REVIEW

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# Brucellosis risk factors and milk hygiene handling practices in pastoral communities in Isiolo county, Kenya

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## Abstract

The study was conducted from June to August 2014 in Isiolo Central division of Isiolo Sub-County and Sericho division of Garbatulla Sub-County and comprised two components: (i) a cross-sectional study on the milk-handling hygiene practices, where milk traders' households were the study units and (ii) a case-control study on the risk factors for *Brucella* spp. infection in humans. Results of the cross-sectional study showed that 26.74% of the respondents never washed their hands before milking, 60.47% never washed the udder before milking and 54.65% never withhold consumption of milk from animals under treatment with antibiotics. The case–control study included household units with previous cases of brucellosis (53.33%) and those without (46.67%) over the previous 5 years and identified drinking of raw milk as the main risk factor for infection (OR = 26.44; 95% CI: 8.04–86.99). Pastoralists' unhygienic handling of milk from production to market is suboptimal and this is due to poor knowledge on hygienic practices, poor knowledge on the risks associated with poor milk hygiene and lack of sufficient and potable water for cleaning of milk containers. Many pastoralists still consume milk raw and this is a major public health risk for milk-borne diseases.

**KEYWORDS**
brucellosis, milk, pastoralists, public health, zoonoses

## 1 | INTRODUCTION

Over 80% of Kenya's landmass is arid or semi-arid, mainly inhabited by livestock rearing nomadic pastoralists' communities (Simpkin, 2005). Livestock play a major role in the livelihoods of pastoralist communities as an asset and food source as well as a symbol of social standing in the community. Livestock are used for social obligations, such as dowry payment, to settle family disputes or to donate to the less fortunate families as a religious offering. During times of financial needs, livestock are sold to cover costs such as school fees or medical emergencies. Livestock are also a key source of protein for these communities in the form of milk and meat (Shirima et al., 2010). In Kenya, it is estimated that over 90% of milk consumed at the household level is raw unpasteurized milk purchased from informal small-scale milk traders (Njarui et al., 2011). This puts a high percentage of the country's population at risk of various public-health related issues from the consumption of unprocessed milk. Milk from camels, cows and goats is sold as either fresh milk or sour milk. Milk production hygiene at the farm level in the pastoral communities is poor and this is attributed to poor personal hygiene as well as lack of clean water to wash the equipment used for milking and the jerry cans typically used for milk storage and transport to the local markets (Kaindi et al., 2012). Poor milk hygiene and lack of pasteurization greatly increase the risk of transmission of milk-borne diseases such as brucellosis (Shirima et al., 2010).

Brucellosis is a zoonotic disease caused by bacteria of the genus *Brucella* of which *Brucella melitensis* and *Brucella abortus*, the species mostly maintained in small ruminants (sheep and goats) and in cattle, are the main cause of human infection (Doganay & Aygen, 2003). Human brucellosis is widely distributed worldwide; however, valid incidence estimates are often lacking as a result of under-reporting and misdiagnosis (Jennings et al., 2007). A study carried out in two Kenyan counties showed that the prevalence of brucellosis in live-stock handlers in pastoralist communities was 31.8% and that of handlers in a semi-intensive rearing system was 5.7% while the prevalence in animals in the two systems was 1.2% and 3.2% respectively (Ogola et al., 2014). It has been proposed that a higher risk of infection for handlers in pastoralist communities could be explained by the close contact between pastoralists and their animals (Njeru, Wareth, et al., 2016).

The main routes of infection of humans with brucellosis are direct contact with infected animals and their parturition fluids and consumption of unpasteurized dairy products from infected animals (Doganay & Aygen, 2003). In the pastoral communities of Sub-Saharan Africa, the incidence of brucellosis in humans is as-sumed to be high due to the close interaction of livestock and hu-mans as well as the consumption of raw unprocessed milk (Seleem et al., 2010). In these settings, diagnosis and identification of en-demic diseases is constrained by under-reporting of cases and lim-ited capacity for laboratory confirmation (Corbel, 2006). Indirect and direct contact with animals and consumption of unpasteur-ized dairy products have been identified as risk factors for human brucellosis by studies carried out among livestock-keeping com-munities in different countries (Cooper, 1992; Kunda et al., 2010; Mangtani et al. 2020; Regassa et al., 2009). However, in Kenya, there is a gap in information on the prevalence of brucellosis in livestock reared by pastoral communities and in livestock keepers as well as on risk factors for infection. The country also lacks an established national brucellosis control programme (Njeru, Melzer, et al., 2016).

