Heliyon 10 (2024) e24998

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Prevalence and risk factors of bovine tuberculosis in cattle in selected districts of Fafan pastoral settings, Eastern Ethiopia

Hassan Abdi Hussein [a,*], Juhar Mohamed Ahmed [a], Abdi Hussein Musse [a], Yonas Gizaw [b]

[a] *College of Veterinary Medicine, Department of One Health, Jigjiga University, P.O. Box, 1020, Jigjiga, Ethiopia*
[b] *College of Agriculture and Environmental Science, Arsi University, P.O. Box, 193, Asella, Ethiopia*

A R T I C L E I N F O

Keywords:
Bovine tuberculosis
M. bovis
Tuberculin test
Somali region
Eastern Ethiopia

A B S T R A C T

Cross-sectional study was conducted from October 2021 to August 2022 to investigate the prevalence and associated risk factors of bovine tuberculosis in cattle in selected districts of the pastoral settings of Fafan zone, Somali region, eastern Ethiopia. A comparative intradermal tuberculin test was performed using purified protein derivatives. Animal-related characteristics, and the owner's knowledge on the importance of BTB were collected using a structured questionnaire. The prevalence was 11.24 % (95 % CI, 8.61–14.35) and 43.3 % (95 % CI, 33.27–53.75) at the individual and herd levels, respectively. There were statistically significant differences in the proportions of positive reactor animals according to body condition score ($P = 0.000$), age ($P = 0.048$), seasonal migration ($P = 0.038$), parity number ($P = 0.005$), and reproductive status ($P = 0.037$). Animals with poor body condition scores had a significantly higher likelihood of testing positive, with their odds being 11.4 times greater (COR = 11.408, CI = 3.43–37.94, $P < 0.001$). In multivariate logistic regression, poor body condition score remained significantly associated with the odds of a positive reaction to tuberculosis (AOR = 0.137, CI = 0.053–0.356, $P < 0.001$). Similarly, the analysis showed that seasonal migration (AOR = 2.882, CI = 1.155–7.191, $P = 0.023$) and parity number (AOR = 11.64, CI = 1.818–74.464, $P = 0.010$) were significant predictors of bovine tuberculosis infection in cattle. According to the questionnaire, 14.2 % (17 of 120) and 13.3 % (16 of 120) of the respondents were knowledgeable about bovine tuberculosis and its transmission from animals to humans, and vice versa, respectively. The general judgment of herders' understanding of bovine tuberculosis transmission methods to humans was very low. The study findings showed a high prevalence of bovine tuberculosis in the study area, emphasizing the need for an effective control and prevention strategy.

1. Introduction

Bovine tuberculosis (BTB) is a chronic, debilitating bacterial disease caused by *Mycobacterium bovis* that infects cattle, other animals, and humans. The most common method of disease transmission in animals is through inhalation of infectious droplets in the air, although bacteria can be consumed through contaminated feed [1]. Although cattle are thought to be the primary hosts of *M. bovis*, isolates have been obtained from a variety of other livestock and wildlife species, raising public health concerns about the possibility of

* Corresponding author.
E-mail address: hassan.abdi@jju.edu.et (H.A. Hussein).

https://doi.org/10.1016/j.heliyon.2024.e24998
Received 7 May 2023; Received in revised form 16 December 2023; Accepted 18 January 2024
Available online 19 January 2024
2405-8440/

ACRONYMS

AFB	Acid Fast Bacilli
BCS	Body Condition Score
BTB	Bovine Tuberculosis
CIDT	Comparative Intra-dermal Test
Cm	Centimeter
CSA	Central Statistics Agency
DNA	Deoxy Ribo Nucleic Acid
FNA	Fine needle aspirate
GIT	Gastro-Intestinal Tract
HIV	Human Immune Deficiency Virus
HTB	Human Tuberculosis
LJ	Lowenstein– Jensen
M	Mycobacterium
MDR	Multi-Drug Resistant
MTBC	Mycobacterium Tuberculosis Complex
OD	Odds Ratio
OIE	Office International Epizootic
PAs	Pastoral Associations
PBS	Phosphate Buffer Sulphate
PPD	Purified Protein Derivatives
RNA	Ribo Nucleic Acid
SRS	Somali Regional State
TB	Tuberculosis
US	United States

human transmission [2].

Tuberculosis (TB) is generally defined by the formation of tubercles, which are distinct granulomatous lesions in affected organs and tissues with variable degrees of calcification, necrosis, and encapsulation [3]. Although cattle, pigs, and goats are the most vulnerable, *M. bovis* is the most widespread mycobacterial infection, infecting various vertebrates, including humans [4]. The most common method of *M. bovis* transmission to humans is through the intake of unpasteurized milk or raw animal byproducts. However, aerosol transmission is possible among individuals in close proximity to sick animals. These potential health risks are particularly significant in many underdeveloped nations, where pasteurization is limited and people live in close proximity to their livestock [5]. Additionally, animals can become infected by ingesting feed and water contaminated with feces, urine, or exudates from diseased animals that contain tubercle bacilli [6].

Mycobacterium bovis is a severe disease that significantly affects livestock production, wildlife, and public health. BTB has a cumulative impact on the economies of developing nations owing to decreased production of milk and meat, trade losses, and movement limitations [7]. From 2005 to 2011, the economic cost of BTB in Ethiopia was estimated to be between 75.2 and 385 million US dollars in pastoral areas and between 500,000 and 4,900,000 US dollars in urban and peri-urban areas [8]. In addition to its economic burden, the disease is of great concern, with nearly 10 million cases of human infection reported annually worldwide [9]. Human BTB infection is a growing concern in developing nations, particularly in sub-Saharan Africa, where people and animals share confined spaces and watering wells, particularly during droughts and dry seasons, which may promote *M. bovis* transmission to humans [10]. *M. bovis* is responsible for 10–15 % of TB cases [2]. BTB is still prevalent in African, Asian, and Latin American countries, accounting for more than half of all TB cases [11].

