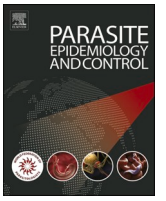
Parasite Epidemiology and Control 26 (2024) e00369

Contents lists available at ScienceDirect

Parasite Epidemiology and Control

journal homepage: www.elsevier.com/locate/parepi



Seroprevalence of *Coxiella burnetii* and potential tick vectors infesting domestic ruminants and community perception of the disease in pastoral areas of south Omo zone, southern Ethiopia

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ARTICLE INFO

Keywords:
Arthropods
Community awareness
Domestic animals
One health
Q fever
Zoonoses

ABSTRACT

Background: Q fever is a worldwide occurring neglected zoonotic disease with great economic importance. The etiological agent, *Coxiella burnetii,* is a bacterium usually associated with subclinical infections in livestock, but may also cause reproductive pathology and spontaneous abortions in artiodactyl species including goats, sheep and cattle which are deemed to be the primary reservoirs of this disease.
Aims: The present cross-sectional and questionnaire survey was undertaken in three districts of the South Omo zone with the aims to comprehend the community perception of livestock keepers and professionals about the disease, estimate the seroprevalence of *Coxiella burnetii* (*C. burnetii*) in cattle and small ruminants and to determine the species of potential tick vectors of *C. burnetii* infesting cattle, sheep and goats.
Methods: A standard questionnaire was used to assess the community perception of livestock keepers and animal health professionals in the area about Q fever. Sera samples were collected from 1350 ruminants comprising 450 cattle, 450 goats and 450 sheep to detect *C. burnetii* antibodies using the ELISA technique. Furthermore, a total of 279 cattle, 197 goats and 73 sheep were examined for the presence of ticks, and overall, 2720 ticks were collected (1299 from cattle, 1020 from goats and 401 from sheep) and identified to the species level using morphologically identification keys.
Results: Findings of the study indicated that 43% of animal owners were aware of the main symptoms of the disease while the remaining 57% did not notice these symptoms in their animals. Additionally, majority of animal health professionals 76.2% in the area reported they were familiar with the causative agent of Q fever, while 23.8% expressed uncertainty regarding the cause of coxiellosis. An overall seroprevalence of *C. burnetii* of 37.6% in cattle (37.4% in female and 37.8% in male cattle) and 28.7% in small ruminants was recorded (which is significantly

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https://doi.org/10.1016/j.parepi.2024.e00369
Received 8 January 2024; Received in revised form 14 May 2024; Accepted 13 July 2024
Available online 15 July 2024

higher in goats than in sheep). The study indicated statistically significantly higher seroprevalence of *C. burnetii* (49.8%) in cattle infested with ticks than in those cattle free of ticks (24.2%), with three times higher seropositivity (OR = 2.97, $p = 0.000$) as compared to those cattle free of ticks (24.2%). Similarly, statistically significantly higher seroprevalence of *C. burnetii* was recorded in both sheep and goats infested with ticks (43.6%) as compared to those animals without ticks (22.9%), with the former being twice as likely to test seropositive (OR = 2.15, $p = 0.000$). A total of nine different tick species were identified, namely *Amblyomma variegatum* (*Am. variegatum*) with 26.3% (342; 217 males, 101 females and 24 nymphs), *Amblyomma cohaerens* (*Am. cohaerens*) with 47.96% (370 males, 253 females), *Amblyomma gemma* (*Am. gemma*) with 4.00% (52; 29 males, 23 female), *Rhipicephalus pulchellus* (*Rh. pulchellus*) with 10.6% (138; 87 males, 51 females), *Rhipicephalus pravus* (*Rh. pravus*) with 0.2% (3; 2 males, 1 females), *Rhipicephalus evertsi* (*Rh. evertsi*) with 4.7% (61; 39 males, 22 females), *Rhipicephalus praetextatus* (*Rh. praetextatus*) with 0.8% (10; 7 males, 3 females), *Rhipicephalus decoloratus* (*Rh decoloratus*) with 2.9% (38; 4 males, 34 females) and *Hyalomma truncatum* (*Hy. truncatum*) with 2.5% (32 females). *Conclusion:* The present study highlighted the significance of Q fever in ruminants and compiled information about the community perception of livestock keepers and veterinary professionals of the study areas. The role of ruminants and their ticks in the epidemiology of *C. burnetii* requires further research using molecular tools to better understand appropriate method of intervention that will help to reduce negative impacts on the productivities of livestock and the health of humans in Ethiopia.

1. Introduction

Query fever (Q fever) is caused by *Coxiella burnetii*, an obligate intracellular Gram-negative bacterium belonging to the order *Legionellales*, the class gamma *Proteobacteria*, the family *Coxiel-laceae* and the genus *Coxiella. Coxiella burnetii* is a short (0.3–1.0 μm) pleomorphic bacterium associated with infectious disease which may appear either as an acute or chronic form in humans (Raoult et al., 2003; De Lange et al., 2014). Coxiellosis has been regarded as a re-emerging zoonotic disease of public health concern with increasing significance and is typically transmitted from animal hosts to humans through inhalation of contaminated aerosols or ingestion of infected animal products such as milk or cheese (Arricau-Bouvery and Rodolakis, 2005). Infection in humans, usually by inhalation, may be asymptomatic (up to 60% of infected individuals) or may manifest clinically after an incubation period ranging between 1 and 3 weeks (Arricau-Bouvery and Rodolakis, 2005).

