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REGULAR ARTICLES

A study on seroprevalence of caprine brucellosis under three livestock production systems in southern and central Ethiopia

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Abstract Caprine brucellosis in Ethiopia is less commonly reported with limited information on the disease status in the country. The objective of this study was therefore to highlight the status of goat brucellosis in three distinctly different livestock production systems of southern and central Ethiopia. A total 3,315 goats of different age and sex, living with other animals in variable flock size, were sampled from 448 flocks raised in sedentary, pastoral and agro-pastoral production systems. Goats were bled aseptically and sera were collected for serial testing using Rose Bengal Plate Test as screening test and subsequently complement fixation test as confirmatory test. Questionnaire and laboratory data were analysed for descriptive, univariable and multivariable logistic regression analysis both at individual and flock level (STATA 11). The study revealed an overall animal level seroprevalence of 1.9 % (95 % CI 1.5, 2.4). In sedentary production system, the observed seroprevalence was 0.6 % (95 % CI 0.2, 0.9) while 1.9 % (95 % CI 1.1, 2.7) and 7.6 % (95 % CI 5.1, 10.1) were the proportion of seroreactors for agro-pastoral and pastoral production systems, respectively. The observed prevalence difference between the three production systems was statistically significant ($P<0.05$). At the flock level analysis, 11.2 % (95 % CI 8.2, 14.1) of the flocks sampled had at least one seropositive goat among themselves. Like individual level analysis, the highest prevalence of 32.5 % (95 % CI 21.9, 43.0) was recorded for pastoral production system, followed by agro-pastoral, 13.0 % (95 % CI 7.0, 19.0) and sedentary production system, 3.6 % (95% CI 1.3, 6.0). Accordingly, the odds of *Brucella* seropositivity were higher (OR=12.8) in pastoral followed by agro-pastoral (OR=4.0) in relation to sedentary production system. Large numbers of seroreactors were observed in adult age living in larger flocks with other livestock species. However, no difference was noted between male and female goats. Finally, the need for nationwide survey and subsequent designing and implementation of appropriate control measure is suggested.

Keywords Caprine brucellosis · Goats · Production systems · Risk factors · Seroprevalence

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Introduction

Small ruminant production is one of the important agricultural activities in Ethiopia. The estimated small ruminants' population is about 48.3 million (CSA 2011). Goats are

important in marginal agricultural land areas, especially in arid and semi-arid areas of Ethiopia (Aklilu and Catley 2009). This is primarily due to their better adaptation to harsh tropical environments (Mekasha 2007) and relative tolerance of feed scarcity in recurring droughts (Desta and Coppock 2004). However, as in other tropical areas, productivity of goats in Ethiopia has been hindered by low reproductive performance of breeding flock (Mekasha 2007).

The sufferance of animals with disease like brucellosis is one of the most recognized factors for low reproductive efficiency worldwide (Elzer et al. 2002; Ahmad 2005). Brucellosis in goats is primarily caused by *Brucella melitensis* and sporadic infections due to *Brucella abortus* and *Brucella suis* have also been reported. It is the disease of sexually matured animal with predilection for placentas, foetal fluids and testes of male animals (OIE 2008; Radostitis et al. 2007). The importance of brucellosis is reflected by its widespread distribution and impact on multiple animal species, including cattle, sheep, goats and pigs of sexually matured animals (McDermott and Arimi 2002).

Caprine brucellosis in sub-Saharan Africa is less commonly reported than brucellosis in cattle (McDermott and Arimi 2002). Similarly published information on goat brucellosis is scarce and is limited to few districts in Ethiopia (Yibeltal 2005; Ashagrie et al. 2011; Megersa et al. 2011). The lack of scientific information on the prevalence of this otherwise very important disease causing public health hazard and heavy economic loss warranted the proposed study to contribute for future control measure in Ethiopia.

Materials and methods

Study area

The study was conducted from November 2009 to May 2011 in three agro-ecologically distinct zones in Oromia and Southern Nation Nationalities Peoples (SNNP) Region. Geographically the area located between 36° 20′ to 41° 40′ E longitude and 3° 36′ to 9° 20′ N latitude. The altitude ranges from 1,500, Alaba area, to 2,275 masl around Ambo. The annual average rainfall was reported as low as 553 mm in Fentalle and 1,000 mm at Ambo area (Fig. 1; FDREMA 2012).