BTB is reported to be prevalent in Ethiopia, with a prevalence higher than 41 % depending on husbandry practices, with pastoral settings showing a lower frequency than intensive dairy farms [12]. Prevalence data on BTB infections in the Somali region are scarce. However, there is sufficient evidence to indicate the occurrence of BTB among livestock and human populations, with prevalence reports ranging from 2 to 20 % [13,14].

Although tuberculosis is known to infect people in the Somali region, very few studies on livestock, particularly cattle, have been conducted. Therefore, the objectives of this study were to estimate the prevalence and risk factors of bovine tuberculosis in cattle in selected districts of the pastoral settings of Fafan zone, Eastern Ethiopia, and to assess the knowledge and practice of cattle owners on the health risks of BTB.

2. Methodologies

2.1. Study area description

The study area encompasses the South Jigjiga, Gursum, and Kebribayah districts of Fafan zone in Somali regional state (SRS) as shown in Fig. 1. The zone has an overall land area of 40, 861 km^2, with 36, 629 km^2 of rangeland. Flat to gentle slopes, hills, and steep slopes made up approximately 52.6 %, 31 %, and 7 % of the zone's topography, respectively. The zone has an elevation ranging from 500 to 1650 m above sea level. The average minimum and maximum temperatures were 16–20 °C and 28–38 °C, respectively [15]. Rainfall in the zone is quite irregular, with an average annual rainfall of 600–700 mm. There are two different production and grazing systems used in the region: pastoral herds that move across large swathes of land in search of pasture and water and agro-pastoral herds maintained by village residents with less mobility unless affected by drought or other circumstances [16]. Fafan zone is estimated to have a cattle population of 663,783 [17].

2.2. Study design

A cross-sectional study was conducted from October 2021 to August 2022 to investigate the prevalence of bovine tuberculosis in cattle and the associated risk factors in selected districts of Fafan zone in Eastern Ethiopia.

2.3. Study population

Cattle of both sexes over the age of six months that were kept in an extensive production system (agro-pastoral and pastoral) were used in this study. Animals with clinical symptoms of acute diseases, those being treated for acute diseases, and those who had been recently vaccinated were excluded because of the possibility of immune suppression interfering with the skin test. Female animals in their final trimester of pregnancy or those who had recently given birth were also barred for the same reason.

2.4. Sample size determination

The sample size for tuberculin testing was calculated using the sampling formula described by Ref. [18]. With an expected prevalence of 20.3 % [14] and an absolute precision value of 5 %.

$$n = \frac{(1.96)^2 P(1-P)}{d^2} \quad n = \frac{(1.96)^2 0.203(1-0.203)}{0.05^2} = 249$$

where: P = expected prevalence.

n = required sample size

d = desired absolute precision.

However, considering the small sample size and low prevalence of bovine tuberculosis in pastoral areas, the sample size was doubled, and finally, 498 animals in 97 herds were sampled.

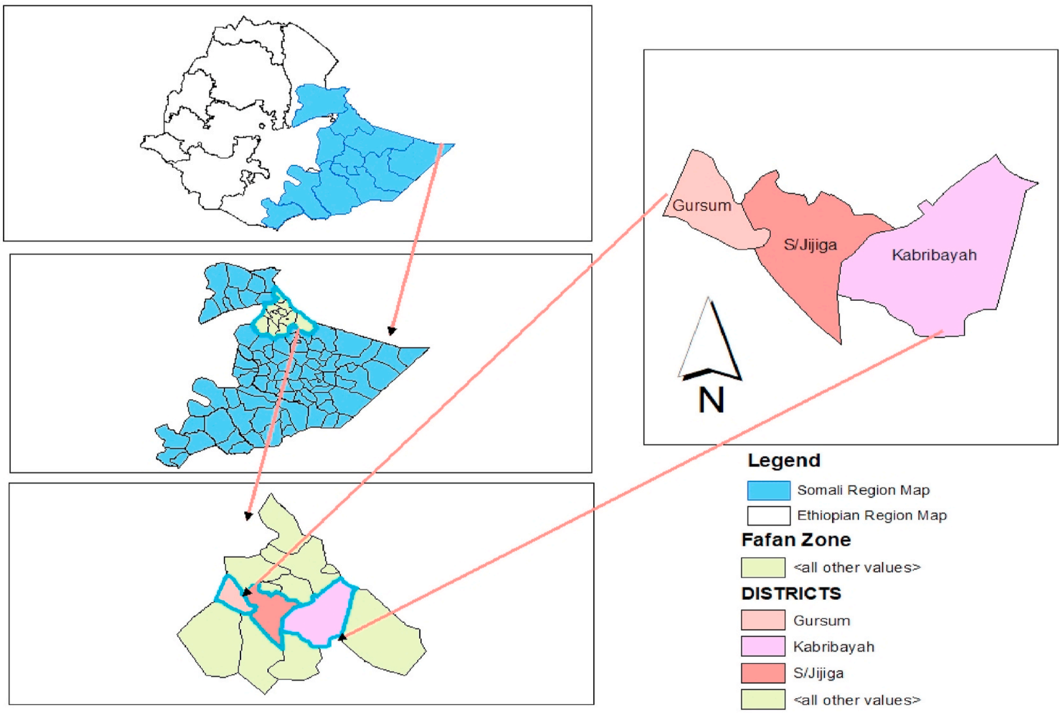

Fig. 1. Study areas (Districts) in Fafan Zone of Somali Region, Eastern Ethiopia.

