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Seroprevalence, Associated Risk Factors and Assessment of Community's Knowledge, Attitude and Practice of Brucellosis in Small Ruminants in Moyale and Yabello Districts, Borena Zone, Oromia, Ethiopia

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Abstract

Small ruminants play an important role in the livelihoods of pastoral communities; however, brucellosis, an infectious bacterial disease caused by the genus Brucella, continues to pose a significant threat to both public and animal health in these areas. The prevalence of brucellosis and the level of community awareness of the disease in the study areas had not previously been well characterized. A cross-sectional study was conducted from January 2024 to May 2025 to estimate the seroprevalence and associated risk factors of brucellosis, and to assess herders' knowledge, attitude, and practice (KAP) regarding the disease in the Moyale and Yabello districts of Ethiopia. A total of 484 blood samples were collected: 242 from Moyale (167 goats and 75 sheep) and 242 from Yabello (167 goats and 75 sheep). Samples were screened using the Rose Bengal plate test (RBPT), and positive samples were confirmed using the complement fixation test (CFT). Of the samples tested, 5.6% (27/484) were seropositive by RBPT, and 70.4% (19/27) of RBPT-positive samples were confirmed positive by CFT. All data were analyzed using SPSS software. Multivariable logistic regression analysis revealed that sex and history of retained fetal membrane were significantly associated with brucellosis seroprevalence (female vs. male, OR = 4.98, P = 0.013; retained fetal membrane, OR = 2.5, P < 0.001). A questionnaire survey was administered to 110 small-ruminant owners to assess their knowledge, attitude, and practice regarding brucellosis. Overall, 43.6% of respondents were aware of brucellosis, but only 5.5% knew that the disease could be transmitted from animals to humans. Approximately 70% (77/110) of respondents assisted their animals during kidding and lambing, yet 89.1% (98/110) did not use any protective equipment, posing a risk of zoonotic transmission. In conclusion, brucellosis remains a public and animal health challenge in the pastoral areas of Moyale and Yabello. Integrated disease-control strategies and community education programs are urgently needed to mitigate the impact of brucellosis on both livestock and human populations.

Keywords: ***Brucellosis; Moyale, Seroprevalence; Small Ruminants; Yabello.***

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1. Introduction

Small ruminants are important in livestock husbandry, particularly in settings where livestock is kept for immediate cash income, milk, meat, wool, and savings [1]. The global small-ruminant population is estimated to range from 1.35 to 1.94 billion [2]. Ethiopia has one of the largest small-ruminant populations in the world, with approximately 33 million sheep and 38.9 million goats [3]. Sheep and goats are among the most important sources of cash income for rural women [4]. In tropical and subtropical Africa, small ruminants support a range of social and cultural activities that vary across cultures, socioeconomic contexts, and agroecologies [5]. Despite their importance to producers' livelihoods, the productivity of goats and sheep in developing countries remains low because of underfeeding, poor management systems, and disease [6]. Brucellosis is among the infectious diseases considered a major constraint to sheep and goat productivity [7].

Brucellosis in small ruminants is caused primarily by Brucella melitensis and, in sporadic cases, by B. ovis and B. abortus [8]. B. melitensis is a highly virulent form of Brucella and has been identified as an agent of biological warfare, and thus a pathogen of bioterrorism concern [9]. Large numbers of the organism are shed in urine, milk, vaginal discharge, semen, and birth products of infected animals [10]. The organism may remain viable in carcasses and tissues for up to 6 months at 0 degrees C, for up to 125 days in soil, and for as long as one year in feces [11]. The disease is characterized by abortion, with the development of yellowish, sticky layers on the placenta in females. In male animals, it causes orchitis, epididymitis, and inflammation of the joints and bursae [12].

Brucellosis is an important bacterial zoonosis that poses a significant health risk to humans [13,14]. It is transmitted through direct contact with infected animals or indirectly through contaminated animal products. Common sources of infection include unpasteurized milk and dairy products, particularly cheese made from the milk of infected sheep and goats, and rennet derived from the stomachs of infected lambs and kids. In humans, brucellosis causes a systemic infection typically presenting with fever, excessive sweating, fatigue, and joint pain [13,15]. The disease is also considered an occupational hazard, particularly among individuals working in animal-health sectors; people who handle animals or infectious materials such as blood, placental tissue, aborted fetuses, and uterine discharges are at increased risk of exposure. This transmission route affects farmers, veterinarians, butchers, shepherds, abattoir workers, hunters, and laboratory workers [13,16,17].

