Small Ruminant Research 206 (2022) 106594

Contents lists available at ScienceDirect

Small Ruminant Research

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

Prevalence and risk factors of *Brucella spp*. in goats in Borana pastoral area, Southern Oromia, Ethiopia

Dereje Teshome [a,*], Teshale Sori [b], Taferi Banti [c], Getachew Kinfe [c], Barbara Wieland [d,e,f], Gezahegn Alemayehu [d]

[a] *Oromia Agricultural Research Institute; Yabello Pastoral and Dryland Agriculture Research Center, P.O. Box: 85, Yabello, Ethiopia*
[b] *College of Veterinary Medicine and Agriculture, Addis Ababa University, P.O. Box 34, Bishoftu, Ethiopia*
[c] *National Animal Health Diagnostic and Investigation Center, P.O. Box: 04. Sebeta, Ethiopia*
[d] *International Livestock Research Institute (ILRI), P.O. Box 5689, Addis Ababa, Ethiopia*
[e] *Institute of Virology and Immunology (IVI), Mittelhäusern, Switzerland*
[f] *Department of Infectious Diseases and Pathobiology (DIP), Vetsuisse Faculty, University of Bern, Switzerland*

ARTICLE INFO

Keywords:
Brucellosis
Borana
Ethiopia
Goats
Risk factors
Sero-prevalence

ABSTRACT

Goat production plays an important role in the livelihood of Borana pastoralists. Optimal utilization of the goat population, is however, impaired by diseases such as brucellosis. Brucellosis is considered as one of the serious diseases incurring considerable loss to the goat industry through reproductive wastages. The situation of brucellosis has not been investigated in goats in Borana pastoral areas despite the frequent occurrence of abortion. This study wasconducted from November 2016 to April 2017, aimed at determining the prevalence of infection with *Brucella* species, identify the risk factors of infection and understand the knowledge, attitude and practice (KAP) of pastoralists about the disease. Serum samples were collected from a total of 789 goats from three randomly selected pastoral districts. The samples were tested using a competitive enzyme-linked immunosorbent assay (cELISA). The study survey results showed that most of the pastoralists (≥64.2 %) and (≥81.6 %) had poor knowledge about brucellosis and its zoonotic importance, respectively. From a total of 789 sera samples 137 (17.36 %; 95 % CI: 14.78, 20.19) tested positive for anti-*Brucella* antibodies. The highest seroprevalence was observed in Elwaya (71/252; 28.17 %; 95 % CI: 22.71, 34.16) followed by Moyale (48/332; 14.46 %; 95 %CI: 10.86, 18.71), whereas the lowest prevalence was observed in Yabello district (15/208; 8.78 %; CI: 5.29, 13.52). The results of multivariable logistic regression analysis revealed that sex and age of goats were significantly associated with seroprevalence of brucellosis. The odds of infection was nearly 7 times (OR: 6.97) higher in female goats than in males ($P < 0.001$). Adult goats were 12 times (OR: 12.19) more likely to be infected than their younger counterparts ($P < 0.001$). For goats raised in large sized flocks ($OR = 2.57$; $P = 0.028$) and for those goats originated from Elwaya district, the risk of infection was significantly higher ($OR = 7.91$; $P < 0.001$). The history of occurrence of reproductive problems in female goats is significantly associated with seropositivity to *Brucella* infection ($OR = 5.32$; $P < 0.001$). This study showed that a significant proportion of goats in Borana pastoral districts were infected with *Brucella,* suggesting its economic implication and zoonotic importance.

1. Introduction

Goats are important domestic animals capable of surviving in harsh environments such as common in arid and semi-arid areas (Tharwat and Al-sobayil, 2017). In Borana pastoral areas, they are the second most important livestock species after cattle and serve the society mostly as source of cash and collaterals for the family to cover school fees for children and other family expenses (Teshome et al., 2019). The optimal utilization of goats, however, is hampered by infectious diseases. One possible disease is brucellosis, which has been recognized as one of the neglected tropical zoonotic diseases and of worldwide public health importance (Olufemi et al., 2018). It is a sub-acute or chronic disease caused by *Brucella* species (Gondal et al., 2017). In livestock it is mainly caused by *Brucella abortus* (*B. abortus*), *Brucella melitensis* (*B. melitensis*), *Brucella suis* (*B. suis*), *Brucella canis* (*B. canis*) and *Brucella ovis* (*B. ovis*). Among these species, *B. melitensis* and *B. ovis* are the common cause of

* Corresponding author.
E-mail address: derejeteshe@gmail.com (D. Teshome).

https://doi.org/10.1016/j.smallrumres.2021.106594
Received 2 June 2021; Received in revised form 3 October 2021; Accepted 29 November 2021
Available online 2 December 2021

brucellosis in sheep and goats (Tekle et al., 2019). Although several species of *Brucella* can infect goats, *B. melitensis* is the primary cause of goat brucellosis (Constable et al., 2017). There are three biovars of *B. meltensis* that have differing geographic distribution, but no difference in pathogenicity or host preference.