2.5. Sampling method

As strict random sampling is difficult to follow in pastoral production systems, where the study population is dispersed across large and remote areas, both probabilistic and non-probabilistic sampling approaches were used at various stages of the sampling units. As a result, three districts were chosen based on their livestock production potential and population, accessibility to vehicles, proximity to livestock markets, and presence of animal watering wells. However, a simple random sampling method was used to choose pastoral associations (PAs), also known as kebeles, from a list provided by the District Pastoral Development Office. The sample size was proportionally distributed among the selected districts and PAs based on the total number of cattle populations. Then sampling of 97 cattle herds were sampled using simple random sampling according to the sampling frame obtained from the kebele's animal health service providers. The total number of cattle within each selected herd was summed and divided into the calculated sample size following the systematic random sampling (SRS) technique. Finally, the animal was sampled at each interval obtained from the SRS technique irrespective of herd size [17–19].

Associated risk factors considered for data collection at the animal and herd levels were recorded, and unique temporary identification numbers were provided for each tested animal. Body condition scoring (BCS) was assessed using a modified guideline described in Ref. [20] as poor, medium, or good [21].

2.6. Tuberculin skin testing

The comparative intradermal tuberculin test (CIDT) was performed using purified protein derivatives (PPD). After obtaining informed consent from the owners, CIDT was performed on individual animals. Two injection sites in the middle third of the side of the neck, one above the other, were separated by at least 12 cm for older cattle. Hair was shaved around the sites to a radius of approximately 2 cm. The skin folds at both sites were then measured with a caliper, and the measurements were recorded.

An aliquot of 28,000 IU/0.1 ml PPD Bovine (PPD-B) (Bovitubal, strain AN5, Bioveta, Czech Republic) was injected intra-dermally at the lower injection site, and similarly, tuberculin containing 28,000 IU/0.1 ml PPD Avian (PPD-A) (Avitubal, strain D 4 ER Bioveta Czech Republic). After 72 h, the thickness of the same skinfold at both sites was measured and recorded.

The difference in skin thickness at both sites before and 72 h after the injection was measured and used to interpret the results. The results were interpreted using Office International des Epizooties (OIE 2018). If the difference between PPD-B and PPD-A was greater than or equal to 4 mm, the animal was considered positive; if the difference was less than 4 mm, the animal was considered negative. When the change in skin thickness was greater at the PPD-A injection site, the animal was considered positive for mycobacterial avian species other than *Mycobacterium bovis*. A herd containing at least one tuberculin reactor animal was considered positive.

2.7. Questionnaire survey

To assess the level of knowledge and awareness of the owners of the research region, 120 herd owners were questioned using pre-tested structured questionnaires. They were questioned about BTB and how it spreads in relation to the use of dairy products, as well as other relevant factors, including living in the same house with cattle and the owners' or herders' propensity to consume raw milk. At the conclusion of the CIDT, each herd owner was interviewed regarding their native tongue. All livestock owners and attendants who took part in the study provided their consent to be interviewed.

2.8. Statistical analysis

The data collected for the study were analyzed using SPSS (statistical package for social science) version 23. Descriptive statistics were used to summarize the distribution of variables. Pearson chi-square test was conducted to assess the relationship between categorical variables and Bovine tuberculosis prevalence in cattle. Firstly, univariate logistic regression analysis was employed to determine the associations of hypothetical risk factors with the tuberculin positive cattle. Odd ratio (OR) was used to point out the degree of risk factors association with the disease occurrence indicated by 95 % confidence intervals. Variables with $P < 0.25$ value on univariate logistic regression analysis was subjected to multivariate logistic regression analysis in attempt to control for potential confounding variables and adjusted odds ratio was determined. The Goodness-of-fit of the model was also tested using backward elimination, by taking away the variables sequentially; starting from the variable which contributes the least until deletion of a variable significantly reduces the amount of the explained variable on dependent variable. Furthermore, the Collinearity between variables was also checked by standard error and model fitness was assured by Hosmer and Lemeshow test and Omnibus test. Throughout the data presentation, confidence level was set at 95 % and P-value less than 0.05 (i.e. $P < 0.05$) was considered statistically significant.

3. Results

According to CIDT, the animal prevalence of BTB was 11.24 % (95 % CI, 8.61–14.35) in N = 56/498 at a 4 mm cut-off point. The assumed risk factors of age ($P = 0.048$), body condition score ($P = 0.000$), seasonal migration ($P = 0.038$), parity number ($P = 0.005$), and reproductive status ($P = 0.037$) all had statistically significant differences in the proportions of bovine positive reactor animals at the 4 mm cut-off point. However, the Pearson chi-square test showed a statistically insignificant association ($P > 0.05$) with all other hypothesized risk factors of herd location (districts), herd size, Sex, Production system (Agro-pastoral and pastoral), and lactation status in cattle at a cut-off value ≥ 4 mm (see Table 1).