The objectives of this study were to identify risk factors for the occurrence of human brucellosis and to describe milk-handling hy-giene in the pastoral communities from Isiolo County in the Eastern Province of Kenya.

## 2 | METHODS

### 2.1 | Study area

Isiolo County is located at latitude N00.35° and longitude E037.58° and an altitude of between 1,730 and 1,890 m above sea level. It comprises of arid and semi-arid regions covering 25,605 km$^2$ with a population of 143,294 people as of the 2009 Kenya Census. The county is covered by sparsely distributed vegetation mainly com-prising of Acacia species and bushy woodlands and receives erratic unreliable rainfall ranging from 237 to 608 mm with ambient tem-peratures of above 25°C annually. The county is subdivided into three sub-counties namely Isiolo, Merti and Garbatulla sub-counties. The study was conducted from June to August 2014 in Isiolo Central division of Isiolo Sub-County and Sericho division of Garbatulla Sub-County as shown in Figure 1.

The study areas are predominantly inhabited by the Borana and Somali communities who rely heavily on their livestock for their live-lihood. The commonly reared livestock include cattle, sheep, goats and camels. The most abundant livestock species in this area is the dromedary or one-humped camel (*Camelus dromedarius*), with camel milk marketing being an important income-earning opportunity for the pastoral households. Cow and goat milk is normally consumed at the household level and the surplus is sold in the local markets.

### 2.2 | Study design and study population

This study was comprised of two components: a cross-sectional household survey on milk-handling hygiene practices and a population-based case–control study to assess human brucellosis infection risk factors at the household level.

### 2.3 | Cross-sectional survey

The cross-sectional survey had milk traders as the unit of interest. The target population was local milk producers regularly engaged in the trading of milk in the study area. A sample frame was not
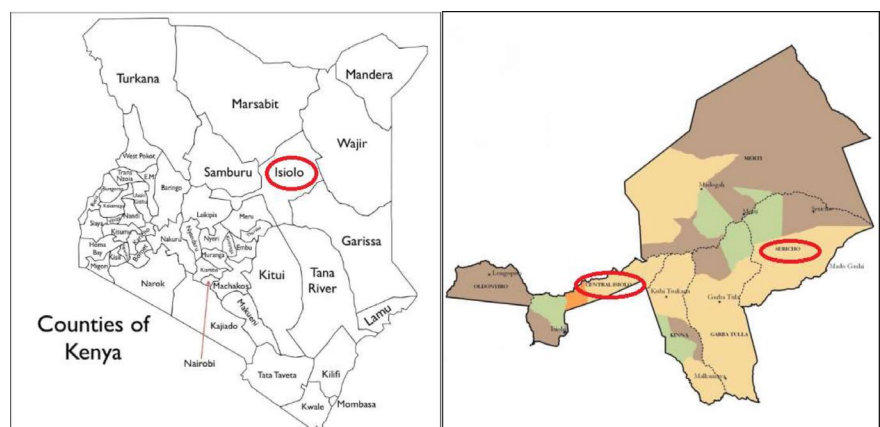


**FIGURE 1** Map of the study areas highlighted in the country and county maps

available but based on the previous experience of the senior author in the area, it was estimated that the target population included at least 400 milk traders. The selection of the study units was carried out in two stages. First, a total of 13 villages from Isiolo Central division in Isiolo Sub-County and Sericho division in Garbatulla Sub-County were selected by simple random sampling. This was based on an expectation of 6 or 7 traders per village and a target number of at least 78 traders. Interviews were administered by the senior author by means of a structured questionnaire described below.