Study population

The study focused on indigenous goats of Ethiopia that include rift valley family (*Woito–Guji* and *Arsi-bale* breeds) and small east African family (central highland breeds) (ESGPIP 2009). Female goats above 4 months of age were eligible to participate in this study.

Study design and sampling

In this cross-sectional study, relevant epidemiological information like age, sex, flock size and presence of other livestock species were collected from three livestock production systems using semi-structured questionnaire format. Sample size was determined using a two-stage cluster sampling technique. To this effect, the sampling frame of the units was prepared using a list of

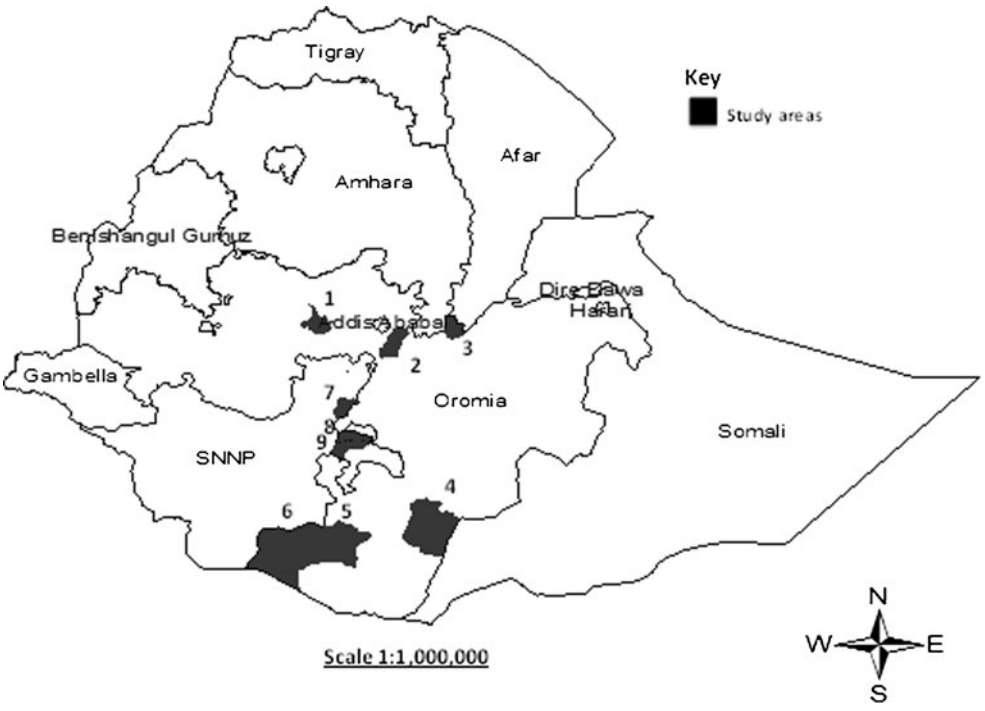

Fig. 1 Map of Ethiopia showing the study area in central and southern part of the country. *1* Ambo, *2* Ada, *3* Fentalle, *4* Liban, *5* Yabello, *6* Teltelle, *7* Alaba, *8* Boricha, *9* Dalle

peasant associations for each district. The actual sample size was calculated with the following predetermined parameters, i.e. confidence level (CL 95 %), desired level of precision (d) 5 %, expected cluster 30.5 % and individual prevalence 2.8 % (Mekuria 2007). The in-between cluster variance (VC) was estimated to be 0.093. Average number of goats per flock was estimated to be 10 in sedentary, 25 in agro-pastoral and 50 for pastoral production systems. The in-between cluster variance was determined by guessing the standard deviations, squaring the standard deviation results in variance components between clusters (Thrusfield 2005). Yet, higher in-between cluster variance was preferred due to the anticipated variations of the three production systems. For all systems, the samples were calculated separately and proportional allocation was made based on the districts' respective goat population using the following formulas: $g = \left[1.96^2\left(p_{\exp}\left(1-\mathrm{p}_{\exp}\right)+\mathrm{vc}\right)\right]/(nd^2)$ and $T_s = 1.96^2 g\, p_{\exp}(1-p_{\exp})/\left(gd^2 - 1.96^2\mathrm{vc}\right)$ where g is the number of clusters needed, $p_{\exp}$ is the expected prevalence, vc is in-between cluster variance, n is flock size, d is the desired level of precision and T_s is total sample size.