As indicated in Table 2, the results suggest that the BCS of the animal is strongly associated with the likelihood of being a tuberculin reactor; animals with poor BCS had a significantly higher likelihood of testing positive, with their odds being 11.4 times greater (COR = 11.408, CI = 3.43–37.94, $P < 0.001$). Conversely, good BCS was associated with a decreased risk of infection. In multivariate logistic regression, poor BCS remained significantly associated with the odds of a positive reaction for tuberculosis (AOR = 0.137, CI = 0.053–0.356, $P < 0.001$). Similarly, the analysis showed that seasonal migration (AOR = 2.882, CI = 1.155–7.191, $P = 0.023$) and parity number (AOR = 11.64, CI = 1.818–74.464, $P = 0.010$) were significant predictors of TB infection in cattle. Age was a significant predictor in univariate logistic regression (COR = 2.396, 1.168–4.916, $P = 0.017$); however, it was insignificant in multivariate logistic regression after adjusting for other factors (AOR = 0.887, CI = 0.150–5.240, $P = 0.895$). Other factors, such as lactation status, reproductive status, and sex, were not significant predictors of BTB infection (see Table 2).

The comparative outcome of skin reactions to PPD-A and PPD-B is summarized in (see Table 3) Based on the ≥4 mm cut-off point, a statistically significant association was found between the skin reaction to PPD-A and PPD-B ($P = 0.000$). Of the tested cattle, 0.6 % (95 % CI, 0.12–1.75) of the tested cattle responded positively to both PPD-A and PPD-B. On the other hand, 10.64 % (95 % CI, 8.07–13.69) reacted only to PPD-B, while 1.0 % (95 % CI, 0.33–2.33) reacted only to PPD-A.

The herd prevalence was 43.3 % (95 % CI, 33.27–53.75) N = 42/97. The logistic regression analysis showed that the district of origin, herd size, and production system were not significantly associated with herd tuberculin positivity. However, the results suggest that seasonal migration (COR = 2.16, CI = 0.947–4.927, $P = 0.067$) may have a borderline significant association with herd tuberculin positivity, with migrating herds having a higher likelihood of being positive (see Table 4).

As indicated in Table 5, the majority of those interviewed were male and older, with a greater prevalence of illiteracy (see Table 5).

The results are presented in Table 6. According to the questionnaire results, approximately 14.2 % (17 of 120) of the respondents were aware that cattle can have tuberculosis, and 13.3 % (16 of 120) knew that bovine TB can spread from animal to human and vice versa; only 1.7 % and 9.2 % of people were aware that raw meat and milk could potentially transmit BTB, while the majority (70.8 %) knew that TB affects humans, the general judgment of herders' understanding of BTB transmission methods to humans was very low (see Table 6).

According to the current study, 77.5 % (93/120) of respondents regularly consumed raw milk. However, 99.2 % (119/120) of the participants stated that they did not consume raw meat. Similarly, 41.7 % of the respondents indicated that they shared water sources

Table 1
Summary of chi-square statistics for different risk factors associated with skin test positivity at 4 mm cut-off point for BTB in Somali Pastoral and agro-pastoral area of Ethiopia.

Variable Categories		Number of cattle examined	Number of positive (%)	X^2	*P*-value
Districts	Gursum	158	19 (12.02)	3.0052	0.223
	Kabribayah	183	15 (8.19)		
	South Jigjiga	157	22 (14.01)		
Herd size					
1–10		205	21 (10.24)	1.7610	0.415
11–20		185	19 (10.27)		
>20		108	16 (14.81)		
Production System					
Pastoral		258	26 (10.07)	0.7311	0.393
Agro-pastoral		240	30 (12.5)		
Age					
1–4		179	12 (6.7)	6.0937	0.048
5–7		142	18 (12.7)		
>7		177	26 (14.7)		
Sex					
Male		151	17 (11.26)	0.0000	0.995
Female		347	39 (11.24)		
BCS					
Good		104	3 (2.9)	47.9594	0.000
Medium		232	12 (5.2)		
Poor		162	41 (25.3)		
Seasonal migration					
Non migrating		234	19 (8.12)	4.3200	0.038
Migrating		264	37 (14.01)		
Lactation Status					
Non lactating		217	19 (8.8)	3.5809	0.058
Lactating		130	20 (15.4)		
Reproductive Status					
Non pregnant		301	38 (12.6)	4.3684	0.037
Pregnant		45	1 (2.22)		
Parity Number					
<2		176	11 (6.25)	10.6226	0.005
3–4		119	17 (14.28)		
>4		52	11 (21.15)		

BCS=Body Condition Score, X^2 = Chi-square, P = Probability.

Table 2
Univariate and Multivariate logistic regression analysis of tuberculin reactors with various host-related risk factors at 4 mm cut-off point.

Variable	Number of cattle examined	Number of positive (%)	COR (95 % CI)	*P*-value	AOR (95 % CI)	*P*-value
Districts						
Gursum	158	19 (12.02)	1			
Kabribayah	183	15 (8.19)	0.653 (0.320–1.333)	0.242	0.840 (0.293–2.411)	0.746
South Jigjiga	157	22 (14.01)	1.192 (0.617–2.302)	0.600	1.163 (0.435–3.106)	0.764
Herd size						
1–10	205	21 (10.24)	1			
11–20	185	19 (10.27)	1.003 (0.521–1.931)	0.993	1.078 (0.405–2.864)	0.881
>20	108	16 (14.81)	1.524 (0.759–3.059)	0.236	0.751 (0.250–2.253)	0.609
Production System						
Pastoral	258	26 (10.07)	1			
Agro-pastoral	240	30 (12.5)	1.274 (0.730–2.226)	0.393	*	*
Age						
1–4	179	12 (6.7)	1			
5–7	142	18 (12.7)	2.020 (0.939–4.348)	0.072	1.934 (0.474–7.888)	0.358
>7	177	26 (14,7)	2.396 (1.168–4.916)	0.017	0.887 (0.150–5.240)	0.895
Sex						
Male	151	17 (11.26)	1			
Female	347	39 (11.24)	0.998 (0.545–1.827)	0.995	*	*
BCS						
Good	104	3 (2.9)	1	0.000		
Medium	232	12 (5.2)	1.836 (0.507–6.650)	0.355	0.137 (0.053–0.357)	0.000
Poor	162	41 (25.3)	11.408 (3.43–37.94)	0.000		
Seasonal migration						
Non-migratory	234	19 (8.12)	1			
Migratory	264	37 (14.01)	1.844 (1.03–3.307)	0.040	2.882 (1.155–7.191)	0.023
Lactation Status						
Non lactating	217	19 (8.8)	1			
Lactating	130	20 (15.4)	1.895 (0.970–3.702)	0.061	1.326 (0.586–2.999)	0.498
Reproductive Status						
Non pregnant	301	38 (12.6)	1			
Pregnant	45	1 (2.22)	0.154 (0.021–1.149)	0.068	0.180 (0.020–1.612)	0.125
Parity Number						
<2	176	11 (6.25)	1	0.007		
3–4	119	17 (14.28)	2.5 (1.126–5.55)	0.024	5.700 (1.466–22.162)	0.012
>4	52	11 (21.15)	4.024 (1.631–9.928)	0.003	11.64 (1.818–74.464)	0.010