## 2.4 | Case–control study

The case–control study had the household as the unit of interest. A required sample size of 194 households was calculated using EpiTools epidemiological calculators (Sergeant, 2014), in order to achieve an 80% power and confidence level of 95%, with a hypothetical proportion of exposed controls of 75% and the assumed odds ratio of 3 based on previous studies conducted on brucellosis risk factors in similar populations (Kiambi, 2012; Regassa et al., 2009). The case and control households were identified from initial focus group discussions held with community members of the same locations that were selected previously for the cross-sectional survey based on access and security. This convenience sampling selection approach was used due to the limitations of logistical support and resources available for the field visits and data collection. Eighteen focus group discussions were held at the 13 selected locations where all community members were invited to participate in the discussions, thus, participation was voluntary. An average of 20 community members (women, men, and youth) participated in group discussions. A checklist was used in the initial focus group discussions with community members to aid in identifying potential case and control households, which were defined based on the identification of previous cases of brucellosis. Households with one or more previous cases of brucellosis were considered as cases while households where there had not been a case of brucellosis were considered as the controls. Controls were selected from the same population and village to ensure that they also have the similar opportunity of exposure to the risk factors of interest. Households who do not own or rear livestock were not excluded in the selection of cases and controls. The checklist specified case households as those with at least one previous confirmed case of brucellosis with records from health centres in the past 5 years or at least one previous case who exhibited clinical signs that strongly suggested they were suffering from brucellosis. Information on medication given and the recovery process thereafter was also to be considered in such situations. The clinical signs that were considered are the typical brucellosis clinical signs of unresolved febrile illness particularly after treatment for malaria (brucellosis can be misdiagnosed as malaria), myalgia and arthralgia, fever, headache, backache, anorexia and weight loss (Doganay & Aygen, 2003; WHO, 2006). The final inclusion of a household as a 'case' was based on verbal confirmation from the respondents that they had previous bouts of brucellosis as confirmed from hospital

laboratory tests and/or the medication used. The laboratory testing is done using the Rose Bengal Plate Test which is only available in the district and provincial hospitals (Njeru, Melzer, et al., 2016). Medical records or test results were not presented as they were either not retained or given to the patients by the healthcare providers. Those who also identified with at least 5 of the clinical signs indicated in the checklist were interviewed further before classifying them as cases or controls. The checklist is available with the senior author and can be availed upon request.

## 2.5 | Data collection

Data collection was done using two questionnaires; one for milk-handling practices of milk traders (cross-sectional survey of milk traders) and the other for household-level risk factors in case and control households. A total of 86 milk traders were interviewed using the individual questionnaire for milk-handling practices which comprised of open and closed questions gathering basic demographic data, livestock species reared and their numbers, milking hygiene practices, milk-handling practices and containers hygiene, and knowledge on milk-borne zoonoses. The individual questionnaire for brucellosis risk factors used gathered basic demographic data, history of brucellosis infection, information on milk handling practices and data relating to potential brucellosis risk factors as identified from previous studies.

## 2.6 | Statistical analysis

The collected data were entered in Microsoft Access database and analysed using R version 2.7.2. Descriptive statistics and measures of effect were obtained. The data collected from the case–control study was used to estimate odds ratios, their confidence intervals and to test for association between hypothetical risk factor and disease using the Pearson's Chi-squared test. The analysis for the brucellosis infection risk factors conducted was only univariate. For purpose of calculation of odds ratios as measures of strength of association between hypothetical risk factors and brucellosis, the exposure variables for household drinking raw milk, assisting calving and handling aborted fetus were recoded to binary variables of "never" and "yes", where those who said they never do that were classified under "never" and those giving a response of sometimes or always were classified under "yes".

## 3 | RESULTS

### 3.1 | Milk hygiene cross-sectional survey

Eighty-six (86) respondents were interviewed in this survey, where 33 were women (38.37%) and 53 were men (61.63%). The main livelihood of the respondents is livestock rearing for 93.02%, small

**TABLE 1** Summary of livestock numbers reared by the interviewed respondents for milk hygiene cross-sectional survey (N = 86), carried out in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Livestock species | Number of households rearing livestock (%) | Minimum number of livestock reared | Maximum number of livestock reared | Mean number of livestock reared | Median of the livestock reared |
|---|---|---|---|---|---|
| Sheep and goats | 32 (37.2) | 8 | 188 | 40 | 30 |
| Cattle | 36 (41.9) | 2 | 80 | 28 | 20 |
| Camels | 45 (52.3) | 2 | 200 | 60 | 59 |

