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Studies on mastitis, milk quality and health risks associated with consumption of milk from pastoral herds in Dodoma and Morogoro regions, Tanzania

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The prevalence of mastitis, milk quality and health risks associated with milk consumption were investigated on 96 randomly selected traditional herds in Dodoma rural and Mvomero districts of Tanzania. Mastitis was investigated based on clinical signs, microbiology and California mastitis test (CMT), while milk quality was evaluated using total viable count (TVC) and total coliform count (TCC). Animals were tested for tuberculosis using a single comparative intradermal tuberculin test. The prevalence of subclinical mastitis based on CMT was low (8.3%). The major isolates were *Staphylococcus aureus* (35.3%), other staphylococci (20.8%), coliforms (27.7%), micrococci (5.8%) and streptococci (9.8%). The average TVC of milk in Dodoma rural district ($1.0 \times 10^7 \pm 3.4 \times 10^7$) was significantly higher than that in Mvomero district ($8.9 \times 10^5 \pm 3.5 \times 10^6$) ($p < 0.001$) and the proportion of TCC-positive samples in Dodoma (70.7%) were significantly higher ($p < 0.001$) than that of Mvomero samples (20.8%). Whereas no tuberculin reactor animal was detected in the study animals, atypical mycobacteria were isolated from milk and one sample from Dodoma had *Mycobacterium tuberculosis*. Knowledge on health risks associated with milk consumption was low (20.8%). It is concluded that lack of awareness on health risks associated with milk consumption amongst rural communities needs to be addressed in order to safeguard their health.

Key words: health risks, mastitis, milk quality, pastoral cattle, Tanzania

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Introduction

Although milk is a very nutritious food that is rich in carbohydrates, protein, fats, vitamins and minerals [3], it can be associated with health risks to consumers, especially those related to the presence of zoonotic pathogens and antimicrobial drug residues [4,14]. The quality of milk may be lowered by a number of factors such as milk adulteration, contamination during and after milking, and presence of udder infections. On the other hand, mastitis, defined as inflammation of the mammary gland, affects lactating animals including cattle, goats, sheep, buffaloes and camels [2,3,13,42,47]. The disease is considered to be one of the most important causes of economic losses in the dairy industry worldwide [11,20,23].

Previous studies on mastitis in Tanzania have mainly focused on the small- [16,22,33,41] and large-scale [15,19, 27] dairy sectors and little is known about the disease in the pastoral and agro-pastoral systems. The two traditional animal farming systems are often characterized by poor animal health delivery services as a result of withdrawal of public services, poor house hygiene and unhygienic milking practices. These factors are likely to result in high udder infections; zoonotic infections and poor quality of milk, the latter which can be measured based on specific gravity, total viable count (TVC) and total coliform count (TCC), resazurin, analysis of antibiotic residues, alcohol and boiling tests [7, 25]. Since information on mastitis and milk quality is lacking in respect to the traditional cattle sector, which provides the bulk of the milk consumed in Tanzania, it is important to gather information in this milk sector, which is increasingly being dependent on for rural household livelihood. Therefore, the purpose of this study was to estimate the magnitude of udder infection and to assess the quality of milk from pastoral and agro-pastoral cattle and community's knowledge and awareness on public health

risks that may be associated with consumption of milk with special reference to tuberculosis.

Materials and Methods

Study area

The study was carried out between August 2003 and January 2004 in Dodoma rural and Mvomero districts of Dodoma and Morogoro regions, respectively. Dodoma region is a semi-arid area and receives an average annual rainfall of 550 mm. The study areas were five villages of Dodoma rural district (namely Chalinze, Ikowa, Msisi, Matumbulu and Chamwino) dominated by agro-pastoral Gogo communities which keep indigenous, Tanzania Shorhorn Zebu cattle (*Bos indicus*).

Four villages of Mvomero district in Morogoro region (namely Wami-Sokoine, Wami-Luhindo, Wami-Dakawa and Kambala) inhabited predominantly by the pastoral Maasai and agro-pastoral Sukuma communities were also involved in the study. The area receives bimodal rainfall, which ranges between 600 and 1,200 mm per annum. The animals kept are also indigenous Tanzania Shorthorn Zebu cattle.