Brucella melitensis infection has major veterinary and human importance in areas where it occurrs and causes considerable economic losses associated with abortion, neonatal death (Rajala et al., 2016), reduced fertility and decreased milk production (Ran et al., 2018). The considerable costs of preventive programs and restrictions on trade of animals and their products constitute an important loss to infected countries. In addition, there is a huge loss associated with human illness (Constable et al., 2017).

In Ethiopia, the occurrence of brucellosis in goats has been known for long time. Conservatively the overall pooled prevalence was estimated to be about 5.3 % (95 % CI = 3.5, 7.5) as reported by Tadesse (2016). The presence of *Brucella* species among goat herds has also been confirmed using bacteriological methods (Tekle et al., 2019). The nationwide average prevalence, however, does not reflect the situation in pastoral areas since pastoralism is a distinct production system from mixed crop-livestock farming. Within the pastoral areas, depending on the local husbandry system, the prevalence can vary. For example, a prevalence of 1.7 % was observed in Somali pastoral region of Ethiopia (Lakew et al., 2019) whereas a prevalence of 4.8 % was reported in goats in Afar pastoral region (Ashenafi et al., 2007). In one study comparing seroprevalence of brucellosis in gaots in Somali and Afar regions, a prevalence of 13.2 % was recorded in Afar where commingling of animals due to communal grazing is the common practice. In contrast in Somali region where herding and rangeland utilization is based on clan basis, the prevalence was 1.7 % (Teshale et al., 2006). From Borana pastoral area, only few serological studies have been reported. In addition information on factors affecting its occurrence as well as knowledge, attitude and practices of the pastoralists is scarce (Edao et al., 2020).

The previous studies employed mostly complement fixation test (CFT) and other screening tets such as rose bengal plate test (RBPT) and indirect ELISA (Curro et al., 2012; Mohseni et al., 2017). An alternative diagnostic approach is the coompetetive ELISA (Yahaya et al., 2019). The sensitivity of the test ranged from 92.31 %–100 %, in comparison with 77.14 %–100 % for the complement fixation test (Perrett et al., 2010).

There is empirical evidence of the frequent occurrence of unconfirmed cases of abortion and stillbirth in goats in pastoralist areas of Southern Ethiopia. Most of those cases are being handled by farmers and community animal health workers. Hence, reliable information is needed on the disease prevalence and the risk factors to reduce the veterinary and public health impacts of brucellosis in goats. Therefore, this study was conducted to estimate the prevalence of brucellosis using competitive ELISA in goats and identify associated risk factors as well as KAP about the disease in Borana pastoral area.

2. Materials and methods

2.1. Description of the study area

The study was conducted in three randomly selected districts of Borana zone namely Elwaya, Moyale and Yabello. Borana is characterized by a semi-arid to arid climate (Kamara et al., 2005; Haile et al., 2011). Geographically it is situated between 4° to 6° N latitude and 36° to 42° E longitude. The altitude of the Borana zone ranges from 1,000–1, 700 m above sea level featured by isolated mountains and valleys (Coppock, 1994; McCarthy et al., 2002). Elwaya, Moyale and Yabello districts are located at a distance of 590, 770 and 570 km South of Finfine (capital city of the Country), respectively (Teshome et al., 2019). The mean annual rainfall of the area ranges from 250 to 700 mm. The mean annual temperature varies from 19 to over 25°C. Extensive pastoralism (nomadic pastoralism) is the main means of livelihood for the Borana people (Gelagay et al., 2007). Cattle, goats, sheep and camels are important livestock species raised in the area (Fig. 1).

2.2. Study design and sampling strategy

A cross-sectional study was employed to collect sera samples and information on potential risk factors such as age, sex, parity of animals, history of occurrence of reproductive problems and herd size. The age of animals was estimated based on information obtained from the owner and dentition (Abebe and Yami, 2008). A multistage clustered sampling method was employed in which the study districts were selected randomly. This was followed by a random selection of villages among all villages registered under the selected districts. Six pastoral association (PAs) or villages were selected randomly: Areri and Adegalchet from Elwaya, Tile Mado and Dambi from Moyale, and Dida Yabello and Harwoyu from Yabello. Within the selected villages, 161 households which have goats were purposively selected and all goats were sampled if the herd size was ≤ 5. In households with more than 5 goats, 4–9 goats were selected. This resulted in a total of 789 goats sampled from the 161 households.

The questionnaire was developed, pre-tested and administered to the households with well trained researchers from Yabello research center who speak local languages to collect information on risk factors and to capture knowledge, attitude and practice of the pastoralists on knowledge about brucellosis (transmission prevention and control), awareness about zoonotic nature of brucellosis, consumption of raw milk, consumption of raw meat, disposing of aborted fetus/fetal membrane, assisting delivery, experience of using protective while handling aborted fetus, fetal membrane and during assisting delivery.

