kit instructions whereby $\Delta mP \leq 40$ is described as negative, $40 < \Delta mP < 60$ is doubtful and $\Delta mP \geq 60$ indicates positive to brucellosis.

General analysis of data

The data from laboratory, interview and observations were recorded in Microsoft Excel and imported to Epi Info (Epi Info™ 7.1.3, Atlanta, USA) for statistical analysis. Data were analyzed by computing descriptive statistics such as frequencies and proportions or percentages for nominal and count data, and mean for continuous data. Measures of variability such as range, standard deviation and confidence interval were computed as well. Association between sero-conversion and other variables was tested by Chi-square test at 5% significance level.

Analysis of data for knowledge assessment

Data from questionnaire interviews were recorded and put in Microsoft office excel and cleaned before further analysis. The Index summated scale was used to assess the knowledge of the individual respondents. Each question was assigned a score and the total score for all correct answers was 11. The distribution of scores were as follows; meaning or defining or naming the disease (1 mark), to mention the affected species (2), clinical signs in animals (1), mode of transmission in animals (1), how to diagnose the disease (1), knowledge of being zoonotic (1), mode of transmission in human (1), symptoms in human (1), control measure in human (1) and the control measures of the disease in animals (1 mark). Individual knowledge index on the disease was categorized based on the score, those who scored zero were considered as having no knowledge, between 1 and 4.0 were regarded to have low knowledge, score between >4.0 and 8.0 had moderate knowledge and those with > 8.0 scores had high knowledge about brucellosis.

The average knowledge score for the entire group of respondents was determined as the total scores of all participants divided by the number of participants.

RESULTS

Demographic information of the study participants

Among 400 stakeholders who participated in this study, 312 (78%) were males and 88 (22%) females with age ranging from 18 to 76 years (mean ± std dev = 37.6 ± 11.5). Majority of the participants (32.50%) were in the age range between 18 and 30 years. Most of the participants had primary level of education (73.25%) and their market attendance varied according to their geographical locations whereby 55.50%, 31.00% and 13.50% were from Magalia, Nung'hu and Sengerema division respectively. Proportions of livestock owners, animal products or meat consumers, meat and food venders at the markets and Butcher men, Hides and skin personnel are as presented in Table 1.

Wet market structures, operation procedures and animal movements

There are four wet markets in Maswa district namely; Senani, Shanwa, Malampaka and Lalago. Each of the wet markets operate once a week on a specific day. Lalago market operates on Monday, Malampaka on Wednesday, Senani on Saturday and Shanwa operates on Sunday. The arrangement of the days observed the existence and operation of other livestock markets in neighboring districts in order to maximize attendance because the same traders visit all wet markets.

Other stakeholders such as buyers of goods other than livestock and food and meat consumers attend the market based on conveniences in terms of distance to the wet market, types of goods on market and market schedule that is day of the market. Lalago market gathers only small ruminants. Shanwa is the largest wet market that records the capacity of gathering up to 1000 cattle, 700 sheep and goats during the pick months between July and October every year. The number of animals yarded for sale is influenced by the season of the year and agricultural calendar. During crop harvest season and the time prior to farming activities the number of animals brought to the wet market for sale reaches the peak.

At individual market day, animals are brought from different villages by trekking and they are assembled at the market ring to give space for buyers to assess and choose animals they need to buy. Therefore, animals from different herds are mixed during auction. The distance to which animals are trekked differs depending on size of the market, animal owners' market preference and available demand and supply situation on a particular season to the extent that some of the animals may move to a distance of more than 20 kilometers to the market.

There are no formal structures/ buildings such as shops, offices or abattoir, except for animal auction rings. All trades and other procedures take place in open areas. After the auction, animals are inspected and given movement permit which depict among other things, place of animal origin, animal identification, vaccination records if any and destination. The movement permits showed that cattle, sheep and goats came from Simiyu region (Maswa, Meatu and Itilima districts), Shinyanga region (Kishapu district) and Mwanza region (Kwimba district). On the other hand, bought ruminants were permitted to travel to secondary markets of Pugu (Dar es salaam), Kirumi (Mara) and Nyamatala (Mwanza), while others were transported to Shinyanga, Dodoma, Arusha and Manyara regions