AOR = Adjusted Odds Ratio, BCS=Body Condition Score, COR: Crude Odds Ratio, *P*=Probability.

Table 3
Response of PPD-A and PPD-B at 4 mm cut-off point.

PPD A result	Number (%) of animals with PPD-B result		
	Positive	Negative	Total number (%)
Positive	3 (0.60)	5 (1.00))	8 (1.61)
Negative	53 (10.64)	437 (87.75)	490 (98.39)
Total	56 (11.24)	442 (88.76)	498 (100)

Positive and negative reactions were determined using the OIE guidelines, with skin indurations ≥4 mm and McNemar's chi-square = 39.72, *P*-value = 0.000.

with livestock. In addition, 20.8 % of those interviewed admitted to keeping some of their animals indoors at night (see Table 7).

4. Discussion

The individual bovine tuberculosis animal prevalence of 11.24 % (56/498) at ≥ 4 mm cut-off is comparable with earlier studies of 11 % [22], 9.7 % [23], and 11.6 %. [24], but higher than earlier reports from Somali pastoral livestock of 2 % [13]. 0.8 % reported from the southern pastoral area of Ethiopia by Ref. [8]. Nonetheless, this finding is lower than previous reports from the eastern pastoral areas of Ethiopia of 20.3 % [14] and 13.9 % and 14.5 % from northern Ethiopia and Eritrea by Refs. [25,26] respectively.

At 4 mm cut-off points, the herd prevalence of 43.3 % (42/97) was slightly lower than the herd prevalence of 51.2 % reported by Ref. [14] and 55 % by Ref. [27]. The higher prevalence of BTB in this study was largely associated with the increase in herd size and age, with a considerable association with seasonal migration, which is a commonly understood transmission factor in herds [28]. However, the current study revealed a higher BTB prevalence with an insignificant association with the agro-pastoral production system, which is consistent with the results of the Ugandan study [29]. Similarly, the seasonal migration of herds was associated with increased intradermal skin positivity. Animal herders can move their animals over longer distances to search for pasture and water

Table 4
Univariate and multivariate logistic regression analysis of herd tuberculin positivity with different risk factors at >4 mm cut-off point.

Variable	Number of Herd examined	Number of positive (%)	COR (95 % CI)	*P*-value
Districts				
Kabribayah	36	12 (33.3)	1	
Gursum	31	14 (45.2)	0.607 (0.226–1.634)	0.323
South Jigjiga	30	16 (53.3)	1.388 (0.507–3.800)	0.524
Herd size				
1–10	40	17 (42.5)	1	
11–20	36	15 (41.7)	0.966 (0.388–2.406)	0.941
>20	21	10 (47.6)	1.23 (0.426–3.55)	0.702
Production System				
Pastoral	50	22 (44)	1	
Agro-pastoral	47	20 (42.6)	0.943 (0.422–2.11)	0.886
Seasonal Migration				
Non-Migrating	45	15 (33.3)	1	
Migrating	52	27 (51.9)	2.16 (0.947–4.927)	0.067

COR=Crude Odds Ratio, *P*=Probability.

Table 5
Description of respondents (n = 120).

Category	Description of Respondents	Interviewed Number	Accurate Response (%)
District	Gursum	120	36 (30.0)
	Kabribayah		37 (30.8)
	S/Jigjiga		47 (39.2)
Sex	Male	120	103 (85.8)
	Female		17 (14.2)
Age	<30 years	120	56 (46.7)
	>30 years		64 (53.3)
Education	Illiterate	120	92 (76.7)
	Literate		28 (23.3)

Table 6
Knowledge of cattle owners about bovine tuberculosis and its transmission to humans in the study area.

Knowledge awareness of Respondents	Interviewed Number	Accurate Response (%)
Know about BTB	120	17 (14.2)
Know BTB to Human transmission	120	16 (13.3)
Know BTB can be in milk	120	11 (9.2)
Know BTB can be in meat	120	2 (1.7)
Know about TB in human	120	85 (70.8)

Table 7
Life style, and milk and meat consumption habit risk of BTB transmission of cattle owners in the study area.

Habit of respondents	Interviewed Number	Accurate Response (%)
Drink boiled Milk	120	27 (22.5)
Eat Cooked Meat	120	119 (99.2)
People and livestock drink from same source	120	50 (41.7)
Share Accommodation with livestock	120	25 (20.)
Family Member was infected with TB once	120	9 (7.5)

sources. As a result, there is a risk of encountering infected herds, including wildlife, in line with [30–32].