The total sample size was determined based on internationally set standard formula (Thrusfield, 2005). Sample size was calculated using 95 % confidence level at 5% absolute precision and expected prevalence of 50 % to get maximum sample size.

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

Where n = required sample size, d = desired absolute precision, P = expected prevalence (50 %) by substituting the value, the minimum sample sizes of 384 small ruminants were obtained. To account for intra-class correlation at herd, village, and district levels, a design effect of 2 was considered, resulting in a minimum sample size of 768 (calculated with EpiInfo 7.2).

2.3. Sample collection and laboratory analysis

Approximately 5−7 mL of blood was collected from the jugular vein of each goat using sterile plain vacutainer tubes and needles. The tubes were labeled individually and were kept in an icebox on ice and transported to Yabello Pastoral and Dryland Agriculture Research Center. The samples were allowed to stand overnight to allow serum separation. The sera were separated after centrifugation at 1500 rpm for 10 min. The sera were then collected into sterile cryogenic tubes and stored at -20°C until transportation to National Animal Health Diagnostic and Investigation Center, Sebeta, Ethiopia for further analysis.

The commercial competitive ELISA (SVANOVA Biotech, *Brucella* Ab c-ELISA, serial number: 10-2701-10, Uppsala, Sweden) was used for detection of anti-*Brucella* antibodies in the samples according to the manufacturer's instructions. Positive and negative controls provided along with the kit were used for validation of the assay. A sample was considered positive to anti-*Brucella* antibody when its percent inhibition (PI) was ≥30; which was computed as 100−((mean OD samples×100)/(mean OD conjugate control)). The c-ELISA, used in this study has a sensitivity of 93.6 % and a specificity of 99.4 % in goats (Nielsen et al., 2005).

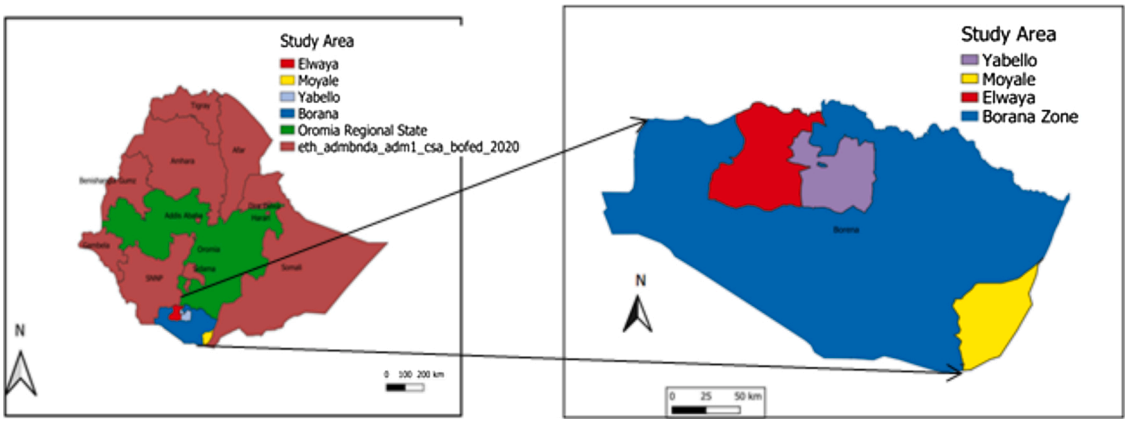

Fig. 1. Map of Ethiopia showing study areas.

2.4. Data management and analysis

The analysis of data such as the effects of risk factors on the prevalence of brucellosis was carried out using STATA software version 13.0 (StataCorp, 4905 Lake way Drive, College Station, Texas 77845 USA). Survey was analzed using Statistical Package for the Social Sciences (SPSS) version 20. Multivariable logistic regression was used to determine the associations between the risk factors and prevalence. The variables were fitted manuaaly while looking for the occurrence of confounding as the stepwise backward elimination and forward building methods do not allow cheking for confounding. The filtness of the logistic regression model was assessed by using the Hosmer-Lemeshow and Pearson methods. Odds ratio was reported as the measure of association between prevalence and risk factors. The effect of clustering was assessed using multilevel mixed-effects generalized linear models. A 95 % confidence interval and a P value < 0.05 were considered significant.

3. Results

3.1. Questionnaire survey result

The questionnaires were administered to a total 161 pastoralist households in three districts to capture awareness about the disease. 83.1 %, 67.3 % and 64.2 % of the respondents in Elwaya, Yabello and Moyale respectively did not have knowledge on transmission, prevention and control of caprine brucellosis. Also in Yabello (81.6 %), Moyale (84.9 %) and in Elwaya (84.7 %) repsondents were not aware of the zoonotic nature of the disease. Of the interviewed respondents 75.6 % in Elwaya, 80.3 % in Moyale and 83.3 % in Yabello consumed raw milk regularly. In addition to raw milk; 10.2 %, 3.8 % and 6.1 % of the respondants in Elwaya, Moyale and Yabello respectively consume raw meat. None of the respondents indicated to either bury nor burn aborted fetuses and fetal membrane; rather 76.3 %, 94.3 % and 40.8 % of them were throw them on the field, while 23.7 %, 5.7 % and 59.2 % in Elwaya, Moyale and Yabello respectively were feeding them to dogs. A large proportion of participants, 100 % in Elwaya, 98.1 % in Moyale and 89.8 % Yabello, normally assist delivery of kids. However, the majority of the respondents, 94.5 % in Elwaya, 96.8 % in Moyale and 87.8 % in Yabello do not use protection while assisting delivery or disposing of aborted fetus as well as fetal membrane (Table 1).