Study villages in Dodoma rural and Mvomero districts were recommended by the district veterinary officer in Dodoma and Morogoro regions based on availability of pastoral and agro-pastoral herds. Then a two-stage random selection procedure was adopted where study herds were randomly selected from a sampling frame comprising all herds with indigenous animals in each village. On average, herds selected to participate in the study constituted about 25% of all herds in the study area. Each of the selected herd was then visited and all lactating animals on the day of visit were listed from which 3-4 cows were randomly selected for examination and sample collection. In total, forty-eight traditional cattle herds were randomly selected from a sampling frame of herds in the study villages of Dodoma rural district. In Dodoma rural district 10 herds from each village were included in the study except for Matumbulu village where only eight herds participated in the study. Forty-eight traditional cattle herds were also randomly selected in Mvomero district and these comprised 19 herds in Wami-Sokoine; 4 in Wami-Luhindo, 11 in Wami-Dakawa and 14 in Kambala village. A total number of 136 and 141 lactating cows in Dodoma and Mvomero districts respectively were then selected randomly from study herds and used for the study.

During farm visits, a structured questionnaire was used to collect animal- and herd-level information on milk yield and sales including outlets; knowledge on clinical and subclinical mastitis; practices related to mastitis control; factors affecting milk quality and knowledge on health risks associated with consumption of milk.

Screening for mastitis

All cows (277) selected in the two districts were clinically examined for evidence of clinical mastitis as manifested by visible changes in milk and in the udder as well as presence of blind teats. The examination was complemented by testing milk from lactating quarters (n = 1077) for subclinical mastitis using California mastitis test (CMT) as a cow-side test, which was carried by mixing equal amounts of milk and CMT reagent (Kruuse, Denmark) into the four cups of the CMT paddle. The results were read immediately as per the manufacturer's recommendation and were classified as either negative, trace, 1+, 2+ or 3+ depending on the amount of gel formed.

In order to shed light on the microbial isolates from traditional cattle, only milk samples collected aseptically from each quarter of cows examined in Mvomero district (n = 550) were used for this purpose. Milk samples were submitted for isolation of fungi, aerobic and anaerobic bacteria. Samples for bacteriological examination were inoculated onto blood (BA) and MacConkey (MC) agars and incubated at 37°C for 24 hours. At 24 hours, the plates were examined for bacterial growth and, if negative, they were re-incubated for 48-96 hrs at 37°C. Bacterial isolates were characterised by macro- and micro-morphology, gram staining and biochemical tests using different sugars [10, 30]. Other tests including motility, coagulase, catalase and oxidase reactions were carried out to assist identification of different bacterial isolates. Where necessary, special tests for suspected organisms such as CAMP test for *Streptococcus agalactiae*, methylene blue staining for Corynebacteria and Ziehl-Neelsen (ZN) staining for *Norcadia* and were performed.

Other aliquots of milk sample were inoculated onto Sabouraud dextrose agar and incubated at 28°C and at 37°C for 48-72 hours in order to isolate fungi. Fungal isolates were characterised by colonial characteristics, size and shape of hyphae, microscopic examination and germ tube formation [24]. Other tests carried out included urease-, carbohydrate and nitrate assimilation- and carbohydrate fermentation tests for *Candida* and other yeast species.

Screening for bovine tuberculosis

In order to establish the prevalence of bovine tuberculosis (BTB), the 277 cattle as indicated above were tuberculin-tested by the singe comparative intradermal tuberculin test (SCITT) using avian and bovine purified protein derivatives (PPDs), kindly supplied by the Central Veterinary Laboratory, Addlestone, Surrey, England. Briefly, 0.1 ml of avian and a similar volume for bovine each containing 2,500 international units (IU) were administered intradermally in the cervical region at a distance of 12.5 cm apart. The skin thickness was measured prior to injection of the PPDs (i.e. 0 hour reading) and thereafter at 72 hours post inoculation. The difference in

the skin thickness between the avian and bovine tuberculin inoculated sites was interpreted as being positive, inconclusive or negative using a standard procedure [37].