In the context of the present study, pastoral production system refers to livestock-dominated system in semi-arid area of Borana, Guji and Part of eastern Shoa zones with little or no crop agriculture and high mobility of animals. Agro-pastoral system is characterized by a high possession of large number of milk and meat animals with some crop-agriculture around the permanent homestead. The sedentary production system refers to mixed crop–livestock system in sub-humid areas of the northern SNNPR and central Oromia.

Serological screening and confirmation

The goats were bled at the jugular vein aseptically using sterile disposable needles and plain vacutainer tubes. The sera were separated by centrifugation (3,000 rpm, 4 °C and 10 min). The test serum (75–90 μl) was placed on a glass slide on to which Rose Bengal Plate Test antigen (RBPT) (25–30 μl) was added. After mixing with a plastic applicator and shaking for 3–4 min, the occurrence of agglutination was noted (Ferreir et al. 2003; Garin-Bastuji et al. 2006; OIE 2008). The agglutination test was repeated on those ambiguous results and positive sera were stored at −20 °C till further processed by complement fixation test for (CFT). These sera were kept at 4 °C for about 12 h before subjected to serial testing using CFT. Sera with a strong reaction [more than 75 % (3+) at a dilution of 1:5 or at least with 50 % (2+) at dilutions of 1:10 and 1:20] were classified as positive (OIE 2008).

Statistical analysis

The data obtained from the questionnaire and laboratory tests were stored in Microsoft excel spread sheet. Following coding and editing, the necessary statistical analysis was performed using STATA 11 (2009, Stata Corp. College station, Texas). Association of exposure variables with *Brucella* seropositivity was analysed using univariable logistic regressions. Non-collinear variables with P value ≤0.25 were all subjected to multivariable logistic regression analysis to construct the likely model ($P<0.05$). In line with this, all variables, except district which was dropped for production systems due to collinearity, were considered and the model was constructed by backward stepwise exclusion method. Finally, the model fitness was tested by Hosmer–Lemeshow goodness-of-fit test (Dohoo et al. 2003). The reliability of both individual and flock level model was assessed using receiver operating characteristic curve (ROC).

Results

The overall animal level seroprevalence was found to be 1.9 % (95 % CI 1.5, 2.4 %) while the flock level prevalence being 11.2 % (95 % CI 8.2, 14.1 %). Details are given on Table 1.

Among sampled goats of sedentary production system, 0.6 % (95 % CI 0.2, 0.9 %) of them was positive to the screening and confirmatory test. In pastoral system, the observed individual level seroprevalence was 7.6 % (95 % CI 5.1, 10.1 %), while the corresponding value for agro-pastoral production system was 1.9 % (95 % CI 1.1, 2.7 %). The proportion of seropositive goats recovered in adult age group (greater than or equal to 10 months) was higher than the young (less than 10 months) age category ($P=0.009$). Similarly, more number of goats from larger flocks reacted positive to the test compared to the smaller flock size in all production systems ($P=0.002$). A higher recovery of seroreactors was observed in flocks where other livestock species (cattle, sheep or camel) were kept together with goats ($P=0.002$). In terms of production systems, the proportions of seropositives were highest in pastoral system followed by agro-pastoral and sedentary production systems, respectively (Table 2).

In the univariate logistic regression analysis of individual animal, most of the risk factors considered demonstrated statistically significant difference between categories of aforementioned risk factors ($P<0.05$) to *Brucella* serostatus except sex (Table 2). However, variables with P value <0.25 from univariable analysis were all included in the final multivariable logistic model except district which was dropped for collinearity with production systems.

Table 1 Individual and flock level seroprevalence of caprine brucellosis in southern and central Ethiopia

Regions	Districts	Number of flocks sampled	Number of goats sampled	Flock level prevalence (95 % CI)	Individual level prevalence (95 % CI)
SNNPR	Dalle	59	444	6.8 (2.3–13.3)	1.1 (0.1–2.1)
	Boricha	74	444	1.6 (1.3–4.0)	0.2 (0.0–0.7)
	Alaba	29	442	3.6 (3.3–10.2)	0.2 (0.0–0.7)
Oromia	Ambo	62	314	1.6 (1.6–4.8)	0.3 (0.0–0.9)
	Ada	24	112	8.3 (3.0–19.7)	1.8 (0.8–4.3)
	Fentalle	105	540	30.5 (21.6–39.3)	7.9 (5.7–10.2)
	Liban	35	300	11.4 (7.1–22.2)	1.3 (0.2–2.6)
	Yabello	33	419	6.1 (2.2–14.4)	0.9 (0.1–1.9)
	Teltelle	27	300	11.1 (8.0–23.2)	1.0 (0.1–2.1)
Total		448	3,315	11.2 (8.2–14.1)	1.9 (1.5–2.4)