Studies on the prevalence of brucellosis have been conducted in many parts of Ethiopia by different researchers. Most of these studies have focused more on caprine than on ovine brucellosis in terms of the number of animals sampled [18]. Previous reports on the overall prevalence of small-ruminant brucellosis range from 0.4%, in a study conducted in and around Bahir Dar [19], to 13.7%, a pooled prevalence reported for the Tellalake district of the Afar Region [20]. Flock-level seroprevalence of brucellosis among small ruminants in Ethiopia has been reported by several researchers [21-25]. However, epidemiological studies of ovine brucellosis in Ethiopia remain limited, even though the epidemiology of ovine brucellosis differs from that of caprine brucellosis, and mixed sheep-and-goat flocks are common, particularly in pastoralist areas of the country [26].

1.1 Statement of the Problem

The economic and public health impact of brucellosis remains a particular concern in developing countries. The disease poses a barrier to the trade of animals and animal products, represents a public health hazard, and impairs the free movement of animals [27]. The role of specific etiologic agents, such as Brucella species, in causing abortion and reproductive loss is well established [28], although abortion and female infertility can also result from a wide range of other etiologic agents. Brucellosis is an important infectious disease causing significant reproductive losses in sexually mature animals, in addition to its zoonotic importance [29]. Among small ruminants, Brucella species are considered one of the major bacterial pathogens of public health significance. In Ethiopia, only a few publications have reported on the seroprevalence of Brucella species in pastoral areas [18-22,25].

A study conducted in Ethiopia found that livestock producers had limited awareness of brucellosis and frequently engaged in practices that increased the risk of disease transmission [30]. However, no research has directly examined the relationship between herders' knowledge and practices and the occurrence of the disease in small ruminants. Raising herders' awareness is crucial to the success of control programs and to preventing the spread of the disease within animal populations [31].

Understanding the risk factors for, and community perceptions of, brucellosis is critical for the formulation of appropriate control strategies. Livestock keepers in the study area are likely to be at heightened risk because of close cohabitation with animals, direct handling of animal cases, and dietary habits. Community knowledge, attitude, and practice regarding this disease predispose residents to zoonotic infection. Assessing the community's KAP toward small-ruminant brucellosis, as well as the risk factors for human infection, is therefore essential in pastoral areas. However, the prevalence of the disease, its economic impact, and community awareness of brucellosis in pastoral areas, particularly in the Moyale and Yabello districts of Ethiopia, have not been well studied.

1.2 Objectives

1.2.1. General Objective

The overall aim of the study was to estimate the seroprevalence and associated risk factors of brucellosis, and to assess the community's knowledge, attitude, and practice regarding brucellosis in small ruminants in the Moyale and Yabello districts, Borena Zone, Oromia, Ethiopia.

1.2.2. Specific Objective

- To estimate the seroprevalence of small-ruminant brucellosis in the study areas.
- To identify potential risk factors for small-ruminant brucellosis in the study areas.
- To assess the knowledge, attitude, and practice of pastoralists regarding brucellosis in the study areas.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in two purposively selected districts of the Borena Zone: Moyale and Yabello (Figure 1). The Borena Zone has a semi-arid to arid climate and lies between 4 degrees and 6 degrees N latitude and 36 degrees and 42 degrees E longitude. Altitude ranges from 1,000 to 1,700 meters above sea level, with isolated mountains and valleys. Mean annual rainfall ranges from 250 to 700 mm, and mean annual temperature ranges from 19 degrees C to 42 degrees C. The primary livelihood in the area is pastoralism, particularly nomadic pastoralism [32]. Moyale district is located 770 km south of Finfinne (the country's capital), while Yabello district is located 570 km south of Finfinne. Yabello district has livestock populations of 104,000 cattle, 86,039 goats, 37,591 sheep, 13,305 camels, 2,902 donkeys, 138 horses, and 159 mules, while Moyale district has 55,134 cattle, 65,485 goats, 14,723 sheep, 16,918 camels, 3,500 donkeys, 10 horses, and 17 mules [33].