Infection by mycobacteria was also determined by screening asceptically collected milk samples from each quarter that were pooled at animal level. A total of 277 samples from both Mvomero (n = 141) and Dodoma rural (n = 136) districts were screened for *M. bovis*, atypical mycobacteria and *M. tuberculosis* at the Faculty of Veterinary Medicine, Sokoine University of Agriculture in Morogoro using standard procedures [18]. Briefly, each sample was decontaminated using 4% sodium hydroxide and then neutralized using concentrated hydrochloric acid. The suspension was then centrifuged at 13,000 *g* and the supernatant was discarded to leave sediment, which was used as the inoculum for isolation of mycobacteria. Primary isolation of *Mycobacterium* spp was done on two egg-based media, namely, International Union against Tuberculosis (IUT) and Lowenstein-Jensen containing pyruvate (L-J pyruvate). The procedure involved spreading of about 0.1 ml of the sediment from each sample on the two media and incubation at 37°C for at least 16 weeks with weekly observation for growth. Positive cultures were subcultured onto another set of media (two slopes of each medium per culture) and incubated for another 3 to 4 weeks for further identification. Growth characteristics on IUT and L-J pyruvate media was the first criterion used to distinguish *M. tuberculosis* from *M. bovis*. Further tests including ZN staining and biochemical tests were used for identification of isolates [5, 8]. In order to differentiate species belonging to the *M. tuberculosis* complex (MTBC) from atypical mycobacteria, additional tests were conducted. These included: (i) growth at 37°C and 45°C to distinguish MTBC from atypical mycobacteria especially *M. avium* group, and (ii) growth on medium containing p-nitrobenzoic acid (PNB), which supports the growth of atypical mycobacteria and not MTBC [18].

Assessment of milk quality

Milk samples for evaluation of quality as defined by TVC and TCC were examined at the Faculty of Veterinary Medicine, Sokoine University of Agriculture using standard procedures [3,17]. Briefly, one ml of 10-fold serially diluted sample was placed on a sterile Petri dish followed by pouring of 20 ml of molten nutrient agar cooled to 45°C onto the dish. The sample and agar were then mixed and left to solidify after which the plates were incubated at 37°C for 24-48 hours. Bacterial colonies were counted using a manual colony counter (Schneider, Swiss) and multiplied by the dilution factor to get TVC value in colony forming unit per ml (CFU/ml) of milk. For TCC determination, the same procedure was adopted except that the media used was violet red bile agar (VRBA), which is selective for coliforms.

Data handling and analysis

Data collected were entered in Epi Info databases [6]. Descriptive statistics were then computed for different variables. The proportions of categorical variables were computed and compared for statistical significance by Chi-squared test at critical probability of $p = 0.05$. For continuous variables, the Bartlett's test for homogeneity of variance at 95% confidence interval was used to decide whether to adopt analysis of variance (ANOVA) or non-parametric Kruskal-Wallis test for two groups for statistical difference.

Definition of variables

A number of outcome variables including status of subclinical mastitis defined by CMT or culture results at cow or quarter levels, clinical mastitis and milk quality defined by TVC and TCC at farm level were used to analyse results against explanatory variables. For CMT results, a quarter was defined as CMT positive if it had a score of ≥1+ and a cow was defined as CMT positive when it had at least one of quarters with a CMT score of ≥1+ [16,22]. For microbiological results, a cow was considered to be positive if at least one-quarter milk sample submitted for culture had a mastitis pathogen (bacteria or fungus). A cow was considered to have clinical mastitis if changes in milk including presence of pus, clots, flakes or blood in milk and changes of the udder including swollen or painful quarter or asymmetry of udder were evident on the day of farm visit. Also, cows were considered to had clinical mastitis in the past if the farmer reported to had observed similar changes of udder and milk in the past two years prior to period when this study was carried.

Results

Characteristics of herds

All and 95.8% of the respondents in Mvomero and Dodoma rural districts, respectively provided information on herd size, number of lactating cows, total milk sold and consumed per day as shown in Table 1. The study revealed that agro-pastoral Gogo community in Dodoma owned significantly smaller herds compared to the Maasai and Sukuma communities in Mvomero district ($p < 0.001$). Fifty four percent and 56% of the respondents in Dodoma rural and Mvomero respectively also reported to be selling milk during the data collection period. Whereas majority of farmers in Mvomero district were selling milk to vendors and milk collection centres, those in Dodoma rural district sold milk mainly to their neighbours and only very few of them sold their milk to vendors. It was also revealed that Mvomero district had significantly higher amount of milk consumed ($p < 0.001$) and sold ($p < 0.01$) than that in Dodoma rural district. The average milk production per cow per day was similar in the two districts.