SNNPR Southern Nation Nationalities People Region

Accordingly, the multivariable logistic regression model, depicted adult age groups and larger flock size to be more at risk. The model further identified presence of other species of livestock in the flock, agro-pastoral and pastoral production systems to be more at risk than sedentary system. Assessment of model fit to the observed data showed insignificant difference between the observed and predicted values (Table 3).

At a flock level analysis, 3.6 % (95 % CI 1.3, 6.0) in sedentary, 13.0 % (95 % CI 7.0, 19.0) in agro-pastoral and 32.5 % (95 % CI 21.9, 43.0) of pastoral flocks had at least one seropositive goat per flock. A consistent result was more or less found in the final model, i.e. goats in agro-pastoral and pastoral production systems and large flock size were observed to be at a higher risk to acquire *Brucella* infection (Table 4).

Discussion

In this cross-sectional study, attempt was made to have an insight on to the status of caprine brucellosis in three livestock production systems practised in southern and central Ethiopia. The overall animal level seroprevalence was found to be 1.9 %. This finding is broadly comparable with 1.3 % and 2.4 % prevalence reported from Arsi and central highland of Ethiopia (Tekelay and Kassali 1990), 1.3 % from south Omo (Mekuria 2007) and 1.9 % from Somali regional state (Mihretab et al. 2011). It also complies with sub-Saharan Africa small ruminants' brucellosis status (McDermott and Arimi 2002). However, the reported low individual level prevalence in this study demands cautious interpretation when viewed in relation to spatial coverage and risk factors considered.

Among the risk factors considered, the adult age group, larger flock size, presence of other livestock (cattle, sheep or camel) in the flock and agro-pastoral and pastoral production systems were found to predispose goats to a higher risk of acquiring *Brucella* infection.

The finding of adult age category at higher risk is in agreement with reports from Afar (Ashenafi et al. 2007), Borana (Megersa et al. 2011), South Omo (Ashagrie et al. 2011) and Jigjiga (Mihretab et al. 2011). Despite the discrepancy in the demarcation of adult age, all the preceding authors reported the recovery of more seroreactors in adult

Table 2 Univariable logistic regression analysis of hypothesized risk factors for caprine brucellosis seropositivity at individual animal level

Factors	Category	Number of goats	Prevalence (95 % CI)	OR (95 % CI)	*P* value
Age	Young	566	0.4 (0.1–0.8)		
	Adult	2,749	2.3 (1.7–2.8)	6.5 (1.6–16.7)	0.009
Sex	Male	909	1.3 (0.6–2.1)		
	Female	2,406	2.2 (1.6–2.7)	1.6 (0.9–3.1)	0.120
Flock category	Small	1,267	0.9 (0.4–1.5)		
	Large	2,048	2.5 (1.9–3.2)	2.7 (1.4–5.1)	0.002
Other livestock spp. in the flock	Yes	1,471	2.9 (1.9–3.6)		
	No	1,844	1.2 (0.7–1.8)	2.3 (1.4–3.8)	0.002
Production systems	Sedentary	1,756	0.6 (0.2–0.9)		
	Agro-pastoral	433	1.9 (1.1–2.7)	3.3 (1.6–7.1)	0.002
	Pastoral	1,126	7.6 (5.1–10.1)	14.4 (7.0–29.5)	0.000

OR odds ratio, *CI* confidence interval (95 %), young (less than 10 months) and adult (10 month and above)

Table 3 Multivariable logistic regression analysis of hypothesized risk factors to seropositivity of *Brucella* infection in breeding goats of the study area

Risk factors	Level	Number of goats	Prevalence (95 % CI)	OR (95 % CI)	*P* value
Age	Young	566	0.4 (0.1–0.8)		
	Adult	2,749	2.3 (1.7–2.8)	4.5 (1.1–18.4)	0.039
Flock category	Small	1,267	0.9 (0.4–1.5)		
	Large	2,048	2.5 (1.9–3.2)	2.0 (1.0–3.1)	0.012
Other livestock spp. in the flock	No	1,844	1.2 (0.7–1.8)		
	Yes	1,471	2.8 (1.9–3.6)	2.2 (1.2–3.9)	0.008
Production systems	Sedentary	1,756	0.6 (0.2–0.9)		
	Agro-pastoral	433	1.9 (1.1–2.7)	3.9 (1.7–8.6)	0.001
	Pastoral	1,126	7.6 (5.1–10.1)	10.9 (5.3–22.7)	0.000