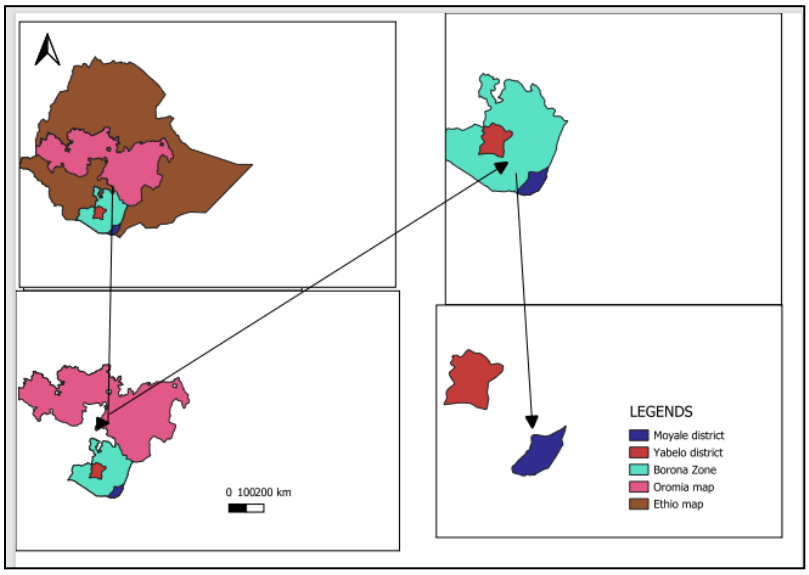

Fig. 1. Map of the study area (Source: ArcGIS software).

2.2 Study Design

A cross-sectional study was carried out in small ruminants from January 2024 to May 2025 to estimate seroprevalence, identify potential risk factors for small-ruminant brucellosis, and assess owners' knowledge, attitude, and practice (KAP) regarding the disease in the Moyale and Yabello districts. The two districts were purposively selected based on accessibility and their ovine and caprine populations. Peasant associations (PAs), the lowest administrative unit within a district, were selected by simple random sampling.

The total number of PAs within the two selected districts was listed and used as the sampling frame. From these, 110 households (the tertiary sampling units) that owned goats and sheep and had sufficient experience rearing small ruminants were selected. The age of each animal and its history of reproductive problems, where present, were obtained from owners and animal attendants. The presence of both animal species per owner, the number of animals

per household, the willingness of herders to cooperate, and the availability of flocks at the time of the visit were used as inclusion criteria to determine the number of animals of each species to be sampled per village.

2.3 Study Population

The study animals were small ruminants kept under an extensive management system in the Moyale and Yabello districts. Sheep and goats older than 6 months with no history of vaccination against brucellosis were included in the study. Flocks were grouped into three size categories: large flocks (greater than or equal to 30 animals), medium flocks (11-30 animals), and small flocks (less than or equal to 10 animals), based on community-level herd groupings.

2.4 Sample Size Determination

The sample size was calculated using the formula recommended by Thrusfield [34] for simple random sampling:

$$n = \frac{(1.96)^2 \, p_{exp} \, (1-p_{exp})}{d^2}$$

where n is the required sample size, P exp is the expected prevalence, and d is the desired absolute precision.

The required sample size was calculated based on an expected prevalence of 50%, a precision of 5%, and a 95% confidence level, yielding a required sample size of 384. To increase precision, 100 additional samples were purposively added, giving a total of 484 blood samples collected from Moyale (167 goats, 75 sheep) and Yabello (167 goats, 75 sheep).

2.5. Questionnaire Survey

The sample size for the questionnaire survey was determined using the formula provided by Arsham [35]:

$$N = 0.25 / SE^2$$

where N is the sample size and SE is the standard error (5%). The required sample size for the questionnaire survey was 110. After adding a 10% allowance for non-response, a total of 110 individuals were interviewed to assess KAP. Respondents were selected using simple random sampling, with 55 individuals from each of the Moyale and Yabello districts. A pretested, structured questionnaire was used to collect information on the knowledge, attitude, and practice of pastoralists toward brucellosis. Verbal consent was obtained from respondents, and the purpose of the survey was explained before each interview. Interviews were conducted in the participants' native language (Afaan Oromo). The questionnaire covered risk factors (species, sex, age, physical condition, reproductive state, parity, abortion history, abortion stage, and history of retained fetal membrane), sociodemographic characteristics, flock characteristics, and knowledge, attitude, and practice regarding brucellosis.

2.6 Sample Collection

Approximately 6 mL of blood was collected from the jugular vein of each sheep and goat using plain vacutainer tubes and sterile needles. Samples were properly labeled and allowed to clot at room temperature for 24 hours. Serum was separated by gently transferring the supernatant into cryovials, which were stored at -20 degrees C at the Yabello Regional Veterinary Laboratory. Serum samples were then transported on ice to the Sebeta Animal Health Institute for

laboratory analysis. Samples were tested using the Rose Bengal plate test (RBPT), followed by confirmatory testing with the complement fixation test (CFT).