Table 1
Knowledge, attitudes and practices of Pastoralists Brucella infection.

Variables	Proportion of Respondents (%)		
	Districts		
	Elwaya (n = 59)	Moyale (n = 53)	Yabello (n = 49)
Knowledge about brucellosis (transmission prevention and control)			
Yes	16.9	35.8	32.7
No	83.1	64.2	67.3
Awareness about zoonotic nature of brucellosis			
Yes	15.3	15.1	18.4
No	84.7	84.9	81.6
Consumption of raw milk			
Yes	75.6	80.3	83.9
No	24.4	19.7	16.1
Consumption of raw meat			
Yes	10.2	3.8	6.1
No	89.8	96.2	93.9
Disposing of aborted fetus/fetal membrane			
Burying/Burning	0.0	0.0	0.0
Throw on field	76.3	94.3	40.8
Give to dog	23.7	5.7	59.2
Assisting delivery			
Yes	100.0	98.1	89.8
No	0.0	1.9	10.2
Experience of using protective while handling aborted fetus, fetal membrane and during assisting delivery			
Yes	5.5	3.2	2.2
No	94.5	96.8	97.8

3.2. Sero-prevalence and associated risk factors for caprine brucellosis

The herd level seroprevalence was 46.61 % (67/161) based on the c-ELISA test. From a total of 789 goat sera tested, 137 (17.36 %; CI95 %: 14.78, 20.19) were positive (Table 2). The prevalence of brucellosis was 28.17 % (CI: 22.71, 34.16), 14.46 % (CI: 10.86, 18.71) and 8.78 % (CI: 5.29, 13.52) in goats tested from Elwaya, Moyale and Yabello districts, respectively. Female goats were more frequently infected with *Brucella* species (20.19 %) than their male counterparts (11.42 %). The odds of infection was nearly 7 times higher in female goats than in males ($P < 0.001$). Similarly, the prevalence was higher in adult goats (26.17 %) than in younger ones (8.07 %). Adult goats were thus 12 times more likely to be infected than their younger counterparts ($P < 0.001$). Higher prevalence was observed in goats sampled from larger herd size compared to those goats tested from medium and small size herds. The prevalence seemed to increase with the parity level of animals and in those goats having history of reproductive problems. For goats raised in large sized flocks (OR = 2.57; P = 0.028) and for those goats originated from Elwaya district the risk of infection was significantly higher (OR = 7.91; $P < 0.001$). The history of occurrence of reproductive problems in female goats was significantly associated with seropositivity to *Brucella* infection (OR = 5.32; $P < 0.001$). When univariable logistic regression was used to analyze the data, parity number was significantly associated

Table 2
Results of multivariable logistic regression analysis on the effects of risk factors on prevalence of brucellosis in goats in Borana zone.

Risk factors	N tested	N positive	Percent	OR	95% CI	P value
District						
Yabello	205	18	8.78	Ref.		
Elwaya	252	71	28.17	7.91	(3.24 - 19.29)	0.000
Moyale	332	48	14.46	1.64	(0.66 - 4.08)	0.289
Sex						
Female	535	108	20.19	6.97	(2.72 - 17.87)	0.000
Male	254	29	11.42	Ref		
Age						
Adult	405	106	26.17	12.19	(3.55 - 41.86)	0.000
Young	384	31	8.07	Ref		
Flock size						
Small	175	24	13.71	Ref		
Medium	267	33	12.36	0.96	(0.39 - 2.33)	0.920
Large	347	80	23.05	2.57	(1.11 - 5.98)	0.028
History of reproductive problems						
Yes	299	84	28.09	5.32	(3.14 - 9.00)	0.000
No	440	53	10.82	Ref		

with prevalence of *Brucella* infection (OR = 1.43; P = < 0.001; CI: 1.17, 1.73). The prevalence was 11.19 % (16/143), 18.19 % (27/146), 25.40 % (32/126), 26.67 % (24/90) and 30.00 % (9/30) in nulliparous pregnant goats, in primiparous goats, in goats having two parity, three parity and four parity, respectively. In multivariable logistic regression analysis, however, its effect was reversed due to the occurrence of multicollinearity with age. It was, therefore, omitted from the multivariable logistic regression model used.