Ruminants (goats, sheep, and cattle) are considered the main reservoirs of the disease, and coxiellosis is also reported in other vertebrates including wildlife, pets, marine mammals, birds, reptiles and rabbits (Das et al., 2013; OIE, 2013). In sheep, goats and cattle, chronic infection of the reproductive apparatus of females may induce late abortions, stillbirths, weak offspring, metritis and infertility, which may shed large amounts of bacteria into the environment; however, in most other animals, *C. burnetii* infection is asymptomatic (De Lange et al., 2014; Arricau-Bouvery and Rodolakis, 2005). The bacteria may persist in the environment for years (Das et al., 2013). Sheep are primarily asymptomatic carriers, but they can shed massive numbers of bacteria at parturition and intermittently in various secretions (De Lange et al., 2014; OIE, 2013).

Several previous studies suggest that ticks are infected during feeding on animals and then transmit *C. burnetii* transovarially and transstadially to their offspring. They excrete *C. burnetii* via feces, saliva and coxal fluid to the environment, and thus, ticks are considered to play a vital role in maintaining the bacteria in the environment, and they are also the major reservoirs of this bacterium (Kumsa et al., 2015a). According to the available information, the Q fever agent was isolated and the genotypes were determined in many species of ticks, and so far, the involvement of >70 tick species belonging to the genera of Ixodes, *Rhipicephalus*, *Amblyomma* and *Dermacentor* has been reported in different countries around the world (Kumsa et al., 2015b).

Studies in different countries show a prevalence of 15–20% in cattle and small ruminants (Alvarez et al., 2012; Gumi et al., 2013). In addition, seroprevalence of 20–40% of *C. burnetii* was recorded in livestock in different parts of the world (Kumsa et al., 2015a; Tesfaye et al., 2020; Ibrahim et al., 2021; Proboste et al., 2021). In humans, the morbidity and mortality of Q fever are associated with several factors, including infectious doses and the environmental dynamicity of the agent. The risk of infection of *C. burnetii* is higher in people living in rural regions and in professionals with close contact with livestock (Nahed and Khaled, 2012). *Coxiella burnetii* was categorized as a biological weapon agent by the Centers for Disease Control and Prevention in the USA (Madariaga et al., 2003).

In Africa, the seroprevalence data on Q fever in livestock were documented in Namibia (Walter et al., 2014), Egypt (Klemmer et al., 2018), Kenya (Larson et al., 2019) and North and East Africa (Devaux et al., 2020). Even though some previous reports are available from Ethiopia, the country does not have well-organized, up-to-date information on Q fever at a national level. A few reports from Ethiopia have investigated *C. burnetii* in ticks collected from livestock (Philip et al., 1966), *C. burnetii* in ticks using PCR techniques and identification of the genotypes (Sulyok et al., 2014; Kumsa et al., 2015a) and Q fever in pastoral livestock in the southeast part of Ethiopia (Gumi et al., 2013) and in Northern Ethiopia (Wude et al., 2018). Information is also available on the seroprevalence of *C. burnetii* in Jimma Town, Southwestern Ethiopia (Deressa et al., 2020), in small ruminants in the Borana zone (Tesfaye et al., 2020) and in the Somali region (Ibrahim et al., 2021).

The livestock sector is the pillar of the economy in the South Omo zone, in which about 85–90% of the population is agro-pastoral and pastoral, their livelihood being entirely dependent on animal production and rearing. Hence, the zone is characterized by very

frequent movement of livestock from the zone to nearby neighboring regions. Despite the presence of very conducive situations for the circulation of *C. burnetii* among domestic ruminants and humans in the region, there is little information on Q fever in cattle and small ruminants in the South Omo zone of Ethiopia. Therefore, the present study is designed to assess the community perception of livestock keepers and professionals about problems associated with infection of *C. burnetii* in animals, determine the seroprevalence of *C. burnetii* in cattle and small ruminants, and identify potential tick vectors infesting cattle and small ruminants as one of the possible factors for coxiellosis in the zone.

2. Materials and methods

2.1. Study area description

The present study was conducted in three districts, namely the Dasenech, BenaTsemay and Debub Ari districts in the South Omo zone. The South Omo zone is located in the extreme southwestern part of the country, named the South Nation Nationalities and People's Region (SNNPR). The zone lies between 4°43′ N to 6°46′ N latitude and 35°75′ E to 37°07′ E longitude (National Metrology Agency (NMA), 2018). The annual temperature ranges from a daily minimum of 12.3 °C to a maximum of 29.5 °C. The mean annual rainfall also ranges from 400 to 1600 mm (South Omo Zone Finance and Economy Development (SOZFED), 2017).

The zone has different agroecological zones comprising hot arid and tropical humid climates (Fig. 1). The lowest altitude is about 365 m a.s.l in the extreme south of the zone near Lake Turkana, and the highest altitude is in Shengama, at 3418 m a.s.l, in the Debub Ari district (South Omo Zone Finance and Economy Development (SOZFED), 2017). The zone has 31.7 persons per sq. km as an average population density. The main production system is pastoral, agro-pastoral and mixed farming systems. Accordingly, the livestock population of the zone is estimated at 2,733,147 cattle, 1,415,361 sheep, 3,110,966 goats, 8393 horses, 2046 mules, 3938 donkeys, 481,237 poultry and 98,991 beehives (Central Statistical Agency (CSA), 2020).

2.2. Study population

The study population comprises indigenous breeds of cattle; goats and sheep are found in the three districts with lowland, midland and highland agroecological zones. Nine Peasant Associations (PAs) were selected in total with three PAs chosen from each district. The selection of the districts and PAs was based on livestock population, agro-ecology (humidity, altitude and temperature), history of animal disease, husbandry practices and other criteria considered.

