GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gscbps.gsconlinepress.com/

(RESEARCH ARTICLE)

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FARMERS' KNOWLEDGE, ATTITUDES AND PRACTICES AND RISK FACTORS FOR *BRUCELLA* SPP. INFECTION IN SMALL RUMINANTS IN THE MAMOU REGION, GUINEA

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GSC Biological and Pharmaceutical Sciences, 2026, 37(02), 110–122

Publication history: Received on 11 November 2026; revised on 16 November 2026; accepted on 18 November 2026

Article DOI: https://doi.org/10.30574/gscbps.2026.37.2.0386

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ABSTRACT

Small ruminant brucellosis is endemic in sub-Saharan Africa, but the factors sustaining *Brucella* infection in Guinean flocks are unknown. This study assessed farmers' knowledge, attitudes and practices (KAP) and the factors associated with *Brucella* spp. seropositivity in sheep and goats in the Mamou region, Guinea. A cross-sectional study was conducted from October 2023 to December 2025 in Dalaba, Mamou and Pita prefectures. Sera from 270 small ruminants (132 sheep, 138 goats) were tested by the Rose Bengal plate test and an indirect ELISA (reference test), and 270 farmers were interviewed. Analyses included Mantel-Haenszel adjustment for prefecture and species-specific multivariable logistic regression. Seroprevalence was 10.7% [7.6-15.0] (n = 29/270). Only 19.3% [15.0-24.4] of farmers were aware of zoonoses and 9.6% [6.7-13.7] of brucellosis, and none screened their animals. Introduction of animals with clinical signs (72.6%), retention of aborted females (80.7%) and carcass handling (73.3%) were common, while glove (21.1%) and mask (22.6%) use was low. Carcass handling remained associated with seropositivity after adjustment for prefecture (adjusted OR 4.45 [1.19-16.70]). In multivariable analysis, only age ⩾ 3 years was retained in sheep (OR 3.40 [1.01-11.47]) and only a history of abortion in goats (OR 26.97 [6.97-104.32]). No herd-level factor was associated

with seropositivity. Farmer education on the safe handling of carcasses and abortion products, screening of animals before introduction and management of aborted females should be prioritised within a One Health approach to curb brucellosis transmission in the region.

Keywords: Brucellosis; Sheep; Goats; Risk factors; Knowledge, Attitudes and practices; Guinea

1 INTRODUCTION

Small ruminant brucellosis is a bacterial zoonosis of considerable economic and public health importance in sub-Saharan Africa. The disease remains endemic in the region, with seroprevalence ranging from 0% to 40% in humans and livestock depending on the geographical area [1, 2, 3]. In small ruminants, a recent meta-analysis estimated the pooled seroprevalence at 4.9% across Africa and at 3.3% in West Africa [4]. In animals, infection mainly causes abortion, stillbirth, reduced fertility and decreased milk yield, which directly affect farmers' income [5, 6]. In Nigeria, annual economic losses due to small ruminant brucellosis were already estimated at USD 3.2 million in the mid-1990s [7]. In humans, brucellosis causes a chronic and debilitating febrile illness whose incidence is largely underestimated owing to the lack of appropriate diagnostic tools [8, 9]. In the extensive livestock systems of West Africa, transmission is favoured by close contact between species, shared pastures and watering points, and herd mobility [10].

The persistence of *Brucella* in flocks depends on both animal-level characteristics and farmers' practices. Age, sex and a history of reproductive disorders modulate the individual risk of infection. Natesan et al. [11] demonstrated this in India, where older age and a history of abortion were associated with seropositivity in small ruminants. At the herd level, several practices have been identified as drivers of infection maintenance, including the introduction of unscreened animals, the retention of females that have aborted, and the unprotected handling of abortion products [12, 13]. Similar findings have been reported in Ethiopia [14], Jordan [15] and Tajikistan [16]. However, these factors vary with husbandry systems and socio-cultural contexts, which limits the transferability of findings from one region to another.

In Guinea, brucellosis was first documented in cattle, with a mean seroprevalence of 6.9% in early surveys [17], followed by 8.7% in 2010 and 11.8% in 2020 [18, 19]. Data on small ruminants remain scarce and inconsistent. Akakpo et al. [20] reported a prevalence of 12.5% in sheep and goats, whereas the national survey conducted by Troupin et al. [21] between 2017 and 2019 using an indirect ELISA detected only 0.4% seropositive sheep and no seropositive goats, without analysing the factors associated with infection. More recently, a preliminary study by Camara et al. [22] in Dounet, Mamou region, found a seroprevalence of 27.8% by the Rose Bengal test. That study also showed that only 18.3% of farmers had any knowledge of the disease and that risky practices were widespread. Subsequent molecular investigations confirmed the circulation of *B. abortus* in sheep and goats in this region, where seroprevalence was 10.74% (n = 29/270) by I-ELISA and 55.17% (n = 16/29) of seropositive samples were confirmed positive by qPCR [23].