4. Discussion

Goats remain valuable resources for the pastoral community inhabiting fragile and marginal lands. Optimum utilization of these resources requires control of infectious diseases such as brucellosis, which is highly communicable, resulting in considerable economic loss due to reproductive wastages (Rashid et al., 2017) and is a risk for public health. In pastoral areas of Ethiopia, different seroprevalence of brucellosis in people have been reported and seem occupationally linked. A prevalence of 2.6 % was reported in Borana by Edao et al. (2020), however higher prevalences of 48.3 %, and 34.9 % were found in Afar and Somali regional state respectively by Tschopp et al. (2021), 21.1 % pooled prevalence by (Tadesse, 2016) and as well as 34.9 % and 29.4 % in Borana and South Omo communities respectively (Megersa et al., 2011).

The present study documented serological evidence of brucellosis in goats and low level of awareness of brucellosis in occupationally exposed household members in three selected districts of Borana zone in Southern Ethiopia. Since we employed competeitive ELISA, which is very sensititive and able to discern Brucella infection from cross-reacting bacteria, the results are a good reflection of the status of brucellosis in goats in the area.

The level of knowledge, attitude and practices of the livestock owners have on zoonotic diseases has a paramount role in reduction of zoonotic disease risks and public wellbeing. The result of the current survey clearly revealed a lack of knowledge about caprine brucellosis and the zoonotic nature of the disease in the study districts. More in depth research on the reasons behind poor practices and willingness to change is warranted.

Current practices related to milk and raw meat consumption and assisting unprotected at parturition increase the risk for livestock keepers to Brucella transmission. Other poor practices, such as disposing of aborted fetus or fetal membrane either dump in the field (environment) or feeding them to dogs are similar to findings of others (Edao et al., 2018 and Wubishet et al., 2018).

The prevalence difference between districts is considerable, ranging from 8.78 % in Yabello to 28.17 % in Elwaya districts. The livestock authorities, veterinary services and public health sectors should take this into consideration. The high seroprevalence observed shows the widespread occurrence of brucellosis in goat population in an area where there is no control program in place. It is comparable to the results of authors who reported brucellosis in goats from different parts of Ethiopia such as Teshale et al. (2006); Ashenafi et al. (2007) and Tsehay et al. (2014) who reported seroprevalence in goats in the range of 15–16.45 % in pastoral areas. It is also comparable to seroprevalence observed (16.2 %) in goats from Sudan (El-Ansary et al., 2001), 16.1 % from Nigeria (Bertu et al., 2010) and 18.70 % from China (Wang, 2012). The higher seroprevalence observed in this study is similar to elsewhere, which could be due to similarity in the animal husbandry practiced in the study areas. The pastoralits often mix animals of different ages and species in communal grazing areas and during night enclosures. Such activities favor transmission and spread of Brucella among animals. The absence of control measures also contributes to the stable high seroprevalence. McDermott and Arimi (2002) also referred to the occurrence of a great variation in the prevalence of brucellosis in sub-Saharan Africa (ranging from 4.8–41%) in the pastoral areas. Our report is higher than the findings of Ashenafi et al. (2007); Megersa et al. (2011); Adugna et al. (2013); Dabassa et al. (2013); Tegegn et al. (2016) and that of (Teferi and Yeshibelay, 2019) The difference in seroprevalence could be attributed to difference in knowledge, attitude and practice of the households in the study area and the types of laboratory tests used for the detection of evidence of infection.

The statistically significant difference observed in the prevalence of brucellosis between female and male goats was suggested to be attributed to the production of a sugar erythritol, which stimulates the growth and multiplication of *Brucella* organisms during consequent pregnancies (Radostits et al., 2010). This observation is in agreement with the reports of Rahman et al. (2011). In female goats the occurrence of reproductive problems is associated with infection with *Brucella*. Reproductive loss due to abortion, birth of weak offspring, and infertility are recorded as the common clinical signs of brucellosis in infected hosts (Radostits et al., 2010).

The high prevalence of brucellosis observed in adult goats in this study is due to the biology of the *Brucella*, which is associated with the sexual maturity of the hosts. There is also a commulative effects of age in which older animals are more likely to be exposed over lifetime. That is, adult animals have greater chance of coming into contact with other animals and become infected due to continued exposure to *Brucella* as they remain in the herds over a long period of time serving as breeding stock. In the pastoral production system young animals are sold for immediate family expenses while adult animals, especially females, remain to produce offsprings. This observation has been reported in Ethiopia and elsewhere in the world (Bertu et al., 2010; Radostits et al., 2010; Zubairu et al., 2014; Asmare et al., 2013; Olufemi et al., 2018; Edao et al., 2020). In addition, adult animals move frequently from place to place during the dry season in serach of pasture and water. This increases the chance of contact with other animals and the chance of infection.

Larger flock size was found to be significantly associated with seropositivity to *Brucella* in goats. This can be ascribed to the fact that an increase in flock size is usually accompanied by an increase in stocking density, one of the determinants for exposure to *Brucella* infection especially following abortion or parturition. The association of flock size with the prevalence of anti-*Brucella* antibody has also been previously reported (Teklue et al., 2013; Asmare et al., 2013).