Table 1. Herd size and milk production, consumption and sales in Dodoma rural and Mvomero districts, Tanzania

Variable	Dodoma	Mvomero
A. Continuous (mean ± SD) (range)		
Herd size	37.6 ± 26.3 (10-140)	122.8 ± 426.3 (10-3000)
Number of lactating cows per herd	5.5 ± 3.9 (2-20)	18.8 ± 19.9 (2-100)
Milk sold (l/day)	2.5 ± 1.7 (0.5-8)	11.0 ± 15.7 (1-80)
Milk consumed at home (l/day)	2.9 ± 2.6 (1-15)	6.7 ± 5.6 (1-25)
Average cow milk production (l/day)	0.8 ± 0.5 (0.25-3.5)	0.7 ± 0.5 (0.25-5)
B. Proportions, n (%)		
Milk outlets:		
i) To neighbours	48 (100.0)	12 (25.0)
ii) To vendors	5 (10.4)	39 (81.3)
iii) To other places (collection centres)	0 (0.0)	16 (33.3)
Time taken from milking to selling:		
i) Immediately (less than 30 min)	45 (93.8)	28 (58.3)
ii) Between 30 min and 5 h	12 (25.0)	47 (97.9)
iii) More than 5 h	3 (2.1)	1 (2.1)
History of milk rejection	3 (6.3)	23 (47.9)
C. Numbers		
Reason for milk rejection:		
i) Clot on boiling	1	1
ii) Clots/flakes in milk	0	7
iii) Watery milk and clots	0	1
iv) Clots, watery milk and offensive odour	3	1

Because of lack of storage facilities, the majority of farmers were selling milk soon after milking. In Mvomero district, most of the farmers reported selling their milk within five hours after milking and this was mainly influenced by the time milk vendors come to collect milk at their homesteads. There was a significantly higher proportion of farmers who reported having had their milk rejected in Mvomero (47.9%) than in Dodoma rural (6.3%) district ($p < 0.001$). The main reason for rejection was the occurrence of milk clots on boiling, the presence of clots/flakes in milk or offensive odour and the increased wateriness of milk (Table 1).

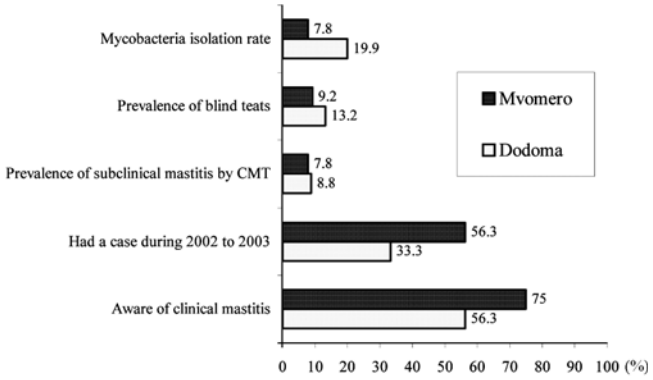

Fig. 1. Prevalence of mastitis, blind teats and isolation of *Mycobacterium* spp. in milk collected from Mvomero and Dodoma rural districts, Tanzania.

Mastitis and quality of milk in the study area

Prevalence of mastitis and isolation of microorganisms from milk

Out of the 96 respondents in the two districts, 66% reported being aware of clinical mastitis.

Overall, 44.8% of 96 herds visited were reported to have had at least one case of clinical mastitis within a period of two years prior to the current study (Fig. 1). Out of 136 and 141 lactating cows that were physically examined in Dodoma and Mvomero, 13.2% and 9.2% had blind teats, respectively. There was no significant difference in the average number of blind teats per cow in Dodoma (1.3 ± 0.7, range = 1-3) and Mvomero (1.1 ± 0.3, range = 1-2) districts. Although some of the animals examined had blind teats, no clinical mastitis cases were diagnosed on days of farm visits. On the other hand, the prevalence of subclinical mastitis based on CMT in lactating cows in Dodoma (8.8%) and Mvomero (7.8%) were comparable.