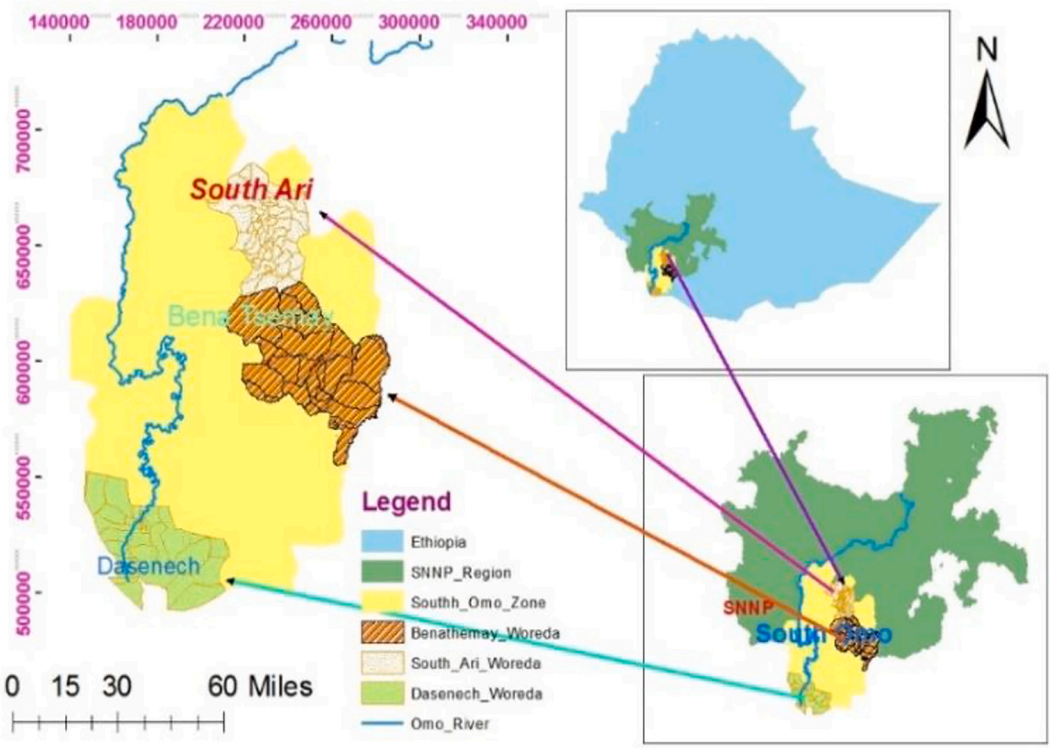

Fig. 1. Map showing the study area in the South Omo zone in Ethiopia.

2.3. Study design

During the present study, a cross-sectional design was employed to assess the seroprevalence of *C. burnetii* in cattle and small ruminants and assess potential tick vectors collected from the animals in the selected districts of the zone.

2.4. Questionnaire survey

For the assessment of community perception, a standard questionnaire was developed and administered to livestock keepers and animal health professionals in the area. The questionnaire survey mainly served to generate information about the respondents' demographic data (age, sex, marital status, education status, etc.), farm description (occupation, husbandry system practiced, etc.) and livestock-keeping tendencies (living with ruminants and pets, which activities they have been involved in, etc.). Livestock keepers and animal health workers were interviewed to assess their community perception regarding Q fever disease. The interview was conducted by one of the authors of this paper after it was translated into local languages like Dasenechigna, Benigna, Arigna and Amaharigna so as to have as high-quality results as possible.

2.5. Sample size determination and sampling technique

A previously developed formula ($N = 0.25/(SE)^2$, where N = sample size; SE = standard error of the proportion with the assumption of 5% standard error (Arsham, 2007)) was used to gather appropriate information on the community perception of livestock keepers about problems associated with the infection *C. burnetii* in animals and febrile illness in humans. Based on this formula with 5% SE (standard error), a total of 100 respondents were calculated as an appropriate sample size and participated from selected districts and PAs. Veterinarians working in the study area were interviewed using the census method of sample size approach. WinEpi (Universidad de Zaragoza©2010, version 8.0.2) software was applied to determine the sample size of the livestock of the present study using the estimated seroprevalence reported from Ethiopia in the previous study by Gumi et al. (2013) with a 95% confidence interval and 5% desired absolute precision. Subsequently, a total of 450 cattle, 450 sheep and 450 goats (1350 ruminant animals) were recruited for blood sample collection. The seroprevalence of *C. burnetii* in cattle and small ruminants was analyzed using cluster sampling analysis.

2.6. Serological study method

2.6.1. Blood collection from cattle and small ruminants

Blood samples of about 10 mL from cattle and 5 mL from small ruminants were collected from the jugular veins of apparently healthy animals using 18-gauge and 21-gauge disposable needles and red-top plain vacutainer tubes. Blood samples from each animal were coded with a specific identification serial number, district and PA. The samples were kept overnight at room temperature to obtain clear sera samples which were harvested in cryo tubes, and transported in an ice box to the Animal Health Institute located in the town of Sebeta and stored at −20 °C until processed.