2.7 Sample Processing

All laboratory procedures followed standard protocols for brucellosis testing. The Rose Bengal plate test (RBPT) was used to screen serum samples using RBT antigen obtained from the Animal and Plant Health Agency (APHA), United Kingdom, following standard protocols. Both serum samples and antigen were brought to room temperature before testing. A mixture of 30 uL of stained Rose Bengal antigen and 75 uL of serum was placed on a card plate and thoroughly mixed. Agglutination was assessed visually and recorded as 0 (negative) or +, ++, or +++ (positive), based on the degree of agglutination observed. Positive samples were confirmed using the complement fixation test (CFT), employing B. abortus antigen, amboceptor, and sheep red blood cells obtained from the National Animal Health Institute of Ethiopia. CFT results were interpreted based on complement fixation at various serum dilutions, with strong fixation reactions indicating the presence of anti-Brucella antibodies.

2.8. Data Analysis

Data generated from the survey and laboratory investigations were recorded and coded in Microsoft Excel (Microsoft Corporation) and analyzed using SPSS version 20. Descriptive statistics were used to assess seroprevalence and respondents' knowledge, attitude, and practice. The association between explanatory and outcome variables was analyzed at the individual-animal level using univariable and multivariable logistic regression. All risk factors with a non-collinear effect and a P-value less than or equal to 0.25 in univariable logistic regression were included in multivariable logistic regression analysis. The odds ratio (OR) was used to assess the strength of association between exposure variables and disease seropositivity. In all analyses, a 95% confidence interval and a P-value < 0.05 were used to determine the statistical significance of associations between dependent and independent variables.

3. Results

3.1. Seroprevalence of Brucellosis

In the present study, of 484 small-ruminant sera collected (334 from goats and 150 from sheep), 27 (5.6%) were positive by RBPT, and of these 27 RBPT-positive samples, 19 (3.9% of the total sample) were confirmed seropositive for brucellosis by CFT (Table 1).

Table 1. Seroprevalence of small ruminant brucellosis in the study area.

Test Assay	Classification	No. of Animals	Prevalence (%)	95% CI
RBPT	Negative	457	–	–
RBPT	Positive	27	5.6	3.90–8.00
CFT	Negative	465	–	–
CFT	Positive	19	3.9	2.50–6.10

Seroprevalence of brucellosis was higher in Moyale district than in Yabello district. Among the peasant associations sampled, the highest and lowest seroprevalence rates were recorded in Bede kebele (Yabello) and Legsure kebele (Moyale), respectively (Table 2).

Table 2. Seroprevalence of brucellosis by district and kebele (study areas).

Risk Factor	Category	No. Tested	No. RBT+	RBT % (95% CI)	No. CFT+	CFT % (95% CI)
Districts	Yabello	242	11	4.5 (2.6–7.9)	10	4.0 (2.3–7.4)
Districts	Moyale	242	16	6.6 (4.1–10.5)	9	4.0 (1.9–6.9)
Kebele	Beke	81	4	5.0 (1.9–12.1)	4	5.0 (1.9–12.1)
Kebele	Bede	81	6	7.4 (3.4–15.2)	5	6.1 (2.7–13.7)
Kebele	Dambi	82	3	3.6 (1.3–10.2)	3	3.6 (1.3–10.2)
Kebele	Kukuba	79	4	5.1 (2.0–12.3)	3	3.8 (1.3–10.6)
Kebele	Legsure	81	6	7.4 (3.4–15.2)	2	2.3 (1.0–8.6)
Kebele	Mormora	80	4	5.0 (1.9–12.2)	2	2.5 (1.0–8.7)

N = number of tested animals; CI = confidence interval.

3.2. Potential Risk Factors for Small Ruminant Brucellosis

Among the risk factors examined, large flocks (5%) showed higher seroprevalence than medium flocks (2%). Female animals had higher seroprevalence than male animals; adult animals showed higher seroprevalence than young animals; and animals with a history of retained fetal membrane had higher seroprevalence than those without such a history. Seroprevalence of brucellosis was higher among parous animals than nulliparous animals, and animals with a history of abortion had higher seroprevalence than those without such a history (Table 3).