Seroprevalence of brucellosis in ruminants

A total of 496 sera samples from adult animals were assessed for Brucella antibodies, out of which 250 were from cattle (102 female and 148 male) and 246 were from small ruminants (144 goats and 102 sheep). Out of 144 goats sampled, 60 (41.67%) were males and 84 (58.33%) were females, whereas among 102 sheep, 24 (23.53%) were males and 78 (76.47%) females. The overall seroprevalences of brucellosis in cattle, goats and sheep were 11.20%, 1.39% and 3.92% respectively based on the $\Delta mP \geq 20$ *mP* Fluorescent Polarization Assay criteria (Table 2). This is the sero-prevalence of ruminants at wet markets in Maswa district, because there has never been S19 vaccination in the study area. However, based on the $\Delta mP \geq 60$ criteria, no sample from sheep and goats seemed to be positive while for cattle the sero-prevalence was 0.4% (n=250).

Based on sex, the overall prevalence in ruminants was 5.31% (95% CI: 2.77 - 9.09) and 8.15% (95% CI: 5.18 - 12.08) for males and females, respectively. Whereas analysis at individual species level showed that the sero-prevalence of brucellosis in male cattle was 8.45% (n=142) whereas the seroprevalence in female cattle was 14.81% (n=108). In small ruminants, both male goats and sheep were negative to brucellosis out of 60 and 24 animals tested respectively while 2.38% of female goats (n=84) and 5.13% of female sheep (n= 78) tested positive (Table 3). There was statistically significant difference in sero-conversion between cattle and small ruminants (X^2 = 14.9, df = 1, p-value = 0.000), whereby cattle were more sero-positive than small ruminants. On the other hand, there was no statistically significant differences in sero-conversion between sex categories (X^2 = 2.1, df = 1, p-value = 0.352).

Brucella sero-prevalence at wet market level

Out of 250 cattle sera, 16 were from Malampaka, 33 from Senani and 201 from Shanwa. The seroprevalence in cattle at individual market level were 9.09% (95% CI: 1.92 - 24.33) at Senani and 12.44% (95% CI: 8.21 - 17.81) at Shanwa wet market. All cattle sera from Malampaka market were negative. In small ruminants, 246 sera were harvested from Malampaka (22), Lalago (44), Senani (76) and Shanwa (104). The overall seroprevalence in small ruminants at market level were 5.26% (95% CI: 1.45 - 12.93) and 1.92% (95% CI: 0.23 - 6.77) at Senani and Shanwa wet markets respectively. However, all animals tested negative for brucellosis at Malampaka and Lalago wet markets (Table 4).

Table 1. Demographic information of study participants

Variables	Levels	Frequencies (N = 400)	Percentage %
Sex	Male	312	78.00
	Female	88	22.00
Age groups	18 – 30	130	32.5
	31 – 40	107	26.75
	41 – 50	107	26.75
	>50	56	14.00
Education	Primary	293	73.25
	Secondary	41	10.25
	Collage/University	27	6.75
	Informal education	39	9.75
Occupation/Duty at Wet Market	Owner	178	44.50
	Butcher/Hides personnel	35	8.75
	Meat/food vendor	66	16.5
	Consumer	121	30.25
Market attended	Lalago	50	12.50
	Malampaka	42	10.5
	Senani	132	33.00
	Shanwa	176	44.00
Administrative Division	Mwagala	222	55.50
	Nhung'hu	124	31.00
	Sengerema	54	13.50

Table 2. Seroprevalence of brucellosis in ruminants at wet markets in Maswa district

Sample source	n (Positive)	Prevalence (%)	95% Confidence Interval
Cattle	250 (28)	11.20	7.57 - 15.78
Goats	144 (2)	1.39	0.17 - 4.93
Sheep	102 (4)	3.92	1.08 - 9.74

Table 3. Sero-prevalence of brucellosis by sex in ruminants at wet markets in Maswa district

Species	Sex	Number tested	Prevalence % (n)	95% CI	p-value
Bovine	Male	142	8.45 (12)	4.44 - 14.30	0.156
	Female	108	14.81 (16)	8.71 - 22.94	
Caprine	Male	60	0.00 (0)	94.04 - 100	0.51
	Female	84	2.38 (2)	0.29 - 8.34	
Ovine	Male	24	0.00 (0)	85.75 - 100	0.57
	Female	78	5.13 (4)	1.41 - 12.61	
Overall	Male	226	5.31 (12)	2.77 - 9.09	0.352
	Female	270	8.15 (22)	5.18 - 12.08	