The results showed a relationship between BTB infection and low body condition score. Although the precise link between cause and effect is unclear, it is likely that animals with poor body condition are more likely to develop tuberculosis or that animals who are positive for the disease also have poor body condition, which is a symptom that typically follows an active *M. bovis* infection [21]. Cattle reproduction status and parity number showed a statistically significant difference in the prevalence of BTB at the 4 mm cut off, with a higher prevalence of BTB seen in cows with 3–4 parity numbers compared to those with fewer than 2 and more than 4 parity numbers. This is in line with the research reports of [29,33]. Risk factors such as study district, herd size, sex, and lactation status were not associated with BTB positivity at the 4 mm cut off. This finding is consistent with that in Ref. [31]. The high degree of similarity in livestock management in pastoralist communities in the study area may mask the effects of risk factors related to husbandry practices and the occurrence of BTB.

The study found that animals with poor BCS showed significantly higher odds of testing positive for tuberculosis, with the odds being 11.4 times greater (COR = 11.408, CI = 3.43–37.94, $P < 0.001$). Consistent with the findings of a prior study by Ref. [34], however, this finding contradicts the results obtained by Ref. [35], who reported no significant association between the body condition score and BTB positivity. Similarly, the analysis showed that seasonal migration (AOR = 2.882, CI = 1.155–7.191, $P = 0.023$) was a significant predictors of TB infection in cattle, which aligns with the findings reported by Refs. [36,37].

The avian PPD prevalence of 1.0 % in cattle detected at ≥4 mm in the present study is comparable with the reported prevalence of 0.7 % in cattle by (Gumi et al., 2011). However, in contrast to our study, a higher prevalence of the avian PPD reactor 10.0 and 11.0 % was reported in cattle from Zambia and Ethiopia by Refs. [23,38] respectively. The observed differences in the prevalence of avian PPD may be due to differences in susceptibility to non-BTB mycobacteria, husbandry, and epidemiological factors.

The questionnaire results showed that only 14.2 % of the respondents (17 of 120) were aware of contracting tuberculosis and had poor knowledge of BTB in the area. Furthermore, only 13.3 % knew about animal-to-human or human-to-animal transmissions. The majority (70.8 %) considered TB to be exclusive to humans. This study found that the habit of consuming raw milk was common in the area, despite only 9.2 % being aware of the possibility of BTB transmission through milk. This finding agrees with those of [39,40]. However, 45.6 % of farmers in the Jimma zone and 31 % of smallholder farmers in Gambella, South West Ethiopia [41,42] showed higher levels of knowledge of BTB among farmers. Low levels of health education, weak connections between health institutions, and insufficient mass media education may be the cause of communities' lack of knowledge of BTB in this area.

The study found that 77.5 % (93 out of 120) of the respondents regularly consumed raw milk, which differed from a report by Ref. [42] in Gambella, where only 43 % consumed raw milk. However, 99.2 % (119 out of 120) of the respondents did not consume raw meat, likely because of religious beliefs. The study also found that 41.7 % and 20.8 % of the respondents reported that people and animals frequently shared water sources and were kept indoors at night, respectively. These practices are common in pastoral areas because there is often a lack of water sources, leading people and animals to share drinking water. Additionally, young animals are kept indoors to protect them from predators and harsh weather conditions.

5. Conclusion

In conclusion, BTB is widespread in Somali pastoral and agro-pastoral areas, yet many inhabitants are not knowledgeable about the disease and its public health consequences. Given the close bond between the Somali people and their livestock, particularly through raw milk consumption as a primary source of nourishment, there could be significant public health risks. Therefore, it is recommended that public health education be conducted through community leaders, alongside routine human and animal-based BTB prevalence surveillance and implementation of effective control and prevention strategies.

Funding

The funding for the procurement of diagnostic reagents and equipments was provided by Jigjiga University to carry out this research work.

Ethics approval

Ethical approval was obtained from the research ethics committee of Jigjiga University, who reviewed the proposal according to the rules and regulations and approved the proposal accordingly with permit No. JJU/REC/011/2021. Verbal consent was obtained from animal owners for inclusion of their animals in the study and for interviewing owners in public health awareness assessments.

Statement of animal rights

Skin tests were performed by a veterinarian to preserve animal health and welfare.

Data availability statement

Data is available in the mendeley data repository (https://data.mendeley.com/datasets/tgh5zwvhj6/1), DOI: 10.17632/tgh5zwvhj6.1.

CRediT authorship contribution statement

Hassan Abdi Hussein: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Juhar Mohamed Ahmed:** Methodology, Investigation, Formal analysis, Data curation. **Abdi Hussein Musse:** Writing – review & editing, Writing – original draft. **Yonas Gizaw:** Writing – review & editing, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors acknowledge Jigjiga University for funding this research. Special thanks to the Animal Health Institute of Ethiopia for their support in acquiring Bovine and Avian PPD. Finally, we acknowledge the pastoralists who are highly appreciated for their tremendous cooperation and allowing us to perform skin tests on their animals and interviews.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24998.