2.6.2. Serological test procedure

The serological enzyme-linked immunosorbent assay (ELISA) technique was employed to test antibodies against *Coxiella burnetii*. ELISA was carried out with the Q fever antibody Test Kit (IDEXX Q Fever Laboratories, Inc. Westbrook, ME 04092, USA). The procedure followed the instructions found in the manufacturer and OIE protocol (OIE, 2018). In brief, sera samples and controls were kept at room temperature for about 30 min, then diluted at 1:400 ratios in wash solution and put into 96 polystyrene microplate wells precoated with inactivated *Coxiella burnetii* antigen. Positive and negative control sera were included in each plate. Antibodies were exposed to the antigens for about 60 min at 37 °C in an incubator shaker. The unbounded materials were removed through the washing procedure; conjugate enzyme was added to the microwells and incubated for another 60 min at 37 °C, and a substrate solution (TMB) was added to be oxidized by the conjugate enzyme. The resulting blue coloration converted to yellow after the addition of a stopping reagent. The reaction is directly proportional to the amount of antibodies in the sample and was evaluated for the strength of the reaction with an automated ELISA reader at a 450 nm wavelength. As suggested by the kit instructions from the manufacturer, ELISA results were interpreted as follows: if S/P% < 30%, the animal was negative; if S/P% 30–40%, the animal was suspect; if S/P% > 40%, the animal is positive. The sensitivity and specificity of the ELISA test kit as provided by the manufacturer were 99% and 98%, respectively.

2.7. Tick collection and identification

Ticks collected from different body regions of cattle, goats and sheep were morphologically identified using identification keys described previously (Kumsa et al., 2016). All the body surfaces of each study animal were thoroughly examined visually for the presence or absence of ticks. Ticks attached to the skin of each animal were carefully removed using forceps or by hand to avoid any damage to the body of animals, and placed into separate, pre-labeled, small plastic tubes containing 70% ethanol for subsequent identification. All ticks from the same animal were put into one vial and transported to the laboratory of Veterinary Parasitology of the College of Veterinary Medicine and Agriculture (CVMA) of Addis Ababa University (AAU) in Bishoftu. Species identification of ticks was possible for adult specimens, whereas larvae and nymphs were identified only at the genus level. Tick genera and species were

abbreviated as has been described previously (Dantas-Tores, 2008).

2.8. Ethical consideration

This study was carried out in accordance with the recommendations of the College of Veterinary Medicine and Agriculture of Addis Ababa University, and performed according to protocols approved by the Institutional Ethical Committee, complying with the international laws and regulations regarding ethical considerations in research animals, certified by Reference No VM/ERC/01/12/0.11/2019.

2.9. Data analysis

The data obtained from the questionnaire, the results of serum analysis and the identification of ticks collected from the animals were recorded using an MS Excel spreadsheet. The data were carefully checked for mistakes prior to proper coding. Then, the data were double-checked, cleaned and imported from the Microsoft Excel spreadsheet to Stata for analysis. Tabulations were used to summarize the results, and a chi-square test was applied to assess the association of variables with the prevalence of *C. burnetii* antibodies, at a significance level of $p < 0.05$.

3. Results

3.1. Questionnaire survey

The demographic information was compiled and generated from a total of 100 livestock keepers comprising 83 male and 17 female participants. The marital status of the respondents showed 92%, 4%, 2% and 2% were married, single, divorced and widowed, respectively. The age distribution of respondents showed that 33% were 18–35 years, 42% were 36–45 years and 23% were 46 and older. Generally, the majority of the respondents (60%) were illiterate, whereas 40% had some education, mostly elementary. A large proportion of the households had an average family size (less than seven people), while the remaining 40% had more than seven individuals per household (Table 1).

Results of the questionnaire survey about the occupation of the respondents revealed that 61% were livestock keepers, 29% were farmers and the remaining 10% were dairy workers. Likewise, the survey indicated the respondents practiced pastoralism (41%), agro-pastoralism (22%), mixed farming (22%) and traditional (15%) husbandry systems. The respondents kept their livestock near the house (28%), in the pasture (51%) and both near the house and in the pasture (21%) (Table 1).

The study also revealed a greater tendency of contact with pets (57%) such as cats (28%), dogs (22%) and both (7%). On the other hand, 43% of respondents did not have any contact with pet animals. The majority of the respondents (65%) assisted with the delivery of animals, and some of them had contact with aborted fetuses (15%), others (27%) and the rest had contact with amniotic fluid (23%). Most of them did not wear protective materials while assisting birth (58%), and few of them (7%) used protective materials made from local materials (Table 1).

Furthermore, livestock keepers reported that they had noticed some symptoms related to Q fever (43%), including abortion in small ruminants and vaginal secretion (8%), stillbirth (10%) and weakness and coughing (25%), while the rest (57%) had not noticed these symptoms in their animals. Respondents reported that they knew the local name for Q fever, whereas others (43%) gave different names according to their native language. Respondents did not know any specific name but mentioned symptoms like abortion (17%)

Table 1
Demographics, farming and inclination to raise livestock of the respondents.

Variable	Category	Proportion %
Participants sex	Male	83
	Female	17
Marital status	Married	92
	Single	4
	Divorced	2
	Widow	2
Age	18–35 year	35
	36-45 ear	42
	>46	23
Husbandry system	Pastoral	41
	Agro pastoral	22
	Mixed farming	22
	Traditional	15
Contact with pets	Yes	57
	No	43
Assisting in the delivery of a birth	Yes	65
	No	35
The trend is to use protection.	Yes	7
	No	58

and (26%) some types of illness. The source of Q fever or means of transmission was not known by most herders (57%), while others believed it to be due to climate change (18%), circulation among livestock (13%) or from arthropods (6%) (Table 2).