Table 3. Potential risk factors of small ruminant brucellosis

Risk Factor	Category	No. Examined	No. CFT+	Prevalence % (95% CI)
Sex	Male	247	4	1.6 (1.1–4.1)
Sex	Female	237	15	6.3 (3.9–10.2)
Age	Adult	421	18	4.3 (2.7–6.7)
Age	Young	63	1	1.6 (0.3–8.5)
Species	Ovine	150	2	1.3 (0.4–4.7)

Risk Factor	Category	No. Examined	No. CFT+	Prevalence % (95% CI)
Species	Caprine	334	17	5.1 (3.2–8.0)
Flock size	Large	326	16	4.9 (3.1–7.8)
Flock size	Medium	133	2	1.5 (0.4–5.3)
Flock size	Small	25	1	16.0 (6.4–34.7)
Parity	Yes	233	15	6.4 (3.9–10.3)
Parity	No	251	4	2.0 (0.6–4.1)
History of abortion	Yes	55	14	25.3 (15.8–38.3)
History of abortion	No	429	5	1.2 (0.5–2.7)
History of retained placenta	Yes	36	14	38.9 (24.8–55.4)
History of retained placenta	No	448	5	1.12 (0.5–2.6)

Univariable logistic regression showed that the occurrence of brucellosis was 1.49 times higher in female animals than in male animals. At the univariable level, sex, parity, history of abortion, and history of retained fetal membrane were associated with seropositivity at $P < 0.25$ and were therefore included in the multivariable logistic regression model (Table 4).

Table 4. Potential risk factors for brucellosis: univariable logistic regression.

Risk Factor	Category	No. Examined	No. CFT+	95% CI	OR	P-value
Sex	Male (Ref.)	247	4	–	–	–
Sex	Female	237	15	NR	1.49	0.01
Age	Young (Ref.)	63	1	–	–	–
Age	Adult	421	18	NR	1.36	0.77
Flock size	Large (Ref.)	326	16	–	–	–
Flock size	Medium	133	2	0.002–211	0.634	0.248
Flock size	Small	25	1	1.1–38.9	2.15	0.50
Parity	No (Ref.)	251	4	–	–	–

Risk Factor	Category	No. Examined	No. CFT+	95% CI	OR	P-value
Parity	Yes	233	15	1–14	11	0.19
History of abortion	No (Ref.)	429	5	–	–	–
History of abortion	Yes	55	14	1.0–3.40	2.0	0.19
History of retained placenta	No (Ref.)	448	5	–	–	–
History of retained placenta	Yes	36	14	1.23–12.09	2.19	0.098

Ref. = reference category; OR = odds ratio; CI = confidence interval; NR = not reliably reported in the source data. Risk factors with P < 0.25 (sex, parity, history of abortion, history of retained placenta) were carried forward to multivariable analysis.

In multivariable logistic regression analysis, female animals showed significantly higher seroprevalence of brucellosis than male animals (P < 0.05); the odds of brucellosis in female animals were 4.98 times higher than in male animals (OR = 4.98). Animals with a history of retained fetal membrane also showed significantly higher seroprevalence than animals without such a history, with 2.5 times higher odds of brucellosis (Table 5).

Table 5. Potential risk factors for brucellosis: multivariable logistic regression.

Risk Factor	Category	No. Tested	No. CFT+	95% CI	OR	P-value
Sex	Male (Ref.)	247	4	–	–	–
Sex	Female	237	15	3.95–14.70	4.98	0.013
History of retained placenta	No (Ref.)	448	5	–	–	–
History of retained placenta	Yes	36	14	1.48–9.85	2.5	0.000

Ref. = reference category; OR = odds ratio; CI = confidence interval.

3.3. Questionnaire Survey

3.3.1. Socio-demographic Characteristics of Respondents

The majority of respondents were in the adult age group (89.1%), male (87.3%), and illiterate (87.3%), with only 3.6% reporting formal education. The study community was religiously diverse: Waaqeffanna followers constituted the largest group (36.3%), followed by Muslims (24.5%), Orthodox Christians (20%), and Protestants (19%) (Table 6).

Table 6. Socio-demographic composition of the study population.