Out of the 550 quarter milk samples from Mvomero district cultured, 31.5% had aerobic mastitis-causing pathogens isolated and the proportions of pathogens recovered were comparable in all four quarters. Various aerobic bacteria that were isolated from the milk included coliforms (27.7%), *S. aureus* (35.3%), other *Staphylococcus* spp. (20.8%), *Micrococcus* spp. (5.8%), *Streptococcus* spp. (9.8%) and others (0.6%). Coliforms (n = 48) that were isolated included 33 *Pseudomonas aureginosa* (68.8%),10 *Klebsiella edwardisii* (20.8%), 3 *Escherichia coli* (6.3%) and 2 unidentified *Enterobacteriaceae* isolates (4.2%). Other less common

Table 2. Quality of raw milk in Dodoma rural and Mvomero districts, Tanzania

	Dodoma (n=41)	Mvomero (n=48)
Positive samples TVC*	32 (78.0%)	34 (70.8%)
mean ± SD TVC	$1.0\times10^{7} \pm 3.4\times10^{7}$	$8.9\times10^{5} \pm 3.5\times10^{7}$
Range TVC	2.5×10^{3} to 1.9×10^{8}	2.0×10^{2} to 1.9×10^{7}
Positive samples TCC*	29 (70.7%)	10 (20.8%)
mean ± SD TCC	$1.3\pm10^{5} \pm 2.9\times10^{5}$	$1.0\times10^{6} \pm 3.1\times10^{6}$
Range TCC	4.0×10^{2} to 8.0×10^{5}	2.0×10^{2} to 1.0×10^{7}

*Units for total viable count (TVC) and total coliform count (TCC) are colony-forming units (CFU) per ml of milk sample.

Table 3. *Mycobacterium* spp. isolated from milk collected from Dodoma and Mvomero districts, Tanzania

Mycobacterium spp.	Dodoma		Mvomero	
	n	%	n	%
M. flavescens	6	22.2	2	18.2
M. phlei	6	22.2	-	0.0
M.smegmatis	3	11.1	-	0.0
M. tuberculosis	1	3.7	-	0.0
Terrae group	11	40.7	9	81.8
Total isolates	27	100.0	11	100.0

microorganisms isolated were *Nocardia asteroides* (1) and *Aspergillus fumigatus (1)*. Anaerobic bacteria were not isolated from any of the milk samples.

Milk quality

The quality of milk in the study area as defined by TVC and TCC is summarized in Table 2. The proportions of raw milk samples positive by TVC in Dodoma (78.0%) and Mvomero (90.5%) districts were comparable. However, bacterial load defined by the average TVC of raw milk collected in Dodoma ($1.0 \times 10^{7} \pm 3.4 \times 10^{7}$) was significantly higher than that of raw milk in Mvomero district ($8.9 \times 10^{5} \pm 3.5 \times 10^{6}$) ($p < 0.001$). It was also found that the proportion of raw milk samples contaminated with faecal material as defined by TCC was significantly higher in Dodoma district (70.7%) than that in Mvomero district (20.8%) ($p < 0.001$).

Prevalence of mycobacterial infection

All the animals in the two districts were negative for tuberculosis by tuberculin test. Infection by various *Mycobacterium* species was revealed through recovery of agents in milk samples. The isolation rate of mycobacteria from milk samples collected from lactating cows was 19.9% and 7.8% in Dodoma rural and Mvomero district, respectively (Fig. 1). Most of the isolates were atypical mycobacteria (Table 3). However, *M. tuberculosis* was recovered from one milk sample from Dodoma district.

Out of the 96 respondents interviewed, only 20.8% were aware that consumption of milk could be associated with health risks and there was no significant difference on the level of awareness in the two districts. The health risks mentioned by 9 respondents in Dodoma district to be associated with milk included zoonotic diseases (8 respondents), presence of antibiotic residues in milk (3 respondents) and reduced milk quality in case the milk was from a mastitic cow (1 respondent). In Mvomero district, respondents mentioned zoonotic diseases (11 respondents) and antibiotic residues (2 respondents). Diseases considered by respondents to be transmitted to human beings through milk consumption are indicated in Table 4. In Dodoma rural district, majority of farmers perceived helminth infection to be the most important disease, followed by tuberculosis, whereas in Mvomero district, tuberculosis was the most feared disease. Overall, 7.3% of all 96 households that participated in the study had at least one member in the family diagnosed to have had tuberculosis within a period of

Table 4. Diseases perceived by respondents in Dodoma rural and Morogoro districts, Tanzania to be transmitted through milk consumption