HLX^2=5.66, *P*=0.795, ROC= 0.7958; other livestock: sheep or cattle or camel

age groups. This could be due to the fact that brucellosis is essentially the disease of sexually matured animals and susceptibility increases with sexual maturity due to the influence of sex hormones and erythritol on the pathogenesis of brucellosis (Radostitis et al. 2007). The preponderance of more seroreactors in larger and mixed flocks had also been noted in several reports (McDermott and Arimi 2002; Kabagambe et al. 2001; Megersa et al. 2011). Hence, our higher serostatus observation is in fever of those authors who suggest increase in frequency and rate of contact due to the mentioned risk factors could increase *Brucella* prevalence (Arimi et al. 2005; Radostitis et al. 2007).

Pertinent to production systems, *Brucella* antigen seroreactors were more abundant in pastoral (7.6 %) followed by agro-pastoral (1.9 %) and sedentary (0.6 %) production systems. The difference observed between production systems were all statistically significant ($P<0.05$). Accordingly, goats in agro-pastoral production system were more than three times (OR=3.3) at risk of acquiring the infection compared to sedentary system due to higher chance of contact with other infected animals. The finding further depicts the infection risk to be far more serious for goats in pastoral system, as the risk increased more than ten times (OR=10.9) relative to sedentary counterpart. Indeed, the observed higher prevalence for pastoral production system is comparable to 5.8 % prevalence reports of Ashenafi et al. (2007) in Afar and 6.4 % seroprevalence in Borana (Mekuria 2007). However, the individual level seroprevalence is much lower than the 16.6 % and 18.4 % prevalence in Dalphagi and Mile district of Afar region, respectively (Teshale et al. 2006; Ali et al. 2007). This difference could be attributed to the study area difference, sample size or the type of diagnostic test used. In general, the recovery of higher proportion of seroreactors in agro-pastoral and pastoral production systems could be due to larger flock size and mingling of flocks in communal grazing areas and at watering points which have been suggested to be major factors responsible for high transmission risk of brucellosis in pastoral and agro-pastoral systems (Mangen et al. 2002; Arimi et al. 2005; Radostitis et al. 2007).

On the contrary, the low seroprevalence level observed in the sedentary livestock keeping areas could be due to the different livestock management practice which is characterized by smaller flock size and lower rate of contact that discourage the infection spread even in the absence of control program (McDermott and Arimi 2002). Despite the limitation of serological testes in providing conclusive evidence, we believe that higher seropositivity in pastoral system is due to natural infection as there has never been history of *Brucella* vaccination in the area.

In conclusion, the result suggests that seroprevalence of brucellosis in goats at animal level is low but not at flock level. Adult age group, larger flock size, presence of other livestock species (cattle, sheep and or camel) in the flock and goats in pastoral and agro-pastoral production systems are more exposed to *Brucella* infection than young age, small flocks and goats kept in sedentary production system.

Table 4 Flock level analysis of caprine brucellosis seroreactors in relation to hypothesized risk factors in studied districts of Oromia and SNNPR

Hypothesized risk factors	Level	Number of flocks	Prevalence (95 % CI)	OR (95 % CI)	*P* value
Flock category	Small	223	4.9 (2.1–7.8)		
	Large	225	17.4 (12.4–22.4)	4.1 (2.0–8.2)	0.000
Production systems	Sedentary	248	3.6 (1.3–6.0)		
	Agro-pastoral	123	13.0 (7.0–19.0)	4.0 (1.7–9.27)	0.001
	Pastoral	77	32.5 (21.9–43.0)	12.8 (5.6–29.0)	0.000

HLX^2=3.53, *P*=0.317, ROC= 0.7871

The other important finding of this work is the recovery of larger proportion of flocks harbouring one or more reactors which suggests the eminent danger of the disease occurrence at a larger scale in the future, if not intervened. In the light of this finding, we recommend that agent isolation and biotyping of the strains complemented with nationwide survey coverage is a worthwhile investment to provide the basis for the designing and implementation of control strategies at national level.

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