The majority of the respondents believed that tick infestation is high in their area (96%), while the rest (4%) did not consider ticks as the problem. Respondents said they remove ticks by hand (24%), use acaridae (35%) or traditional treatment (10%), while some of them (31%) do not take any control measures to remove ticks from their animals. Respondents believe that Q fever mainly affects cattle (52.4%), sheep and goats (33.3%), while the rest (14.3%) did not know of their presence among ruminant species. The majority of the herders also believe that treatment of Q fever is possible (71%), while few respondents (8%) believe there is no treatment and others (21%) did not have any idea about the treatment of Q fever in animals. The majority of the respondents believe that modern drugs can be used to treat Q fever (66%) in humans, while some believe in traditional remedies (15%) and the rest (19%) do not know of any treatment for Q fever in humans. The majority of the respondents reported that a lack of treatment on time could lead to death (50%) and progression to a chronic stage (27%), while some believe in self-curing (19%) and the rest (4%) do not know the consequences of Q fever in humans.

Most of the animal health professionals working in the area (76.2%) reported that they know the causative agent of Q fever, while the rest (23.8%) do not know the exact cause of Q fever. These professionals know the transmission means of Q fever (76.2%) such as contact with birth materials (28.6%), consumption of raw milk (19.0%), direct contact with infected animals (9.5%) and aerosol transmission (19.1%), while the rest (23.8%) of them do not know the means of transmission. Animal health professionals indicated domestic animals (42.9%) and arthropods (38.09%) as the reservoir hosts for Q fever while the rest (19.05%) do not know this aspect of the disease (Table 3). The majority of the animal health professionals reported that they had assisted birth delivery and came into contact with abortive fetuses (19.05%), placenta (28.5%), fluid (19.1%) or all birth materials (23.8%), while the rest (9.5%) had no contact with any materials during delivery. These professionals reported that they consume dairy products, including raw milk (28.6%) and milk and yogurt (9.5%) (Table 2). Veterinary practitioners reported they had encountered suspected cases of Q fever symptoms at veterinary clinics (47.6%) and they had treated these cases with an injection of oxytetracycline 20%, oxytetracycline 10% and pen-strep.

3.2. Seroprevalence of *Coxiella burnetii*

In this study, a total of 1350 blood samples from cattle (450), goats (450) and sheep (450) were collected. An overall seroprevalence of 31.6% (427/1350) of antibodies against *C. burnetii* was registered in all three species of domestic ruminants with an overall seroprevalence of 37.6% (169/450) in cattle, 36.7% (165/450) in goats and 26.7% (93/450) in sheep. Statistically significant variation in the seroprevalence of antibodies against *C. burnetii* was not observed among animals of various sex and age groups (Tables 4 and 5).

In the present study, an overall Q fever seroprevalence of 37.6% (169/450) was recorded in cattle. Statistically significant variation in the seroprevalence of Q fever in cattle was not observed among the three study districts (Table 4). Statistically significant variation was not observed between male 73 (37.8%) and female 96 (37.4%) cattle. Likewise, overall seroprevalence of 29 (33.9%) in young cattle and 130 (38.8%) in adult cattle were recorded (Table 4).

The seroprevalence of antibodies against *C. burnetii* in cattle infested with ticks was 235 (49.8%), while the seroprevalence in cattle without tick infestation was 215 (24.2%), as clearly depicted in Fig. 2.

In the present study, an overall Q fever seroprevalence of 28.7% was recorded in small ruminants, with a significantly higher prevalence in goats (36.7%) than in sheep (20.7%). The statistically significant highest (33.7%) seroprevalence of Q fever was recorded in BenaTsemay and the lowest was recorded in Debub Ari district (24.7%) (Table 5). Statistically significant variation was not observed between male 92 (31.9%) and female 166 (27.1%) animals. Likewise, overall seroprevalence of 49 (29.3%) in young animals and 209 (28.7%) in adult animals was recorded. The study revealed that a statistically significantly ($Ch^2 = 37.749$, $p = 0.000$) higher seroprevalence of Q fever 109 (43.6%) in small ruminants infested with ticks than in animals without 149 (22.9%) tick infestations (Table 5).

3.3. Survey of tick vectors

During the present study, ticks were collected from 62% of cattle ($n = 279$), 43.8% of goats ($n = 197$) and 16.2% of sheep ($n = 73$). A total of 1299 ticks were collected from cattle, of which 464 were collected from lowland (35.7%), 621 from midland (47.8%) and 214 from highland agroecology (16.5%). From cattle, the following were collected and identified (Table 5): *Am. cohaerens* 48% (370 males, 253 females), *Am. variegatum* 26.3% (342; 217 males, 101 females and 24 nymphs), *Rh. pulchellus* 10.6% (138; 87 males, 51 females), *Rh. evertsi* 4.70% (61; 39 males, 22 females), *Am. gemma* 4.0% (52; 29 males, 23 females), *Rh. decoloratus* 2.9% (38; 4 males, 34

Table 2
Source of Q fever as reported by respondents.

Source of Q Fever	Frequency	Proportion (%)
Do not know the source	57	57.0
Climate Change	18	18.0
Livestock	13	13.0
Arthropods	6	6.0
Others	6	6.0

Table 3
Response of veterinary professionals working in the South Omo zone about some aspects of Q fever in animals.

Characteristics	Percentage (%)
Information about the causative agent	
Yes	76.2
No	23.8
Source of transmission	
Birth material	28.6
Raw milk	19.0
Diseased animal	9.5
Aerosol form	19.1
Did not have known the means	23.8
Reservoir host of Q fever	
Domestic animal	42.9
Arthropods	38.09
Do not know with this specific aspect	19.05

Table 4
Seroprevalence of Q fever in cattle in the study districts in the South Omo zone.