**TABLE 2** Summary results on interviewees hygiene practices concerning milking and consumption (N = 86) carried out in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Practice | Always (n [%]) | Sometimes (n [%]) | Never (n [%]) |
|---|---|---|---|
| Washing hands before milking | 30 (34.9) | 33 (38.4) | 23 (26.7) |
| Washing the udder before milking | 24 (27.9) | 10 (11.6) | 52 (60.5) |
| Consuming raw milk without boiling | 35 (40.7) | 41 (47.7) | 10 (11.6) |
| Boiling milk before selling | 38 (44.2) | 19 (22.1) | 29 (33.7) |

**TABLE 3** Milk-handling containers used by the study respondents (N = 86) in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Type of Containers | Milking container | | Milk storage container | | Milk transportation container | |
|---|---|---|---|---|---|---|
| | n | % | n | % | n | % |
| Plastic jerry can | 37 | 43.0 | 24 | 27.9 | 74 | 86.1 |
| Aluminium milk can | 35 | 40.7 | 17 | 19.8 | 12 | 13.9 |
| Traditional wooden gourd | 12 | 14.0 | 1 | 1.1 | 0 | 0 |
| Plastic container | 2 | 2.3 | 0 | 0 | 0 | 0 |
| Cooking Pan | 0 | 0 | 44 | 51.2 | 0 | 0 |
| Totals | 86 | 100 | 86 | 100 | 86 | 100 |

businesses/trade for 4.65% and casual employment for 2.33%. The mean household size of the respondents is 8 with a range of 3 to 16 people, and the proportions of households rearing camels, cattle and sheep were 52.3%, 41.9% and 37.2% respectively. The average number of livestock reared per household is 60 camels, 28 cattle and 40 sheep. The livestock species and numbers reared for the respondents are summarized in Table 1.

Regarding milking hygiene and consumption of raw milk, the results showed that 26.74% of the respondents do not wash their hands before milking, 60.47% do not wash the udder before milking compared to 34.88% and 27.91% who always wash their hands and udders, respectively, before they milk their livestock. About 41% of the respondents consume milk raw without boiling compared to 11.63% who always boil milk. On the milk sold in the markets, 44.19% of the respondents ensure that they boil the milk before selling it in the local markets and the main reason given for doing so was to increase the shelf life of the milk to be sold. The detailed results are given in Table 2.

The containers used for milking, storage and transportation of milk varied from plastic containers, plastic jerry cans (these are containers in which cooking oil is sold and they are re-used for milk handling), traditional wooden gourds and aluminum milk cans. For milking, 43.02% of households use plastic jerry cans, 40.7% use aluminum milk cans while 13.95% still use the traditional wooden gourds. For milk transportation, 86.05% of the households use plastic jerry cans and 13.95% use aluminum milk cans. These containers are cleaned by washing with soap and water (68.6%), washing with plain water (20.93%) or by the traditional smoking method (10.47%). The summary of the containers used for the various activities is shown in Table 3.

Following the treatment of lactating animals with antimicrobials, 20.93% of the respondents always withhold consuming the milk, 24.42% would sometimes do it and 54.65% never withhold

**TABLE 4** Use or disposal practices of milk from treated animals by the study respondents (N = 86) in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Household group | Practice | n | % |
|---|---|---|---|
| Those who withhold milk from treated animals (N = 39) | Sold at the market | 25 | 64.1 |
| | Poured out | 7 | 18.0 |
| | Used at home | 2 | 5.1 |
| | Give to the young animals | 5 | 12.8 |
| Those who do not withhold milk from treated animals (N = 47) | Sold at the market | 28 | 59.6 |
| | Used at home | 17 | 36.2 |
| | Give to the young animals | 2 | 4.2 |
| | Poured out | 0 | 0.0 |

consumption of milk from treated animals. Of the 39 respondents who withhold milk from treated animals, 12.79% do so for 1–2 days, 23.26% do it for 3–4 days while 9.3% withhold for 4 days or more depending on the drugs used on the particular animal. The 47 respondents who do not withhold consuming milk from treated animals indicated that they were unaware that they need to withhold the milk (37.5%) or that they needed the milk either for household consumption or to sell for income (60.42%). The milk from treated animals is handled in various ways by both groups (Table 4).