Parameter	Category	No. of Respondents	Percentage (%)
Age	Adult	98	89.1

Parameter	Category	No. of Respondents	Percentage (%)
Age	Young	12	10.9
Sex	Male	96	87.3
Sex	Female	14	12.7
Education	Educated	4	3.6
Education	Read and write	27	24.6
Education	Illiterate	79	71.8
Religion	Waaqeffanna	40	36.3
Religion	Orthodox Christian	22	20.0
Religion	Muslim	27	24.5
Religion	Protestant	21	19.0

3.3.2. Knowledge, Attitude and Practice of the Community towards Brucellosis

Overall, 43.6% of respondents were aware of small-ruminant brucellosis, and 8.2% reported having heard about the disease from a veterinarian. Less than half of respondents (41.8%) knew that brucellosis can affect small ruminants, and only 8.2% were aware that the disease can be transmitted between animals. Among respondents, 25.5% believed that brucellosis is transmitted between animals through contaminated feed and water, and only 5.5% were aware of the disease's zoonotic importance. Approximately 24.5% of respondents reported having observed abortion or retained fetal membrane in their animals, and 19.1% believed that brucellosis could cause abortion at a late gestational stage. Overall, 98.2% of respondents had no awareness of brucellosis treatment, and 27.3% of the 110 respondents were able to identify important clinical signs of small-ruminant brucellosis (Table 7).

Table 7. Community knowledge of brucellosis (n = 110).

Parameter	Category	No. of Respondents	Percentage (%)
Have you heard of brucellosis?	Yes	48	43.6
Have you heard of brucellosis?	No	62	56.4
Where did you hear about it?	Local community	40	36.4
Where did you hear about it?	Veterinarian	9	8.2
Where did you hear about it?	Never heard	61	55.5
Do you know brucellosis affects shoats?	Yes	46	41.8

Parameter	Category	No. of Respondents	Percentage (%)
Do you know brucellosis affects shoats?	No	64	58.2
Have you seen clinical signs (e.g., hygroma, joint swelling)?	Yes	30	27.3
Have you seen clinical signs (e.g., hygroma, joint swelling)?	No	80	72.7
Do you know brucellosis is transmitted between animals?	Yes	9	8.2
Do you know brucellosis is transmitted between animals?	No	101	91.8
How is brucellosis transmitted between animals?	Contaminated water/feed	82	74.5
How is brucellosis transmitted between animals?	I don’t know	28	25.5
Do you know brucellosis is a zoonotic disease?	Yes	6	5.5
Do you know brucellosis is a zoonotic disease?	No	104	94.5
Has any abortion/retained placenta occurred in your animals?	Yes	27	24.5
Has any abortion/retained placenta occurred in your animals?	No	83	75.5
At what gestation stage did abortion occur?	Early	8	7.3
At what gestation stage did abortion occur?	Late	21	19.1
At what gestation stage did abortion occur?	No abortion	81	73.6
How are humans infected from shoats?	Close contact with affected animal	6	5.5
How are humans infected from shoats?	Consumption of raw animal products	5	4.5
How are humans infected from shoats?	I don’t know	99	90.0
Does brucellosis have a treatment?	Yes	2	1.8
Does brucellosis have a treatment?	No	108	98.2

Regarding community attitudes, 92.7% and 72.7% of respondents, respectively, did not believe that boiling milk or cooking meat could prevent brucellosis. Only 8.2% of respondents perceived their family members to be at risk of contracting the disease, while more than 93% expressed a need for more information on small-ruminant brucellosis from veterinarians (Table 8).

Table 8. Community attitude towards brucellosis (n = 110).

Parameter	Category	No. of Respondents	Percentage (%)
Do you believe a family member is at risk of brucellosis?	Yes	9	8.2
Do you believe a family member is at risk of brucellosis?	No	101	91.8
Do you want more information on this disease?	Yes	103	93.6
Do you want more information on this disease?	No	7	6.4
From where would you like to receive information?	Booklet	11	10.0
From where would you like to receive information?	Veterinarian	99	90.0
Do you think boiling milk prevents brucellosis?	Yes	8	7.3
Do you think boiling milk prevents brucellosis?	No	102	92.7
Do you think cooking meat prevents brucellosis?	Yes	30	27.3
Do you think cooking meat prevents brucellosis?	No	80	72.7

With respect to practice, 70% of respondents assisted their animals during kidding and lambing, and 89.1% did not use any protective equipment while assisting animals during parturition, handling aborted materials, or removing retained placentas. In addition, 73.6% of respondents washed their hands after milking small ruminants, and 76.4% disposed of aborted or dead fetuses in open dumps (Table 9).

Table 9. Community practice regarding brucellosis (n = 110).