Variables	Samples	Positive	Prevalence (%)	OR	*p*-Value
District					
Dasenech	150	47	31.3		
BenaTsemay	150	57	38.0	1.19	0.486
Debub Ari	150	65	43.3	1.36	0.220
Age					
1–3	115	39	33.9		
4–7	335	130	38.8	0.87	0.350
Sex					
Female	257	96	37.4		
Male	193	73	37.8	0.97	0.878
Coat color					
Light	268	100	37.3		
Dark	182	69	37.9	1.08	0.745
Overall	450	169	37.55		

females), *H. truncatum* 2.5% (32 females), *Rh. bergeoni* 0.8% (10; 7 males, 3 females) and *Rh. pravus* 0.2% (3; 2 males, 1 female). A total of 749 ticks were collected from female cattle (57.7%) and the remaining 550 from male cattle (42.3%). Likewise, 23.6% (306) of ticks were collected from young cattle and the remaining 76.4% (993) were from adult cattle. **From goats, the following** were collected and identified (Table 5): *Rh. evertsi* 27.0% (276; 182 males, 94 females), *Am. cohaerens* 23.2% (237; 179 males, 58 females), *Rh. pulchellus* 23.1% (235; 144 males, 73 females, 18 nymphs), *Rh. pravus* 10.2% (104; 46 males, 58 female), *Am. gemma* 7.0% (72; 43 males, 29 females), ***Am.*** *variegatum* 6.1% (62; 23 males, 8 females, 31 nymphs), *Rh. decoloratus 2.6*% (26; 9 males, 17 females) and *Hy. truncatum* 0.8% (8; 5 males, 3 females). From sheep, the following were collected and identified: *Rh. pulchellus* 47.9%, *Am. cohaerens* 12.7%, *Hy. truncatum* 12.0%, ***Am.*** *variegatum* 8.0% (32 males), *Rh. evertsi* 7.7%, *Rh. pravus* 7.5%, *Rh. decoloratus* 3.2% and *Am. gemma* 1.0%. The proportion of ticks on female animals was 58.6% (235), and the majority of the collected ticks were adults (80.0%) (Table 6).

4. Discussion

The current study documented information regarding the seroprevalence and community perception among livestock keepers and veterinary professionals using standard questionnaire of Q fever in domestic ruminants in the South Omo zone in Ethiopia which is characterized by pastoral and agro-pastoral production systems with high livestock density and movement. An overall of 100 livestock keepers and 21 veterinary professionals were interviewed to assess community perception relevant to Q fever in animals and humans of the study area. The result revealed low overall knowledge of Q fever and inadequate attitude with inappropriate practice of respondents. The study showed that livestock owners have low knowledge of Q fever with most of the herders (57%) do not know the source of Q fever or means of transmission which was associated to higher proportion of respondents were illiterate (60%). These

Table 5
Seroprevalence of antibodies against *Coxiella burnetii* in small ruminants in districts of the South Omo zone.

Variables	Samples	Positive	Prevalence (%)	OR	p-Value
District					
Dasenech	300	83	27.7		
BenaTsemay	300	101	33.7	1.28	0.188
Debub Ari	300	74	24.7	0.84	0.370
Species					
Goats	450	165	36.7		
Sheep	450	93	20.7	0.56	0.000
Sex					
Female	612	166	27.1		
Male	288	92	31.9	1.15	0.408
Age					
1–3 years	167	49	29.3		
4–7 years	733	209	28.5	0.98	0.811
Tick infestation					
Absent	650	149	22.9		
Present	250	109	43.6	2.15	0.000
Overall	900	258	28.66		

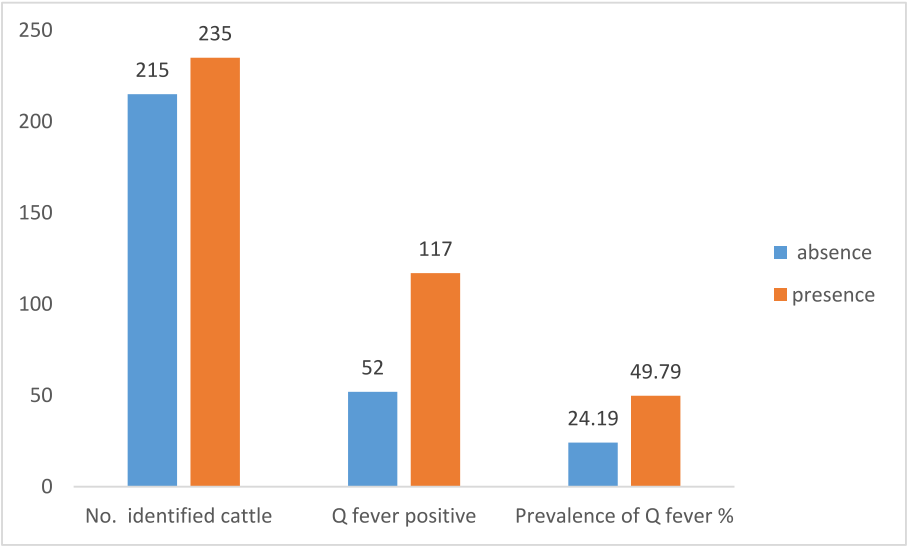

Fig. 2. Number of cases and prevalence of *Coxiella burnetii* in cattle with and without tick infestation.

results are in agreement with study undertaken in Northern Regions of Cameroon (Zangue et al., 2022) and in Erzurum, Turkey (Özlü et al., 2020).