References

[1] Y. Liu, Q. Kang, B. Yang, F. Li, X. Li, L. Zhang, L. Zhao, Prevalence of bovine tuberculosis in the Aksu region of Xinjiang, China, between 1985 and 2016, Arq. Bras. Med. Vet. Zootec. 71 (2019) 374–378.
[2] A. El-Sayed, S. El-Shannat, M. Kamel, M. Castañeda-Vazquez, H. Castañeda-Vazquez, Molecular epidemiology of Mycobacterium bovis in humans and cattle, Zoonoses Public Health, 63, (4 (2016) 251–264.
[3] M. Thakur, N. Sood, K. Gupta, Pathomorphological study of atypical pulmonary tuberculosis in cross-bred cow-A case report, Indian J. Vet. Pathol 44 (3) (2020) 172–176.
[4] M.T. Rahman, M.A. Sobur, M.S. Islam, S. Ievy, M.J. Hossain, M.E. El Zowalaty, A.T. Rahman, H.M. Ashour, Zoonotic diseases: etiology, impact, and control, Microorganisms 8 (9) (2020) 1405.
[5] T.T. Deneke, A. Bekele, H.L. Moore, T. Mamo, G. Almaw, G.A. Mekonnen, A. Mihret, R. Tschopp, L. Yeheyis, C. Hodge, Milk and meat consumption patterns and the potential risk of zoonotic disease transmission among urban and peri-urban dairy farmers in Ethiopia, BMC Publ. Health 22 (1) (2022) 222.
[6] A.R. Allen, T. Ford, R.A. Skuce, Does Mycobacterium tuberculosis var. bovis survival in the environment confound bovine tuberculosis control and eradication? A literature review, Vet. Med. Int. (2021), https://doi.org/10.1155/2021/8812898, 2021.
[7] F. Olea-Popelka, A. Muwonge, A. Perera, A.S. Dean, E. Mumford, E. Erlacher-Vindel, S. Forcella, B.J. Silk, L. Ditiu, A. El Idrissi, Zoonotic tuberculosis in human beings caused by Mycobacterium bovis—a call for action, Lancet Infect. Dis. 17 (1) (2017) e21–e25.
[8] R. Tschopp, A. Aseffa, E. Schelling, S. Berg, E. Hailu, E. Gadisa, M. Habtamu, K. Argaw, J. Zinsstag, Bovine tuberculosis at the wildlife-livestock-human interface in Hamer Woreda, south Omo, southern Ethiopia, PLoS One 5 (8) (2010) e12205.
[9] World Health Organization, Global tuberculosis report 2021: supplementary material, in: Global Tuberculosis Report 2021: Supplementary Material, 2022. *https://pesquisa.bvsalud.org/portal/resource/pt/who-360605?lang=en*.
[10] O. Cosivi, J.M. Grange, C.J. Daborn, M.C. Raviglione, T. Fujikura, D. Cousins, R. Robinson, H. Huchzermeyer, I. de Kantor, F.-X. Meslin, Zoonotic tuberculosis due to Mycobacterium bovis in developing countries, Emerg. Infect. Dis. 4 (1) (1998) 59.
[11] D. Ashford, E. Whitney, P. Raghunathan, O. Cosivi, Epidemiology of selected mycobacteria that infect humans and other animals, Rev. Sci. Tech. - Off. Int. Épizoot 1 (2001) 325–337.
[12] D.B. Areda, A. Muwonge, A.B. Dibaba, Status of bovine tuberculosis in Ethiopia: challenges and opportunities for future control and prevention, Tuberculosis in Animals: An African Perspective (2019) 317–337, https://doi.org/10.1007/978-3-030-18690-6_14.
[13] B. Gumi, E. Schelling, R. Firdessa, G. Erenso, D. Biffa, A. Aseffa, R. Tschopp, L. Yamuah, D. Young, J. Zinsstag, Low prevalence of bovine tuberculosis in Somali pastoral livestock, southeast Ethiopia, Trop. Anim. Health Prod. 44 (2012) 1445–1450.
[14] J. Kemal, B. Sibhat, A. Abraham, Y. Terefe, K.T. Tulu, K. Welay, N. Getahun, Bovine tuberculosis in eastern Ethiopia: prevalence, risk factors and its public health importance, BMC Infect. Dis. 19 (1) (2019) 1–9.
[15] D. Mège, P. Purcell, S. Pochat, T. Guidat, The landscape and landforms of the Ogaden, Southeast Ethiopia,, Landscapes and landforms of Ethiopia (2015) 323–348.
[16] Y. Lemma, F. Beyene, B. Hundie, Climate change and variability: implications for household food security in agro-pastoral area of Jigjiga district, Eastern Ethiopia, Ethiop. J. Econ 22 (1) (2013) 71–106.
[17] CSA, The federal democratic republic of Ethiopia central statistical agency report on area and production of major, Central Statistical Agency, Stat. Bull (2016).
[18] M. Thrusfield, Veterinary Epidemiology, John Wiley & Sons, 2018.
[19] D. Pfeiffer, Veterinary Epidemiology: an Introduction, John Wiley & Sons, 2010.
[20] M. Nicholson, M.H. Butterworth, A guide to condition scoring of zebu cattle: ILRI (aka ILCA and ILRAD) (1986).
[21] R. Kazwala, D. Kambarage, C. Daborn, J. Nyange, S. Jiwa, J. Sharp, Risk factors associated with the occurrence of bovine tuberculosis in cattle in the Southern Highlands of Tanzania, Vet. Res. Commun. 25 (2001) 609–614.
[22] G. Ameni, A. Erkihun, Bovine tuberculosis on small-scale dairy farms in Adama Town, central Ethiopia, and farmer awareness of the disease, Rev. Sci. Tech. - Off. Int. Épizoot 26 (3) (2007) 711–720.
[23] T. Fetene, N. Kebede, Bovine tuberculosis of cattle in three districts of northwestern Ethiopia, Trop. Anim. Health Prod. 41 (2009) 273–277.
[24] A. Regassa, A. Tassew, K. Amenu, B. Megersa, F. Abunna, B. Mekibib, T. Macrotty, G. Ameni, A cross-sectional study on bovine tuberculosis in Hawassa town and its surroundings, Southern Ethiopia, Trop. Anim. Health Prod. 42 (2010) 915–920.
[25] G. Girmay, M. Pal, Y. Deneke, G. Weldesilasse, Y. Equar, Prevalence and public health importance of bovine tuberculosis in and around Mekelle town, Ethiopia, Int. J. Livest. Res 2 (2) (2012) 180–188.
[26] M. Omer, E. Skjerve, Z. Woldehiwet, G. Holstad, A cross-sectional study of bovine tuberculosis in dairy farms in Asmara, Eritrea, Trop. Anim. Health Prod. 33 (2001) 295–303.
[27] R. Firdessa, R. Tschopp, A. Wubete, M. Sombo, E. Hailu, G. Erenso, T. Kiros, L. Yamuah, M. Vordermeier, R.G. Hewinson, High prevalence of bovine tuberculosis in dairy cattle in central Ethiopia: implications for the dairy industry and public health, PLoS One 7 (12) (2012) e52851.
[28] L.M. O'Reilly, C. Daborn, The epidemiology of Mycobacterium bovis infections in animals and man: a review, Tuberc. Lung Dis 76 (1995) 1–46.
[29] F. Inangolet, B. Demelash, J. Oloya, J. Opuda-Asibo, E. Skjerve, A cross-sectional study of bovine tuberculosis in the transhumant and agro-pastoral cattle herds in the border areas of Katakwi and Moroto districts, Uganda, Trop. Anim. Health Prod. 40 (2008) 501–508.
[30] G. Ameni, A. Aseffa, H. Engers, D. Young, S. Gordon, G. Hewinson, M. Vordermeier, High prevalence and increased severity of pathology of bovine tuberculosis in Holsteins compared to zebu breeds under field cattle husbandry in central Ethiopia, Clin. Vaccine Immunol. 14 (10) (2007) 1356–1361.
[31] B. Gumi, E. Schelling, R. Firdessa, A. Aseffa, R. Tschopp, L. Yamuah, D. Young, J. Zinsstag, Prevalence of bovine tuberculosis in pastoral cattle herds in the Oromia region, southern Ethiopia, Trop. Anim. Health Prod. 43 (2011) 1081–1087.
[32] B.Z. Katale, E.V. Mbugi, E.D. Karimuribo, J.D. Keyyu, S. Kendall, G.S. Kibiki, P. Godfrey-Faussett, A.L. Michel, R.R. Kazwala, P. Van Helden, Prevalence and risk factors for infection of bovine tuberculosis in indigenous cattle in the Serengeti ecosystem, Tanzania, BMC Vet. Res. 9 (2013) 1–11.