Disease/symptom	Dodoma		Mvomero	
	Ranked no. 1	Ranked no. 2	Ranked no. 1	Ranked no. 2
Coughing	-	2 (40.0%)	1 (4.8%)	2 (28.6%)
Helminth	7 (63.6%)	-	-	2 (28.6%)
Tuberculosis	3 (27.3%)	2 (40.0%)	20 (95.2%)	-
Diarrhoea	-	1 (20.0%)	-	1 (14.3%)
Ulcers	1 (9.1%)	-	-	-
FMD*	-	-	-	2 (28.6%)
Total	11	5	21	7

*FMD: foot and mouth disease.

two years before the current study. The number of households that had family member with tuberculosis within this period in Dodoma and Mvomero district was 3 and 4, respectively.

Most farmers (94.5%) reported the fermentation of milk from raw unboiled milk. The practice of fermenting milk mainly for home consumption was high in both Dodoma rural (95.8%) and Mvomero (93.8%) districts. In addition to use of fermented milk, some members of the communities reported having other milk use practices. For instance, whereas a low proportion of farmers in Dodoma rural (20.8%) were also drinking boiled raw milk, the number of people consuming boiled raw milk was high (93.8%) in Mvomero district. Others also reported the use of milk for preparing tea. The proportions of farmers using milk in tea in Dodoma rural and Mvomero district were reported to be 50.0% and 89.6%, respectively.

Discussion

This study has shown that the Gogo ethnic community in Dodoma rural district owns relatively small-sized herds of cattle compared to the Maasai and Sukuma communities in Mvomero district. This difference is likely to be attributed to the tradition of each community. For instance, whereas the Gogo people keep animals, they also grow crops such as maize, sorghum, millet, groundnuts, sweet potatoes, cassava and sunflower compared to the Maasai who solely depend on livestock keeping for their livelihood. The Sukuma people in Mvomero district, who also belong to the agro-pastoral category, have migrated from the Sukumaland in Mwanza and Shinyanga regions. It is possible that those owning bigger herds in the Sukumaland are more likely to migrate than those owning smaller herds to new areas due to grazing pressure and, hence this may explain why Sukuma communities in Mvomero district had bigger herds. Other factors that may influence size of herds include the availability of enough pasture and water for animals and humans. For instance, Dodoma is usually drier and receives less rainfall than Mvomero district and consequently the district has generally less amount of pasture and rangelands available for communal grazing. Ownership of large herds by both Sukuma and Masai in Mvomero district may also be attributed to more access to pasture and water especially from Dakawa river in that district than in Dodoma rural district.

The study has also shown that there are more opportunities for selling milk in Mvomero than in Dodoma rural district. This is mainly attributed to presence of milk vendors and established milk collection centres in Mvomero. This implies that farmers in Mvomero are likely to receive more money accrued from milk sales as compared to those in Dodoma and this may have a differential impact with respect to poverty reduction. Findings of this study also show that the average milk produced per cow in the two districts was low (0.7 to 0.8 l/day) and this may be explained by type of cows owned by farmers which were of indigenous Tanzania Shorthorn Zebu type. Other possible explanation for low milk production may be the season when this study was carried out i.e. during the dry-short rain period of August to January when most of the areas do not have enough pasture. It is possible that improved milk production is likely to occur during the long rains (March to May) when cows get enough pasture and water as reported by others [35].

Despite the presence of blind teats and reports of farmers having encountered clinical cases two years prior to the period of this study, of interest was the low prevalence of subclinical mastitis in animals in the agro-pastoral and pastoral herds. Results of this study are in agreement with observations made by others in traditional cattle in Tanzania [35]. The low prevalence of subclinical mastitis in traditional cattle is contrary to the status of the disease in smallholder crossbred animals in Tanzania [16,41] where higher prevalence of between 60% and 80% have been reported [22,33,34].

A number of factors have been reported to influence the occurrence of mastitis in dairy cattle. They include managerial factors particularly those related to poor milking hygiene, environmental population of mastitis pathogens, predisposing factors such as teat injuries and sores and incomplete emptying of mammary gland quarters and hereditary factors [3,12,16,38]. Most of these factors, with the exception of hereditary factors and complete emptying of udder, favour higher prevalence of mastitis in traditional Zebu cows than crossbred animals reared under smallholder and large-scale farming systems. Therefore, it is possible that traditional cattle have low mastitis burdens largely because of the association of the major histocompatibility complex (MHC) class I genes which in cattle is also known as the bovine leucocyte antigen system (BoLA) with susceptibility or resistance to mastitis [31,40] as also reported in respect to the association between BoLA MHC class II and mastitis [21]. Although scanty information on characterization of local and crossbred cattle in Tanzania is available [9], some work carried out in the country reported breed-associated resistance with Zebu animals found to be less infested with ticks than crossbred animals [45].