On the issue of disease transmission through milk, 65.12% of the respondents do believe that there are diseases transmitted in livestock milk while 34.88% do not believe that one can get diseases from the consumption of milk from livestock. On the knowledge of zoonotic diseases transmitted through livestock milk, 58.14% of the

respondents mentioned brucellosis as the main disease one can get through milk and 16.28% are unaware of any diseases that can be transmitted through milk. Other diseases mentioned as the main zoonoses transmitted through milk included typhoid (12.79%), flu (9.3%), tuberculosis (2.33%) and malaria (1.16%). The importance of various methods to control milk zoonoses was assessed where 75.58% of the respondents believe it is relevant to boil milk, 38.37% believe it is important to avoid milk from sick animals and 56.98% indicated that vaccination and treatment of animals are important in the prevention of zoonoses. The detailed results are shown in Table 5.

Other methods of controlling and managing milk-borne zoonoses mentioned were more treatment by 38.37% of the respondents, prayer by 17.44% and improved hygiene by 5.81%. Also, 38.37% said they were not aware of any other measure that can be taken in controlling milk-borne diseases.

## 3.2 | Case–control study

For the case–control study, the number of household respondents included in the study was 180. They were represented by 116 men (64.44%) and 64 women (35.56%). The average family size of the respondents is 7 people ranging from 3 to 14 people per household. The median household size is six people. The main livelihood sources of the respondents is livestock rearing for 68.89%, engagement in small businesses and trade by 25% and full-time employment by 6.11% of the respondents.

This was an unmatched study where 96 (53.33%) of the households were categorized as case households based on the case definition presented above and the remaining 84 (46.67%) were classified as control households.

The proportions of households in which raw milk is consumed daily, at least once in a week and never were 36.5%, 54.1% and 9.4% among case households and 6%, 53.5% and 40.5% among control households. The category "never" was used as the reference to compute odds ratios for the other categories. The odds ratio for the daily consumption of raw milk was 26.44 (95% CI: 8.04–86.99) and for the consumption of raw milk at least once a week was 4.37 (95% CI: 1.89–10.07) in comparing the case and control households. The results provide strong evidence of an association between brucellosis and households' consumption of raw milk.

| Prevention method | Relevant (n [%]) | Somehow relevant (n [%]) | Not important (n [%]) |
|---|---|---|---|
| Boiling milk | 65 (75.6) | 15 (17.4) | 6 (7.0) |
| Avoiding milk from sick animals | 33 (38.4) | 34 (39.5) | 19 (22.1) |
| Vaccination and treatment | 49 (57.0) | 23 (26.7) | 14 (16.3) |

**TABLE 5** Summary results of the respondents' perception of the importance of various methods for preventing milk-borne zoonoses (N = 86) from Sericho and Isiolo Central divisions, Isiolo County in 2014

**TABLE 6** Univariable analysis of the brucellosis risk factors among the study respondents (N = 180) in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Variables | | Cases n (%) | Controls n (%) | Totals N (%) | Odds ratio (OR) | Pearson's Chi-squared test |
|---|---|---|---|---|---|---|
| Households drinking raw milk | Daily | 35 (36.5%) | 5 (6%) | 40 (22.2%) | 26.44 (95% CI: 8.04–86.99) | $\chi^2 = 36.87$ $Df = 1$ $p < 0.0001$ |
| | Weekly | 52 (54.1%) | 45 (53.5%) | 97 (53.9%) | 4.37 (95% CI: 1.89–10.07) | $\chi^2 = 12.94$ $df = 1$ $p < 0.0001$ |
| | Never | 9 (9.4%) | 34 (40.5%) | 43 (23.9%) | 1 | |
| Assisting calving | Always | 19 (19.8%) | 32 (38.1%) | 51 (28.3%) | 0.51 (95% CI: 0.29–1.17) | $\chi^2 = 2.34$ $df = 1$ $p = 0.126$ |
| | Sometimes | 30 (31.2%) | 6 (7.1%) | 36 (20%) | 4.89 (95% CI: 1.86–12.86) | $\chi^2 = 11.60$ $df = 1$ $p = 0.001$ |
| | Never | 47 (49%) | 46 (54.8%) | 93 (51.7%) | 1 | |
| Handling aborted fetus | Always | 13 (13.5%) | 9 (10.7%) | 22 (12.2%) | 1.42 (95% CI: 0.56–3.57) | $\chi^2 = 0.56$ $df = 1$ $p = 0.455$ |
| | Sometimes | 23 (24%) | 16 (19%) | 39 (21.7%) | 1.41 (95% CI: 0.68–2.94) | $\chi^2 = 0.86$ $df = 1$ $p = 0.353$ |
| | Never | 60 (62.5%) | 59 (70.2%) | 119 (66.1%) | 1 | |