In this study, seropositivity to *Brucella* infection in goats was

significantly associated with history of reproductive problems. Although the proportion of *Brucella* infected goats developing reproductive problems remains to be explored in the future, the observed association reveals the possible effects of brucellosis on the optimal utilization of the goats by pastoralists and the nation.

In general, the distribution of anti-*Brucella* antibodies among different districts and herds was found to be variable. This could be associated with variability of the herd sizes and the geographical locations of the districts. Borana pastoralists trek their livestock, with the exception of lactating and few pregnant animals, to different districts, or even crossing national borders by traveling several kilometres in search of pasture, water and sometimes market. This results in massive concentration of animals in areas with relatively better pasture and watering points. This in turn, may contribute to increased transmission of *Brucella* organisms among different herds and districts. This situation also contributes to wider spread of the infection since there is no official brucellosis control program in Ethiopia.

5. Conclusion and recommendations

The present study documented high prevalence of brucellosis (17.36 %) in goats in Borana pastoral area suggesting its widespread occurrence. This may result in considerable economic loss in terms of reproductive wastages like abortion, still birth, infertility, sterility and delivery of weak offspring. In addition to this, it has a public health importance. Location, age, sex, history of the reproductive problem and flock size were risk factors of brucella infection. The Ethiopian government should institute brucellosis control measures based on vaccination, as well as awareness creation for the community on the economic and public health implication of brucellosis for the contribution to successful prevention and control of the disease.

Funding information

This study was supported by the Oromia Agricultural Research Institute (IQQO) and the CGIAR Research Program on Livestock. We thank all donors who support this research.

Compliance with ethical standards

Ethical clearance on the use of goats for this study was obtained from animal research ethics review committee of Addis Ababa University, College of Veterinary Medicine and Agriculture, before the start of this study. All procedures performed in this study were in accordance with the ethical standards of the institution. The owners of goats used in this study and the local administration were informed about objectives of the study and the owners revealed their consent in the presence of administrative bodies and elders.

Data availability

No data was used for the research described in the article.
Data will be made available on request.
All data is within the manuscript and figure

Declaration of Competing Interest

The authors have no conflicts of interest regarding this work.

Acknowledgments

The authors are grateful to the International Livestock Research Institute for financing the research, National Animal Health Diagnostic and Investigation Center (NAHDIC) Sebeta, Ethiopia, for the technical assistance in the laboratory analysis. We acknowledge the pastoralists from our study area for their participation and cooperation in this study.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.smallrumres.2021.106594.

References

Abebe, G., Yami, A., 2008. Sheep and goat management. In: Yami, A., Merkel, R.C. (Eds.), Sheep and Goat Production Handbook for Ethiopia. Ethiopia Sheep and Goat Productivity Improvement Program (ESGPIP). Ethiopian Ministry of Agriculture and Rural Development, Ethiopia, pp. 33–57.

Adugna, K.E., Agga, G.E., Zewde, G., 2013. Seroepidemiological survey of bovine brucellosis in cattle under a traditional production system in Western Ethiopia. Rev. Sci. Tech. 32, 765–773.

Ashenafi, F., Teshale, S., Ejeta, G., Fikru, R., Laikemariam, Y., 2007. Distribution of brucellosis among small ruminants in the pastoral region of Afar. Eastern Ethiopia Rev. Sci. Tech. 26 (3), 731–739.

Asmare, K., Sibhat, B., Molla, W., Ayelet, G., Shiferaw, J., Martine, A.D., et al., 2013. The status of bovine brucellosis in Ethiopia with special emphasis on exotic and cross bred cattle in dairy and breeding farms. Acta Trop. 126, 186–192.

Bertu, W.J., Ajogi, I., Bale, J.O., Kwaga, J.K.P., Ocholi, R.A., 2010. Sero-epidemiology of brucellosis in small ruminants in Plateau State, Nigeria. Afr. J. Microbiol. Res. 4 (19), 1935–1938.

Constable, P.D., Hinchcliff, K.W., Done, S.Ha, Grünberg, W., 2017. Veterinary Medicine. A Textbook of the Diseases of Cattle, Horses, Sheep, Pigs, and Goats, 11th edition, vol. 1. Elsevier, 3251 Riverport Lane, St. Louis, Missouri 63043, pp. 1781–1784.

Coppock, D.L., 1994. The Boran Pleatue of Southern Ethiopia: Synthesis of Pastoral Research, Development and Change, 1980-91. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia, p. 393.

Curro, V., Marineo, S., Vicari, D., Galuppo, L., Galluzzo, P., Nifosì, D., Pugliese, M., Migliazzo, A., Torina, A., Caracappa, S., 2012. The isolation of *Brucella* spp. From sheep and goat farms in Sicily. Small Rumin. Res. 106, S2–S5.