Table 4. Seroprevalence of brucellosis in ruminants at wet market level in Maswa district

Wet market	Species	n (Positive)	Prevalence (%)	95% CI
Shanwa	Cattle	201 (25)	12.44	8.21 - 17.81
	Shoats	104 (2)	1.92	0.23 - 6.77
Senani	Cattle	33 (3)	9.09	1.92 - 24.33
	Shoats	76 (4)	5.26	1.45 - 12.93
Malampaka	Cattle	16 (0)	0.00	79.41 - 100.00
	Shoats	22 (0)	0.00	84.56 - 100.00
Lalago	Shoats	44 (0)	0.00	91.96 - 100.00

Knowledge level of study participants about brucellosis in Maswa district

Out of 400 participants, 76% reported to have heard about brucellosis and most of them (61%) acknowledged to have witnessed abortion cases in animals in their localities. The results showed that 36% had no knowledge about brucellosis, 57.5% had low knowledge, 5.75% had moderate knowledge and 0.75% had good knowledge about brucellosis.

The knowledge about the disease also was extremely poor among Livestock owners whereby 37.64% had no knowledge and 57.87% had moderate knowledge about the disease, followed by animal products' consumers (30.58%). On the 11-point summated scale, the minimum knowledge score was zero and the maximum score was 8. The average knowledge score index was 2 out of 11 points (standard deviation = 1.7), which was categorized as low knowledge on brucellosis. A total of 113 (28.25%) of respondents had no knowledge, 251 (62.75%) had low knowledge, 36 (9%) had moderate knowledge and none of respondents had high knowledge.

DISCUSSION

Detection of Brucella antibodies in ruminants in Maswa which is located in the lake zone of Tanzania adds up to earlier reports of the disease in different areas of Tanzania. There have been reports on occurrence of the disease in cattle in Mbeya (Southern Highland zone) (Mathew *et al.* , 2015; Sagamiko *et al.* , 2018), Dodoma (Central zone) (Luwumba et al., 2019; Shirima et al., 2014), Morogoro (Eastern zone) (Asakura et al., 2018; Ukita et al., 2021), Katavi and Kigoma (Western zone) (Assenga et al., 2015; Chitupila et al., 2015; Swai et al., 2021). There are also reports of brucellosis in small ruminants in Katavi, Morogoro and

Mbeya (Assenga et al., 2015; Kassuku, 2017; Mathew et al., 2015). In pigs, brucella antibodies have also been reported in Dar es salaam (Simon et al. 2015). Buffaloes and lions of the Katavi human-livestock-wildlife interface have been found to be brucella sero-positive (Assenga et al., 2015). This spatio-temporal pattern of brucella antibody detection in different livestock and wildlife species suggests that the disease is endemic in Tanzania. Furthermore, its detection in humans in Morogoro (Asakura et al., 2020), Moshi (Bouley *et al.,* 2012), Arusha, (Bodenham *et al.* , 2020), Kagera and Kigoma (Katandukila *et al.,* 2021) and Dodoma (Luwumba *et al.,* 2019) illustrates the wide spread zoonotic characteristics across different areas of Tanzania. Besides, critical analysis of present reports informs that large part of the livestock production chain may be contaminated with brucella pathogens. That is, there have been reports of infections in live livestock at the farm (Mathew *et al.,* 2015), cattle and goats ready for slaughter at abattoirs (Luwumba *et al.* , 2019) and in cow milk (Assenga et al., 2015; Swai & Schoonman, 2011), human being (abattoir workers, livestock keepers and probably animal product consumers) (Bouley *et al.,* 2012; Luwumba *et al.*, 2019; Bodenham *et al.,* 2020, Katandukila *et al.,* 2021) and now livestock at wet markets are in the list to rejuvenate the infection cycle. Therefore, this time-space-species distribution of brucellosis indicators poses an infection risk and call for public health attention.