On examining the relationship between assisting calving and brucellosis cases, 54.8% of the controls have never assisted livestock to calve, while 19.8% of the cases always assist livestock calving. Using the category of "never assisting calving" as a reference to compute the odds ratio, no clear evidence supporting the association was found (OR = 0.51; 95% CI: 0.29–1.17).

In assessing the relationship between brucellosis cases and handling aborted fetuses, 70.2% of the controls have never handled aborted fetus and 13.5% of the cases always handle aborted fetuses. Using the category of "never handling aborted fetus" as the odds ratio computation reference, no evidence was found to support this association (OR = 1.42; 95% CI = 0.56–3.57). The summary of these results is shown in Table 6.

A logistic regression model with the location (village) as a random effect and household size as a potential confounder was used in the multivariable analysis. The two significantly associated explanatory variables in the univariate analysis, namely: households drinking raw milk and assisting calving were included in the multivariable analysis. Selected variables were included in the logistic model and manual backward elimination was used to obtain a final model, with the least significant variables removed, providing their removal did not alter the odds ratios (OR) of other variables by more than 20% and $p \geq 0.05$. The analysis was then repeated including one variable once a time. Adjusted OR and 95% confidence intervals (CIs) were obtained, with variables only retained if $p < 0.05$. Multivariable analyses was carried out using the function glmer implemented in r package lm4 (R version 4.0.2, 2020). The two variables were tested for colinearity using Cramer's phi test and week association was found (0.27) (values of > 0.7 indicate a high association). These are summarized in Table 7.

**TABLE 7** Multivariable analysis of the brucellosis risk factors among the study respondents ($N = 180$) in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Explanatory Variables | Adjusted odds ratio (95% CI) | p value |
|---|---|---|
| (a) The two variables taken together with household size considered as confounder and location as random effect. | | |
| Household size considered as binary variable (i.e. ≤ or > median of 6) | | |
| Assisting with calving | 1.47 (0.97–2.24) | 0.07 |
| Households drinking raw milk | 1.36 (0.91–2.05) | 0.13 |
| Household size considered as numerical variable (based on quartiles) | | |
| Assisting with calving | 1.45 (0.95–2.21) | 0.08 |
| Households drinking raw milk | 1.37 (0.91–2.07) | 0.13 |
| (b) Each variable taken separately with the household size considered as confounder and location as random effect. | | |
| Household size considered as binary variable (i.e. ≤ or > median of 6) | | |
| Assisting calving | 1.62 (1.09–2.43) | 0.02 |
| Households drinking raw milk | 1.53 (1.04–2.25) | 0.03 |
| Household size considered as numerical variable (based on quartiles) | | |
| Assisting calving | 1.61 (1.07–2.40) | 0.02 |
| Households drinking raw milk | 1.54 (1.04–2.27) | 0.03 |
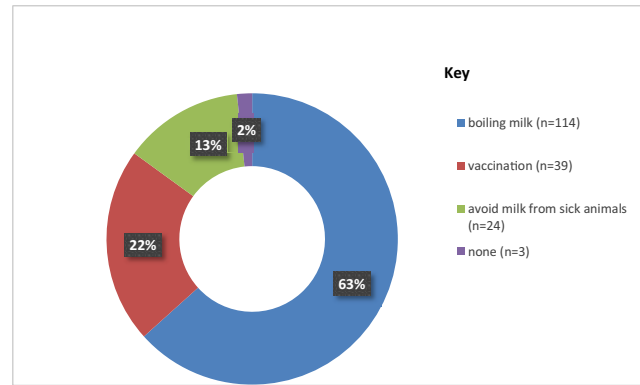