[33] S. Cadmus, C. Agada, I. Onoja, I. Salisu, Risk factors associated with bovine tuberculosis in some selected herds in Nigeria, Trop. Anim. Health Prod. 42 (2010) 547–549.
[34] P. Admasu, W. Berihun, A. Niguse, Prevalence of bovine tuberculosis in dairy cattle of Yeki District, Southern Ethiopia, Afr. J. Basic Appl. Sci. 6 (5) (2014) 135–140.
[35] G. Mamo, F. Abebe, Y. Worku, N. Hussein, M. Legesse, G. Tilahun, G. Medhin, G. Bjune, G. Ameni, Bovine tuberculosis and its associated risk factors in pastoral and agro-pastoral cattle herds of Afar Region, Northeast Ethiopia, J Vet Med Anim Health 5 (6) (2013) 171–179.
[36] W.T. Johnston, F. Vial, G. Gettinby, F.J. Bourne, R. Clifton-Hadley, D. Cox, P. Crea, C.A. Donnelly, J. McInerney, A. Mitchell, Herd-level risk factors of bovine tuberculosis in England and Wales after the 2001 foot-and-mouth disease epidemic, Int. J. Infect. Dis. 15 (12) (2011) e833–e840.
[37] G.A. Mekonnen, A.J. Conlan, S. Berg, B.T. Ayele, A. Alemu, S. Guta, M. Lakew, B. Tadesse, S. Gebre, J.L. Wood, Prevalence of bovine tuberculosis and its associated risk factors in the emerging dairy belts of regional cities in Ethiopia, Prev. Vet. Med. 168 (2019) 81–89.
[38] G. Shirima, R. Kazwala, D. Kambarage, Prevalence of bovine tuberculosis in cattle in different farming systems in the eastern zone of Tanzania, Prev. Vet. Med. 57 (3) (2003) 167–172.
[39] M.A. Reta, T.W. Bereda, A.N. Alemu, Bacterial contaminations of raw cow's milk consumed at Jigjiga City of Somali Regional State, Eastern Ethiopia, Int. J. Food Contam 3 (1) (2016) 1–9.
[40] A. Bihon, S. Zinabu, Y. Muktar, A. Assefa, Human and bovine tuberculosis knowledge, attitude and practice (KAP) among cattle owners in Ethiopia, Heliyon. 7. (3 (2021) e06325.
[41] T. Kuma, B. Deressa, F. Alem, W. Tigre, Farmer's awareness and practices on rabies, bovine tuberculosis, taeniasis, hydatidosis and brucellosis in Mana and Limmukosa districts of Jimma zone, south west Ethiopia, World Appl. Sci. J. 23 (6) (2013) 782–787.
[42] G. Asebe, E. Gudina, Community knowledge, attitudes and practices on bovine tuberculosis and associated risk factors in Gambella Regional State Lare Woreda, South West Ethiopia, Veterinaria 67 (2018) 1.