Dabassa, G., Tefera, M., Addis, M., 2013. Small ruminant brucellosis; serological survey in Yabello district. Asian J. Anim. Sci. 7, 14–21.

Edao, B.M., Hailegebreal, G., Berg, S., Zewude, A., Zeleke, Y., Sori, T., Almaw, G., Whatmore, A.M., Ameni, G., Wood, J.L.N., 2018. Brucellosis in the Addis Ababa dairy cattle: the myths andthe realities. BMC Vet Res. 14 (December (1)), 396.

Edao, B.M., Ameni, G., Assefa, Z., Berg, S., Whatmore, A.M., Wood, J.L.N., 2020. Brucellosis in ruminants and pastoralists in Borena, Southern Ethiopia. PLoS Negl. Trop. Dis. 14 (7) https://doi.org/10.1371/journal.pntd.0008461 e0008461.

El-Ansary, E.H., Mohammed, B., Hamad, A.A.R., Karom, A.G., 2001. Brucellosis among animals and human contacts in Eastern Sudan. Saudi Med. J. 7 (22), 577–579.

Gelagay, A., Teshale, S., Amsalu, W., Esayas, G., 2007. Prevalence of contagious caprine pleuropneumonia in the Borana pastoral areas of Ethiopia. Small Rumin. Res. 70 (2), 131–135.

Gondal, Muhammad Asif, Khan, Abid Ali, Ali, Anwar, Khan, Mirza Ali, Ahmed, Siraj, Wazir, Inamullah, Sajjad, Said, 2017. Molecular and serological study of caprine and ovine brucellosis in district Peshawar. J. Entomol. Zool. Stud. 5 (6), 1436–1440.

Haile, A., Ayalew, W., Kebede, N., Dessie, T., Tegegne, A., 2011. Breeding strategy to improve Ethiopian Boran cattle for meat and milk production. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 26. ILRI, Nairobi, Kenya.

Kamara, A., Kirk, M., Swallow, B., 2005. Property rights and land use change: implications for sustainable resource management in Borana, Southern Ethiopia. J. Sustain. Agric 25, 41–61.

Lakew, A., Adem, H., Ashebr, A., Shimelis, M., 2019. Sero-prevalence and community awareness on the risks associated with Livestock and Human brucellosis in selected districts of Fafan Zone of Ethiopian-Somali National Regional State. Vet. Anim. Sci. 7. https://doi.org/10.1016/j.vas.2019.100047.

McCarthy, N., Kamara, A., Kirk, M., 2002. the effect of environmental variability on livestock and land use management: the borana plateau, Southern Ethiopia. Socioeconomics and Policy Research Working Paper 35. ILRI. (International Livestock Research Institute), Nairobi, Kenya, and IFPRI (International Food Policy Research Institute), Washington, DC, USA, p. 35.

McDermott, J.J., Arimi, S.M., 2002. Brucellosis in sub-Saharan Africa: epidemiology, control and impact. Vet. Microbiol. 90, 111–134.

Megersa, B., Biffa, D., Abunna, F., Regassa, A., Godfroid, J., Skjerve, E., 2011. Seroprevalence of brucellosis and its contribution to abortion in cattle, camel, and goat kept under pastoral management in Borana, Ethiopia. Trop. Anim. Health Prod. 43, 651–656.

Mohseni, K., Mirnejad, R., Piranfar, V., Mirkalantari, S., 2017. A comparative evaluation of ELISA, PCR, and serum agglutination tests for diagnosis of Brucella Using human serum. Iran J. Pathol. Fall 12 (4), 371–376.

Nielsen, K., Gall, D., Smith, P., Bermudez, R., Moreno, F., Renteria, T., Ruiz, A., Aparicio, L., Vazquez, S., Dajer, A., Luna, E., Samartino, L., Halbert, G., 2005. Evaluation of serological tests for detection of caprine antibody to Brucella melitensis. Small Rumin. Res. 56, 253–258.

Olufemi, Olaolu T., Dantala, Danjuma B., Shinggu, Paul A., Dike, Umesi A., Otolorin, Gbeminiyi R., Nwuku, Jivini A., Baba-Onoja, Eyiojo B.T., Jatau, Tenmuso D., Amama, Francis I., 2018. Seroprevalence of brucellosis and associated risk factors among indigenous breeds of goats in Wukari, Taraba State, Nigeria. J. Pathog. 1–5, 2018.

Perrett, L.L., McGiven, J.A., Brew, S.D., Stack, J.A., 2010. Evaluation of competitive ELISA for detection of antibodies to Brucella infection in domestic animals. Croat. Med. J. 51 (4), 314–319.

Radostits, O., Gay, C., Hinchcliff, K., Constable, P., 2010. A Textbook of Disease of Cattle, Sheep, Pigs, Goats and Horses, 10th ed., pp. 674–762

Rahman, M.S., Faruk, M.O., Her, M., Kim, J.Y., Kang, S.I., Jung, S.C., 2011. Prevalence of brucellosis in ruminants in Bangladesh. Vet. Med. 56 (8), 379–385.