**FIGURE 2** Chart showing the practices used by the respondents to avoid brucellosis

**TABLE 8** Discarding practices for aborted fetuses by the study respondents ($N = 180$) in Sericho and Isiolo Central divisions, Isiolo County in 2014

| Practice | Always (n [%]) | Sometimes (n [%]) | Never (n [%]) |
|---|---|---|---|
| Burning the aborted fetus | 17 (9.5) | 60 (33.3) | 103 (57.2) |
| Burying the aborted fetus | 17 (9.4) | 59 (32.8) | 104 (57.8) |
| Discarding the aborted fetus in bush | 128 (71.1) | 7 (3.9) | 45 (25.0) |

In the assessment on the respondents' main strategy used to avoid brucellosis infections, 114 (63.33%) of them boil milk, 39 (21.67%) have their livestock vaccinated, 24 (13.33%) avoid milk from the sick animals and 3 (1.67%) do not do anything in particular to avoid brucellosis infection. This assessment was for the first strategy employed by the respondents, although in actual practice more than one may be used. This proportion is shown in Figure 2.

The respondents' disposal of aborted fetuses varies from burning, burying or just discarding it in the bush for wild and domestic carnivores to consume them. Also, 71% of the respondents always discard the fetuses in the bush and 9.44% either burn or bury the fetuses. The summary of this is shown in Table 8.

## 4 | DISCUSSION

The general outcome of this study shows that milk-handling and hygiene practices are suboptimal and need to be improved particularly in the type of containers used for storage and handling of milk. Milk production and handling hygiene have been poor in this region due to poor knowledge of hygiene coupled with challenges of lack of water for frequent use of cleaning the udders and milk equipment. This is also evident in studies conducted in other pastoralist communities facing the same challenge of water shortage and unaware of the need to apply hygienic milking and milk-handling practices (Amenu et al., 2019). Traditional practices and beliefs have also hindered the uptake of improved hygiene practices introduced to the communities

by government extension workers or non-governmental organizations (NGOs) through training conducted with the communities for the control of brucellosis and other milk-borne diseases (Kelly et al., 2016). An example of these traditional practices includes the head of the household (the man) being given the first portion of milk milked to drink as a sign of respect without boiling it (although the milking and selling of milk is primarily the women's duty). There are also other beliefs such as that drinking raw camel milk will cure various diseases particularly gastrointestinal infections; that raw camel milk cannot contain disease-causing microorganisms and that boiling camel milk destroys its medicinal properties (Kaindi et al., 2012).

Pastoralists suffer a lot of post-harvesting losses as a result of poor milking hygiene and practices; poor personal hygiene and low level of milking technology applied at the production level (Worku et al., 2014). Milk traders do not put much effort in maintaining proper hygiene for the milk they sell at the markets as the milk is often not boiled before selling and neither are the milk containers properly cleaned to prevent spoilage and contamination of the milk. The plastic jerry cans are readily available and cheaper than the steel or aluminum milk cans; they are the most commonly used containers for milk transportation and sale. These are commonly cleaned with soap and water, although not thoroughly scrubbed to reach the inner crevices of the containers thus they harbour bacteria that contribute to spoilage and contamination of the milk. Cleaning of the jerry cans in some instances is also done via smoking and this leads to corrosion of the plastic material which contributes to spoilage and milk contamination. The practice of withholding milk following the treatment of livestock is still not implemented by many livestock owners in these pastoral communities. This is as a result of poor knowledge and also poverty, as all the milk collected from the livestock is needed for either household use or is sold for income. Knowledge of milk-borne diseases and zoonoses is also low, although this has improved following the extension training conducted by government officers and NGOs working in the county. The communities following these training are now improving the handling practices of milk from production to sale and the consumers are also willing to spend more for better quality milk (Wayua et al., 2012). Brucellosis is the most commonly known zoonotic disease despite the fact that many cases of brucellosis are likely to be misdiagnosed for malaria due to a lack of access to laboratory diagnostics in the rural areas.