The seroprevalence of brucellosis of 11.2% in cattle from the current study is higher compared to a seroprevalence of 9.3% reported in southern highlands of Tanzania (Sagamiko *et al.,* 2018), a seroprevalence of 7.3% recorded in animals brought for slaughter at Dodoma abattoir (Luwumba *et al.,* 2019), and a seroprevalence of 7.0% in agro-pastoral cattle in Morogoro (Ukita *et al.,* 2021). The recorded seroprevalence inf the current study is however lower than that of 30.8% reported from Kasulu (Swai *et al.,* 2021). There are also differences in findings between results of the current study in small ruminants and other studies. For instance, a study conducted in Mbarali, Mbeya reported higher prevalences of 2% and 5.7% in goats and sheep, respectively (Mathew *et al.,* 2015). The differences in sero-prevalences may be attributed to type of sample used in detection and sample analysis procedures. Moreover, the low brucella sero-positivity in small ruminants compared to cattle may be due spill-over of the pathogen from cattle to sheep and goats in the herd (Mathew *et al.,* 2015). Despite the low prevalence in small ruminants, it is anticipated that the wet markets may play a potential role in transmission of the pathogen to humans because the number of small ruminants slaughtered at wet market is higher than cattle, for instance, in Shanwa wet market, the number of goat slaughter goes up to 150 goats per market day.

Detection of brucella antibodies in ruminants in Maswa district is considered to be due to natural infection because there is no vaccination against brucellosis meaning that the sero-positive animals may be infective to the other members of the population. The wet markets may act as potential epicenters for transmission because after the sell animals are taken to different areas, within and outside the region. If infected animals are sold, then they may transmit the pathogen to in-contact animals along the route and to the destination. On the other hand, animals which are not sold at the auction are taken back to the herd, with a possibility of being exposed at the market. Consequently, this may introduce the disease to the non-infected animals in the herd. Therefore, wet markets may be the source of back-and-forth brucellosis transmission in animal populations. Apart from the need for control campaign at farm level, we think wet markets can play a vital role in surveillance of brucellosis.

The current study has revealed that more than 90% the participants have completely no or little knowledge about brucellosis in ruminants and its zoonotic implication. Lack of awareness and knowledge about brucellosis has been reported earlier in several studies conducted in Tanzania including studies in Kigoma (Chitupila *et al.,* 2015), Kagera (Ntirandekura *et al.,* 2018) and Morogoro (Mburu *et al.,* 2021).

The low knowledge about brucellosis among livestock keepers and other stakeholders such as livestock traders, animal health workers, abattoir workers, human health workers and livestock product consumers may not motivate them to value and engage in control endeavors

(Zhang et al., 2019), through allocation of resources such as finances and time, use of skills and techniques and adherence to guidelines. This is because they are less informed about the burden and impact of the disease. Recently, Tanzania has established control programs for notifiable and zoonotic diseases through vaccination of animals. A number of challenges have been noticed, including poor response of the livestock keepers (URT, 2018). This may probably be related to low knowledge and financial constraints among the rural livestock keepers as well as non-participatory approaches used (URT, 2011; Zhang *et al.,* 2019). Poor or low knowledge may lead to negligence in disease prevention and misdiagnosis, delayed treatment and disease transmission risk practices (Zhang *et al.*, 2019, Lupindu and Nzalawahe, 2021). Therefore, assessment of knowledge of stakeholders in respect of brucellosis is essential in planning community education and control strategies.Community knowledge about diseases has a great influence on participation, sustainability and outcome of intervention. There are examples of community education studies which have resulted in improvement of disease control outcome after training. For instance, a health education intervention trial in Mbulu district managed to improve knowledge and reduce incidence of porcine cysticercosis (Ngowi *et al.*, 2008), likewise, a community health education in Burkina Faso led to drop in cysticercosis (Carabin *et al.*, 2018). Therefore, there is a need for creation of awareness to stakeholders and train them on brucellosis before embarking on participatory intervention campaign.

The present study has shown clear evidence of presence of natural infection of brucellosis in ruminant population presented for sale at wet markets in Maswa district, which may serve as source of infection to in-contact animal population.

The study is also reporting low knowledge among wet market stakeholders about brucellosis and its zoonotic potential, which in one way or another, may affect control plans. Therefore, there is a need for a participatory brucellosis control program in study area and similar settings that is preceded by community awareness and education campaigns. Considerations of important surveillance centers should take the wet markets on board.

COMPETING INTEREST

The authors declare that they have no competing interests

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