Pathogens isolated in milk in the current study are similar to those documented in other studies involving crossbred dairy cows in Tanzania [16,22] and other developing countries [26]. Predominance of contagious pathogens in developing countries may be related to poor house and milking hygiene, as was the situation in developed countries in the 1960s and 1970s [39,46].

Although there were no tuberculosis-positive reactor animals in this study, a number of *Mycobacterium* species were isolated from milk and majority were atypical species as also reported in milk from traditional cattle [18] and

crossbred dairy animals [22] in Tanzania. Normally, atypical mycobacteria are non-pathogenic in healthy individuals but become important in immunocompromised people and are also associated with alcoholism and homelessness [24,29, 43]. Since, 63% of the milk consumed in Tanzania comes from the traditional sector, the presence of atypical mycobacteria in milk from traditional animals may be more important during this era of HIV-AIDS pandemicity than before. However, more work is required to ascertain the role of these organisms in contributing to morbidities and mortalities in HIV infected persons and AIDS patients.

This work also reported recovery of *M. tuberculosis*, an obligate species that is known to cause tuberculosis in humans. Presence of *M. tuberculosis* in milk has also been reported in Burkina Faso [44] and India [1] and it may possibly be due to post-milking contamination by people involved in either milking or handling milk thereafter through coughing. To the best of our knowledge, this is the first report of isolation of *M. tuberculosis* in milk in Tanzania. Thus, the recovery of *M. tuberculosis* from milk is epidemiologically important especially in agro-pastoral and pastoral communities in Tanzania where most people consume raw fermented milk.

Findings of this study showed that the level of knowledge and awareness of health risks associated with drinking milk was low. Even with the low proportion (21%) of respondents who reported to be aware of such risks, further investigation revealed that some of the symptoms and conditions mentioned such as helminth infection, diarrhoea and ulcers were not essentially zoonotic diseases. The citation of diarrhoea by respondents in this study may be through experience of diarrhoeic cases associated with milk consumption attributed to lactose intolerance syndrome, which is considered to be high amongst black populations [32]. The low level of knowledge observed in this study may be influenced by low education level of respondents in the current study as it has also been reported elsewhere [28,36]; inadequacy of information due to remoteness of study areas and lack of health programmes to educate disadvantaged communities such as the pastoralists. On the other hand, the high level of awareness of tuberculosis as a zoonotic condition amongst pastoral communities in Tanzania, as also been reported by others [36], may be related to the numerous reports of the link between tuberculosis and HIV/AIDS problem in the country.

The present study also showed that quality of milk in study areas was poor. This was based on high values of TVC and TCC in milk samples. High TCC values are indicative of contamination of milk with faecal material. For instance, whereas the average lowest TCC value in this study was $1.5 \times 10^6 \pm 5.1 \times 10^6$ CFU/ml, which was higher than the acceptable levels of between 25 and 50 CFU/ml [3]. The hypothesis of post-milking contamination is also supported by isolation of *M. tuberculosis* in milk, which is a primary pathogen of humans. Findings that milk quality in Dodoma was poorer than that in Mvomero may be attributed to the differential market demands as milk vendors and milk collection centres present only in Mvomero district often use organoleptic tests before acceptance of milk. This practice may be an incentive to improved milk quality in order to avoid rejection of the milk.

Although mastitis occurs in the pastoral and agro-pastoral animals, its prevalence is much lower than that in the smallholder or large-scale dairy animals in Tanzania. This is likely to be attributed to genetic factors, as these animals are known to be less susceptible to diseases than exotic and crossbred ones. In addition, the presence of atypical mycobacteria in milk and the habit of consuming fermented milk prepared from raw unboiled milk call for health education strategies designed to change milk consumption habits. However, further studies on other zoonotic infections associated with milk consumption are required before devising comprehensive health education programmes in order to reduce associated morbidities and mortalities, especially during this era of HIV/AIDS pandemicity.

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