Parameter	Category	No.	Percentage (%)
How often do you wash hands during milking?	Every time	22	20.0
How often do you wash hands during milking?	Sometimes	81	73.6

Parameter	Category	No.	Percentage (%)
How often do you wash hands during milking?	Never	7	6.4
What do you do with the fetus/retained placenta?	Given to dogs	26	23.6
What do you do with the fetus/retained placenta?	Open dump	84	76.4
Do you assist during kidding/lambing?	Yes	77	70.0
Do you assist during kidding/lambing?	No	33	30.0
Would you take protective action while assisting kidding/lambing?	Yes	12	10.9
Would you take protective action while assisting kidding/lambing?	No	98	89.1

4. Discussions

The present study found a CFT-based seroprevalence of small-ruminant brucellosis of 3.9% in the Moyale and Yabello districts of the Borena Zone, Oromia Regional State. This result closely agrees with findings reported by Teklue and colleagues [22], who reported a seroprevalence of 3.5% in the Southern Zone of Tigray, and by Melese [36], who reported 3.7% elsewhere in Ethiopia. In contrast, the present result was lower than previously reported seroprevalence rates of small-ruminant brucellosis in other parts of Ethiopia, including 12.35% in the Afar region reported by Anteneh and colleagues [37], 9.6% in the Yabello pastoral area reported by Yohannes and co-workers [38], and 9.11% in Dire Dawa reported by Negash and colleagues [30]. However, the seroprevalence obtained in the present study was higher than that reported by Teshale and colleagues [39], who found a seroprevalence of 1.7% in goats and 1.6% in sheep in the Somali pastoral area; by Nigatu and colleagues [40], who reported 2.7% in selected export abattoirs in Addis Ababa; and by Bezabih and Bulto [41], who reported 2.25% at the Werer Agricultural Research Center in Afar. These differences may be attributable to variations in the sensitivity and specificity of the diagnostic tests used, agroecological setting, sample size, study population, and differences in management, production systems, and animal husbandry practices across study areas.

In the present study, sex was significantly associated with the occurrence of small-ruminant brucellosis ($P < 0.05$), with the occurrence of brucellosis 4.98 times higher in female animals than in male animals. This finding may be explained by the fact that male animals are generally less susceptible to Brucella infection because of the lower concentration of the four-carbon sugar erythritol in male reproductive tissue [42]. A history of retained fetal membrane was also significantly associated with the occurrence of small-ruminant brucellosis, with 2.5 times higher odds of infection in animals with such a history than in animals without it.

Age was proposed as a risk factor for brucellosis in the present study; higher seroprevalence was observed in adult animals than in young animals, although no statistically significant association between age and disease occurrence was found. Flock size was also proposed as a risk factor, but no statistically significant association was found between flock

size and the occurrence of small-ruminant brucellosis. Animals with a history of parity had higher seroprevalence than nulliparous animals, although no significant association was found between parity and disease occurrence. Similarly, animals with a history of abortion had higher seroprevalence of brucellosis than animals without such a history, but no statistically significant association was found between abortion history and Brucella occurrence.

In the present study, 87.6% of small-ruminant owners were illiterate, which may be an important contributing factor to their limited awareness of diseases affecting their animals. This proportion of illiteracy was higher than the 65% and 15% reported for the southeastern Somali region [43,44]. Comparable findings of limited literacy contributing to disease transmission between animals and humans have also been reported in the West Bank [45]. A high illiteracy rate suggests that many owners may lack the knowledge and resources needed to effectively prevent and manage brucellosis, underscoring the need for targeted education and awareness programs to strengthen animal health, protect public health, and support disease control in affected communities [45].

Our findings showed that 94.5% of small-ruminant owners were unaware of the zoonotic importance of brucellosis, highlighting a significant public health risk. This finding is consistent with reports from other regions, including 96.4% poor awareness reported in Egypt [46], approximately 55% poor awareness reported in the Amhara region by Gizaw and colleagues [47], findings from Kenya reported by Njenga and colleagues [48], and 77.6% poor awareness reported in Saudi Arabia by Harbi and co-workers [49], who also found that only 46.6% of participants had any information about brucellosis, more than half (53.4%) consumed raw milk, and 89% considered using gloves when handling animals. These findings suggest that awareness of brucellosis can vary considerably by region and by individual, likely reflecting differences in educational infrastructure, health extension services, culture, and public health awareness across study areas.