Rajala, Elisabeth Lindahl, Grahn, Cecilia, Ljung, Isabel, Sattorov, Nosirjon, Boqvist, Sofia, Magnusson, Ulf, 2016. Prevalence and risk factors for Brucella seropositivity among sheep and goats in a Peri-Urban Region of Tajikistan. Trop. Anim. Health Prod. 48, 553–558. https://doi.org/10.1007/s11250-015-0992-3.

Ran, X., Chen, X., Wang, M., Cheng, J., Ni, H., Zhang, X., Wen, X., 2018. Brucellosis seroprevalence in ovine and caprine flocks in China during 2000–2018: a systematic review and meta-analysis. BMC Vet. Res. 14, 2–9, 393L.

Tadesse, G., 2016. Brucellosis seropositivity in animals and humans in Ethiopia : a meta-analysis. PLoS Negl. Trop. Dis. 10 (10), 1–30.

Teferi, A., Yeshibelay, G., 2019. Sero-Prevalence of Caprine Brucellosis in Babile Woreda, Eastern Hararghe, Ethiopia. Dairy and Vet. Sci. J 10 (3), 1–5. https://doi.org/10.19080/JDVS.2019.10.555789.

Tegegn, Anteneh Hailu, Feleke, Aklilu, Adugna, Wesinew, Melaku, Simenew Keskes, 2016. Small ruminant brucellosis and public health awareness in two districts of Afar Region, Ethiopia. J. Vet. Sci. Technol. 7 (4) https://doi.org/10.4172/2157-7579.1000335.

Tekle, M., Legesse, M., Edao, B.M., Ameni, G., Mamo, G., 2019. Isolation and identification of Brucella melitensis using bacteriological and molecular tools from aborted goats in the Afar region of north-eastern Ethiopia. BMC Microbiol. 19 (1), 1–6.

Teklue, T., Tolosa, T., Tuli, G., Beyene, B., Hailu, B., 2013. Sero-prevalence and risk factors study of brucellosis in small ruminants in Southern Zone of Tigray Region, Northern Ethiopia. Trop. Anim. Health Prod. 45, 1809–1815.

Teshale, S., Muhie, Y., Dagne, A., Kidanemariam, A., 2006. Seroprevalence of small ruminant brucellosis in selected districts of Afar and Somali pastoral areas of Eastern Ethiopia: the impact of husbandry practice. Rev.Med. Vet. 157 (11), 557–563.

Teshome, D., Sori, T., Sacchini, F., Wieland, B., 2019. Epidemiological investigations of contagious caprine pleuropneumonia in selected districts of Borana zone, Southern Oromia, Ethiopia. Trop. Anim. Health Prod. 51 (3), 703–711.

Tharwat, Mohamed, Al-sobayil, Fahd, 2017. Ultrasonographic findings in goats with contagious caprine pleuropneumonia caused by Mycoplasma capricolum subsp. Capripneumoniae 1–8. https://doi.org/10.1186/s12917-017-1167-4.

Thrusfield, M., 2005. Veterinary Epidemiology, 3rd ed. Black well science ltd., UK, p. 233.

Tschopp, R., Gebregiorgis, A., Tassachew, Y., Andualem, H., Osman, M., Waqjira, M.W., Hattendorf, J., Mohammed, A., Hamid, M., Molla, W., Mitiku, S.A., Walke, H., Negron, M., Kadzik, M., Mamo, G., 2021. Integrated human-animal sero-surveillance of Brucellosis in the pastoral Afar and Somali regions of Ethiopia. PLoS Negl. Trop. Dis. 15 (8), 1–15.

Tsehay, H., Getachew, G., Morka, A., Tadesse, B., Eyob, H., 2014. Seroprevalence of small ruminants in pastoral areas of Oromia and Somali Regional States, Ethiopia. J. Vet. Med. Anim. Health 6, 289–294.

Wang, Q., 2012. Seroepidemiology Survey of Brucellosis, Foot-and-Mouth Disease and Hepatitis E in Sheep and Goats in Part Areas of Shandong. Master. Shandong Agricultural University. In Chinese.

Wubishet, Z., Sadik, K., Abdala, B., Mokonin, B., Getachew, T., Getachew, K., 2018. Small ruminant brucellosis and awareness of pastoralists community about zoonotic importance of the disease in Yabello districts of borena zone oromia regional state, Southern Ethiopia. Curr. Trends Biomed. Eng. Biosci. 12 (1), 1–6.

Yahaya, S.M., Bejo, S.K., Bitrus, A.A., Omar, A.M., Zuniat, Z., 2019. Occurrence of brucellosis in cattle and goats in Malaysia: a review. J. Dairy Vet. Anim. Res. 8 (2), 94–100.

Zubairu, A., Ardo, M., Mai, H., 2014. Seroprevalence of ruminant brucellosis in three selected local government areas of Taraba state. Sokoto J. Vet. Sci. 12 (1), 51–56.