Regular consumption of raw milk puts pastoral communities at risk of zoonotic milk-borne diseases such as brucellosis, which is highly prevalent in pastoral communities (Kunda et al., 2010; Regassa et al., 2009; Seleem et al., 2010; Shirima et al., 2010). Consumption of raw milk emerges in this study as the main risk factor for brucellosis. In contrast to findings of studies in rural communities of other low and middle-income countries (Mangtani et al. 2020), our study does not provide evidence supporting an important role of direct contact with livestock (as opposed to milk-borne) route of infection. Previous studies have shown that handling aborted fetuses and assisting calving are risk factors for brucellosis that put occupationally exposed groups (livestock keepers) at higher risk of infection (Kunda et al., 2010). Studies have also shown that close contact with livestock is a major risk factor for brucellosis in humans (Kunda et al., 2010; Regassa et al., 2009; Seleem et al., 2010; Shirima et al., 2010). Although our study does not provide evidence in support of an association between these practices and brucellosis in the study population, the results are compatible with a moderate association (weaker than with raw milk consumption) as a result of the relatively small sample size, power and lack of adjustment for potential confounders.

A study conducted by Kang'ethe et al. (2000) in 1999–2000 showed that between 2.4% and 4.9% of raw milk samples from informal markets in Narok County, Kenya, had antibodies against *Brucella*. Several other studies conducted in other central and southern parts of Kenya have also shown variable apparent prevalence and high bacteria counts of zoonotic diseases and health hazards in raw milk marketed in the local markets which could be partly due to ineffective regulation on the sale of milk by licensed and non-licensed traders (Omore et al., 2002). The government extension officers and NGOs working in the area should focus on these issues when providing training on milk hygiene and handling practices.

The approach used in this study had some limitations such as the clustering of the case-control study units to households instead of individuals and the selection approach for the respondents in the cross-sectional survey. With the availability of more resources, the study approach would assess risk factors at an individual level and not clustered as was done. These may have introduced bias in the results achieved. Future studies on brucellosis risk factors should also include a component of assessing the prevalence of brucellosis in the populations at risk incorporating hospital and health centres records to get a clear picture of reported and confirmed cases.

## 5 | CONCLUSION

Pastoralists' handling of milk from production to market is suboptimal and this is due to poor knowledge of hygienic practices and of the risks associated with poor milk hygiene and the use of unsuitable milk-handling containers. Lack of sufficient and potable water for cleaning of milk containers is likely to contribute to milk contamination and faster milk spoilage. The preference for the plastic jerry cans for milk transportation over the stainless steel or aluminum milk cans is a major contributing factor to poor milk hygiene and this is primarily due to the low cost of the jerry cans compared with the cans which may be expensive for some of the low-income earning pastoralist households. Many pastoralists still consume milk raw and this is a major public health risk for milk-borne diseases. Public health awareness on zoonoses and other issues on milk hygiene need to be developed and disseminated in the region. Consumption of raw milk emerges as the main route of infection in this study in the target pastoralist population. The pastoralists' knowledge of how brucellosis can be transmitted to man is limited to the consumption of raw milk. Therefore, although our study only provides evidence supporting the role of the milk-borne route and not the direct contact route, public health extension training should also cover the risk of

infection due to direct contact with infected animals and, in particular, the handling of livestock during parturition.

## CONFLICT OF INTEREST

The authors declare that they have no competing interests.

## AUTHOR CONTRIBUTION

**Diana Lynette Adhiambo Onyango:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Validation; Visualization; Writing-original draft; Writing-review & editing. **Javier Guitian:** Project administration; Supervision; Validation; Writing-review & editing. **Imadidden Musallam:** Supervision; Validation; Writing-review & editing.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was reviewed and ethically approved by the National Council of Science, Technology, and Innovations (NACOSTI) of the Ministry of Education in the Government of Kenya. It was also ethically approved by the Royal Veterinary College Ethical Committee. The study was presented to the communities from which data were collected from where verbal approval was given by the local leaders and participating members. The interviewees' participation was purely voluntary and it was clearly stated that no monetary gain was to be expected. The participants were reassured that the information collected will not be used for any other purpose other than for the research study and any personal information considered private will not be shared without their approval.

## CONSENT FOR PUBLICATION

Not applicable.

## PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/vms3.453.

## DATA AVAILABILITY STATEMENT

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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