In the present study, 89.1% of small-ruminant owners did not use protective equipment during kidding or lambing. This finding is consistent with that of Teshale and colleagues [39], who reported a similar rate of 85% in the pastoral region of Afar. The proportion observed in the present study was higher than that reported by Alemayehu and colleagues [50] (70% across three agroecologies of Ethiopia), Wubaye and colleagues [51] (74% in the Chiro and Burka Dhintu districts of West Hararghe), and Dosa and colleagues [52] (79.7% in the southern region of Ethiopia). Madzingira and colleagues [53] similarly reported that the likelihood of consuming raw milk and milk products increased with respondent age and was more common among men than women in Namibia. These variations likely reflect differences in cultural practices, resource availability, and local interventions promoting the safe handling of animals during critical periods.

In the present study, 92.7% of respondents consumed raw milk, a proportion closely comparable to the 94.5% reported by Dosa and colleagues [52] in southern Ethiopia, lower than the 97.6% reported by Legesse and colleagues [54] in the Afar region, and higher than the 79% reported by Njenga and colleagues [48] in Kenya. Madzingira and colleagues [53] also reported that the likelihood of consuming raw milk and milk products in Namibia increased with respondent age and was more common among men. The consumption of raw milk is a recognized risk factor for the transmission of

brucellosis from animals to humans and has been attributed to the belief among animal owners that raw goat milk has a superior taste and various medicinal properties, including purported benefits for sexual desire and performance [48]. The present study also found that 92.7% and 72.7% of respondents consumed raw milk and raw meat, respectively, and that 76.4% disposed of aborted or dead fetuses in open dumps. Similarly, Bulcha and Etefa [55] reported that 55.8% of respondents discarded or dumped aborted fetuses into the environment, potentially facilitating environmental contamination, while only 27.5% buried fetuses and 16.6% gave them to dogs. Jilo [56] reported that 87.9% of respondents in a pastoral community in Borena disposed of aborted fetuses in the environment. Bile and colleagues [57] reported a similar figure of 89.1% in the Garowe district of Somalia; Legesse and colleagues [54] reported 94.5% in the southern region and 97.6% in the Afar region; and Njenga and colleagues [48] reported 79% in Kenya. These findings suggest that dietary practices and cultural attitudes toward raw food consumption vary considerably across settings.

5. Conclusion and Recommendations

The seroprevalence of small-ruminant brucellosis in the study area was 5.6% by RBPT and 3.9% by CFT, indicating that small-ruminant brucellosis remains a public health and animal health concern in the Yabello and Moyale districts of the Borena Zone, Oromia Region, Ethiopia. Sex (with female animals more heavily affected) and history of retained placenta were significantly associated with brucellosis seropositivity. Livestock owners generally lacked awareness of the zoonotic importance of brucellosis and its transmission routes, and practices such as the consumption of raw milk, assisting with parturition, and handling aborted materials without protection were common. These factors contribute to the occurrence of brucellosis in both animals and humans and represent an ongoing threat to public health. Based on these findings, the following recommendations are made:

- Government agencies should develop and implement awareness programs on brucellosis and its transmission routes in the study areas.
- Hygienic livestock management practices, particularly the responsible handling and disposal of retained fetal membranes, should be promoted.
- Special care should be given to female animals during parturition and following abortion to reduce the risk of disease transmission.
- Consumption of raw sheep and goat products, including raw milk and meat, should be discouraged.
- A One Health approach involving collaboration between veterinary, human health, and environmental health services should be strengthened to improve the effectiveness of control measures.
- Further molecular characterization of Brucella species in the study area should be carried out.

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7. Authors Contribution

Conceptualization: Gete Misgana, Getachew Kinfe. Data curation: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Formal analysis: Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Funding acquisition: Gete Misgana, Getachew Kinfe. Investigation: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Methodology: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Project administration: Gete Misgana. Resources: Gete Misgana, Getachew Kinfe, Segni Bedasa. Software: Gete Misgana, Tesfaye Rebuma, Mahendra Pal. Supervision: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Validation: Gete Misgana, Getachew Kinfe, Segni Bedasa. Visualization: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal. Writing, original draft: Gete Misgana. Writing, review and editing: Gete Misgana, Getachew Kinfe, Segni Bedasa, Tesfaye Rebuma, Mahendra Pal.

8. Ethics Approval

Ethical clearance for this study was obtained from the Ambo University, Guder Mamo Mezemir Campus Ethical Review Board. Before conducting the research, verbal consent was obtained from livestock owners for the collection of blood samples from their animals for testing of antibodies against Brucella infection.

9. Conflict of Interest

The authors declare no conflict of interest.

10. Funding

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