Findings of the present study also indicate the presence of regular close contact between livestock and rural community (61% livestock keepers, 29% farmers and the remaining 10% were dairy workers) which is implicated as one of the risk factors that predispose to infection by *Coxiella burnetii* as has been previous reported (Noden et al., 2014). Furthermore, the observation of the present study in which (65%) of the respondents assisted delivery of animals is in line with the previous studies conducted in Australia and New Zealand which reported 56% of Q fever cases were associated with occupation (Palmer et al., 2007). The prevalence of Q fever is usually higher in people engaged in animal related jobs such as farmers (16.1%) and abattoir/meat (13.9%) workers as has been previously reported in Australia (Department of Health and Ageing (DOHA), 2012). Findings of the present study also indicated majority of respondents consume dairy products such as raw milk (28.6%) as well as milk and yogurt (9.5%) which is in line with the previous observation of consumption of unpasteurized milk from farm animals that contain high levels of pathogenic material, including contaminated urine or semen, feces, and milk which lead to infection of Q fever (Bernard et al., 2012; Porter et al., 2011).

The present serological study has shown that Q fever was widely spread in goats, sheep and cattle, with an overall seroprevalence of

Table 6
Ticks collected from the study cattle (450), goats (450) and sheep (450) in the South Omo zone.

Tick Species	Cattle % (N)	Goats % (N)	Sheep % (N)
Am. variegatum	26.3 (342)	6.1 (62)	8.0 (32)
Am. cohaerens	48 (623)	23.2 (237)	12.7 (51)
Am. gemma	4.00 (52)	7.0 (72)	1.0 (4)
Rh. pulchellus	10.6 (138)	23.1 (235)	47.9 (192)
Rh. pravus	0.2 (3)	10.2 (104)	7.5 (30)
Rh. evertsi	4.70 (61)	27.0 (276)	7.7 (31)
Rh. bergeoni	0.8 (10)	0	0
Rh. decoloratus	2.9 (38)	2.6 (26)	3.2 (13)
Hy. truncatum	2.5 (32)	0.8 (8)	12.0 (48)
Overall	100 (1299)	100 (1020)	100 (401)

31.6% (427/1350) antibodies against *C. burnetii* in the South Omo zone in Ethiopia. This high overall seroprevalence of Q fever among cattle, goats and sheep in the present study is most probably attributed to practices of mixing large numbers of animals, the movement of livestock in search of pastures, sharing grazing areas with wildlife and the concentration of animals around water points in pastoral communities (Kumsa et al., 2015a). Q fever infections have a socio-economic burden due to production and reproductive losses associated with abortions, stillbirths and infertility (Noden et al., 2014; Palmer et al., 2007; DOHA, 2013), and this is also a threat to human health, especially among people living in close proximity to the animals, such as the pastoralist communities in the South Omo zone of Ethiopia.

The observation of an overall seroprevalence of 37.6% of Q fever in cattle in the present study is in agreement with the previous report of 31.6% in pastoral production systems in Southeastern Ethiopian (Gumi et al., 2013), 30.61% in Saudi Arabia (Abdulrahman et al., 2018) and 33% in Northern Ethiopia (Wude et al., 2018). On the other hand, lower prevalence rates of 14.8% in Turkey (Saglam and Sahin, 2016), 19.3% in Egypt (Njeru et al., 2016), 9.6% in the Somali region of Ethiopia (Ibrahim et al., 2021) and 20% in the Oromia region of Ethiopia (Proboste et al., 2021) were also reported. On the contrary, however, our finding is lower than some of the previous reports of 59% in Denmark (Agger et al., 2010) and 63% in Nigeria (Vanderburg et al., 2014). These differences among various studies could be attributed to variations in the types of tests used, agroecological zones, animal production systems, human density patterns and tick burdens (Palmer et al., 2007).

The observation of statistically significantly ($p = 0.000$) higher seroprevalence of Q fever (49.8%) in cattle infested with ticks than those without tick infestations (24.19%) agrees with the earlier observations (Kumsa et al., 2015a; Sulyok et al., 2014). This observation is correlated to the previous reports on the role of ticks as a reservoir or vector of Q fever transmission between infected and susceptible animals. High tick infestations were recorded in the present study, particularly of *Am. cohaerens* 48% and *Am. variegatum* 26.3% in cattle, *Am. cohaerens* 23.2% in goats and *Am. cohaerens* 12.7% in sheep, which have already been reported as the major vectors of *C. burnetii* and are reported to play a pivotal role in the epidemiology of Q fever and circulate among ruminants and humans.

The finding of an overall Q fever seroprevalence of 28.7% in small ruminants in the present study is in line with several previous reports, including 28.5% in the Borana pastoral area of Southern Ethiopia (Tesfaye et al., 2020), 29.80% in Iran (Rad et al., 2014) and 23% to 32% in Egypt (Abushahba et al., 2017; Nusinovici et al., 2015). Likewise, the significantly higher seroprevalence in goats (36.7%) than in sheep (20.7%) recorded in the present study is in line with previous reports of 32–65.7% in Ethiopia (Tesfaye et al., 2020; Ibrahim et al., 2021; Wude et al., 2018; Alemnew et al., 2021). This suggests that goats might be more susceptible than sheep and shed more organisms in feces, milk and birth materials, which increases the dissemination of the pathogen and subsequent infections, as has been suggested before (Rodolakis et al., 2007). This finding is very important as domestic ruminants are implicated as the sources of human infection, through direct contact or contamination of the environment during parturition or abortion (Ohlson et al., 2014). In support of this idea, South Omo seems to be very conducive for transmission, as animal husbandry practices are characterized by high populations and multiple species of animals herded together and sharing the same grazing area and watering points.

The observation of significantly ($p = 0.000$) higher seroprevalence of Q fever (43.6%) in small ruminants infested with ticks than those animals without tick infestations (22.9%) is in line with several previous reports from western Kenya (Psaroulaki et al., 2006; Wardrop et al., 2016), in which a strong correlation between seropositivity and infestation of ticks in animals was documented. This is likely attributed to the fact that ticks are implicated to spread Q fever by acting as a reservoir of the pathogen, as has been previously reported (Astobiza et al., 2011).

The current study showed that cattle and small ruminants were infested by different species of ticks. *Am. cohaerens* (48%) was encountered as the predominant tick on cattle, followed by *Am. variegatum* (26.3%) and *Rh. pulchellus* (10.6%), in line with previous reports from Guba-Koricha in the West Harerghe zone (Henok et al., 2017), the Humbo district in Southern Ethiopia (Morka et al., 2014), and Dandi in West Shoa Oromia (Kumisa et al., 2017). The predominance of *Amblyomma* spp. was also reported previously (Pawlos and Derese, 2013; Kemal et al., 2016). The lower incidence of tick infestation in young cattle (23.6%) than in adult cattle (76.4%) observed in the current study is in accordance with earlier reports (Kumsa et al., 2015a; Tamirat et al., 2017; Fessha and Mathewos, 2020).

The observations of *Rh. evertsi* (27.0%) as the most predominant tick species on goats, followed by ***Am.*** *coherence* (23.2%) and *Rh. pulchellus* (23.1%), and the predominance of *Rh. pulchellus* (47.9%) on sheep followed by *Am. cohaerens* (12.7%) and *Hy. truncatum* (12.0%), are in line with previous reports on sheep ticks from different parts of Ethiopia (Habtemichael et al., 2020; Kifle et al., 2021)

and on goat ticks from the town of Gondar (Fentahun et al., 2012), the Sodo Zuria district (27.5%) (Israel et al., 2015) and the Bench Maji zone, Southern Ethiopia (31.3%) (Tesfaheywet and Simeon, 2016; Abebe et al., 2011).

The higher prevalence of ticks on female goats (60.5%) than on male goats (39.5%) and the respective figures for sheep (58.6% and 41.4%) encountered in the present study are in line with the previous reports (Mathewos et al., 2021). Possible explanations might include lactation and pregnancy hormones that are suggested to stress female animals as compared to their male counterparts, as has been suggested before. Likewise, the higher prevalence of ticks in 86.8% of adult goats compared to 13.2% of young goats and also in 80.5% of adult sheep and 19.5% of young sheep is in agreement with the previous reports from Dire Dawa (Mathewos et al., 2021), Eastern Ethiopia (Ahmed et al., 2017), and the Boloso Sore district of the Wolaita zone, Southern Ethiopia (Mathewos et al., 2021). This variation is most probably attributed to the fact that the majority of animal owners keep young grazing animals near the house, and also because young animals have less acquired immunity against ticks than adult animals.

5. Conclusions

This study has shown that Q fever is prevalent in the South Omo zone in Southern Ethiopia. The high seroprevalence in goats, sheep and cattle indicates the presence of risks of human infection in the study area. Livestock farmers whose livelihoods are associated with animals and who live in close proximity to Q-fever-positive livestock are at high risk. Both cattle and small ruminants were infested with several species of ticks, with *Am. cohaerens* (48%), *Am. variegatum* (26.3%), *Rh. evertsi* (27.0%) and *Rh. pulchellus* (23.1%) as the most predominant tick species on domestic ruminants in addition to the four other tick species. In this regard, the observation of significantly higher seroprevalence of Q fever in ruminants with tick infestation as compared to those animals without tick infestation demonstrates the important role of ticks in the epidemiology of this disease. Further detailed research using molecular characterization and genotyping of *Coxiella burnetii* is required, and it is also important to establish the rate of infection in other parts of the country and assess the need for the inclusion of Q fever among diseases under surveillance. Important extension works need to be carried out to raise awareness about *Coxiella burnetii* and Q fever in the South Omo zone and other parts of Ethiopia. Collaboration between veterinary services and the Ministry of Health is the key to controlling *Coxiella burnetii* and Q fever in the country. Tick control program should be implemented, and the efficacy of acaricide used at the field level should be evaluated.

5.1. Limitations

The present study sought to provide original data on the presence and distribution of Q fever in the study area. However, the study has the limitation of not being able to utilize molecular techniques to determine and characterize *Coxiella burnetii* in the blood samples of cattle and sheep and ticks collected during the study period.

Funding

This research received no external funding.

CRediT authorship contribution statement

Senait Getachew: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Bersissa Kumsa:** Writing – review & editing, Supervision, Methodology, Investigation, Data curation, Conceptualization. **Yitbarek Getachew:** Supervision, Methodology. **Getachew Kinfe:** Methodology, Data curation. **Balako Gumi:** Supervision, Data curation. **Tesfaye Rufael:** Supervision, Methodology, Data curation. **Bekele Megersa:** Writing – review & editing, Supervision, Methodology, Data curation.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The data that supports the findings of this study are available from the lead author upon reasonable request.

Acknowledgments

We would like to acknowledge the Southern Agricultural Institute, Hawasa; the Jinka Agricultural Research Center, South Omo, Zone Jinka; the College of Veterinary Medicine and Agriculture, Addis Ababa University, Bishoftu; and the Pastoral, Agro-Pastoral and Special Support Requiring Resource Research and Capacity-Building Directorate, Addis Ababa, for financing this research work. Special thanks to the Animal Health Institute, Sebeta, and Dereje Berededa PLS, USA, for supporting the serological kit and processing the samples.

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