Which individual factors and husbandry practices actually drive seropositivity in these animals, however, had not yet been established. Such knowledge is needed to design control measures that fit local conditions: it helps to target at-risk animals and herds, to focus awareness messages on the practices that matter most and to set priorities for control within a One Health approach [24]. This study therefore set out to assess the knowledge, attitudes and practices of small ruminant farmers in the Mamou region regarding brucellosis, and to identify the individual and husbandry factors associated with *Brucella* spp. seropositivity in sheep and goats.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted from October 2023 to December 2025 in the administrative region of Mamou, Middle Guinea. The region covers 17,074 km^2 and had 803,483 inhabitants at the 2017 census [25]. It lies on the south-eastern foothills of the Fouta Djallon, 270 km from Conakry. The climate is tropical, with a dry season from November to May and a rainy season from June to October. Annual rainfall ranges from 650 to 2,400 mm and mean temperatures from 15 to 36 °C [26].

The study covered the three prefectures of the region (Dalaba, Mamou and Pita). In each prefecture, five sub-prefectures were selected on the basis of small ruminant farming activity: Dalaba-Centre, Kankalabé, Kébaly, Mafara and Mombeyah in Dalaba; Dounet, Kounkouré, Soyah, Timbo and Tolo in Mamou; and Pita-Centre, Bantignel, Brouwel Tappé, Donghol-Touma and Syntaly in Pita. Overall, 15 sub-prefectures were included, of which two were peri-urban (Dalaba-Centre and Pita-Centre) and thirteen rural (Fig. 1).

More than 80% of the population is engaged in agropastoral activities. In 2022, the regional livestock population was estimated at 422,315 sheep and 435,171 goats [27]. Livestock farming is mainly family-based and extensive or semi-intensive, with animals roaming freely throughout the year except during the cropping season. It is characterised by communal grazing, seasonal transhumance, shared watering points and frequent cohabitation of cattle, sheep and goats. Mamou prefecture hosts the main livestock markets of the region. These conditions favour contact between herds and the interspecies transmission of *Brucella* spp.

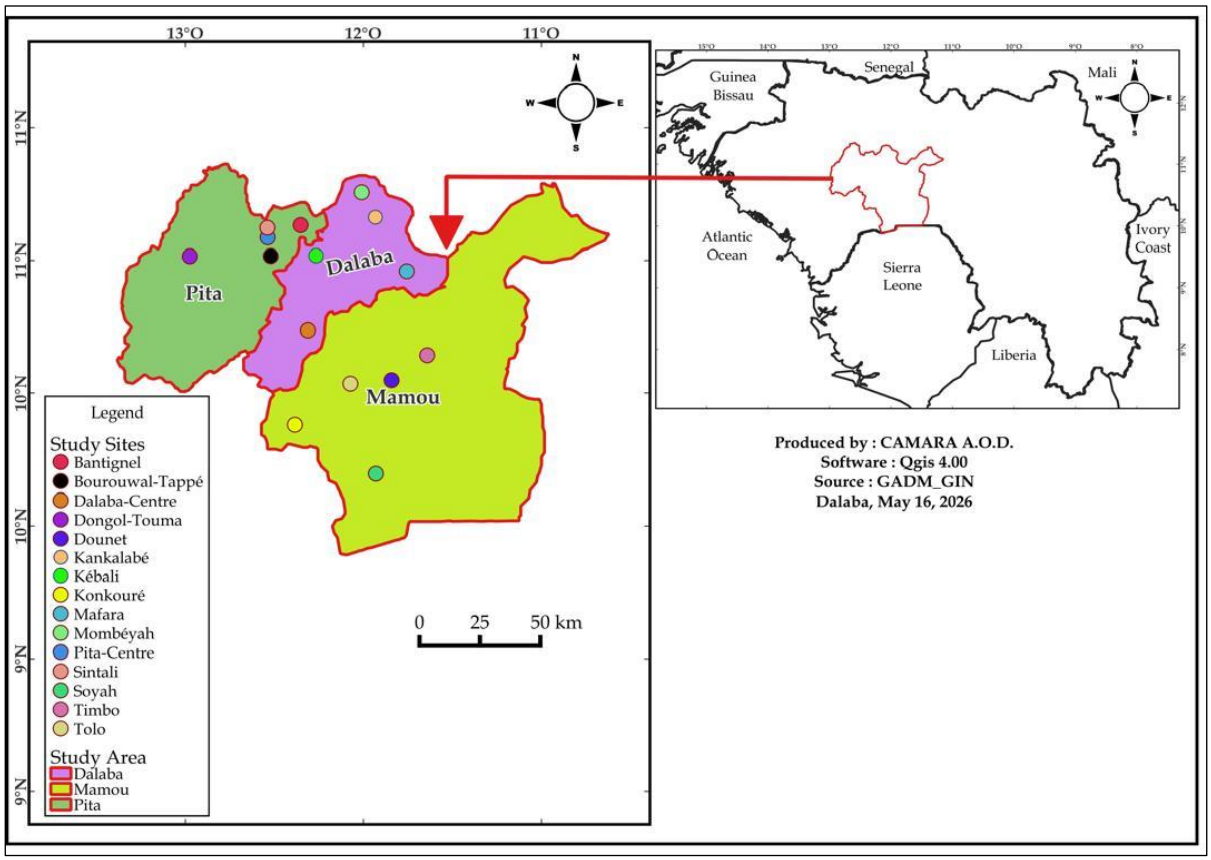


Figure 1: Location of the study area and of the sampled sub-prefectures in the Mamou region, Guinea.

2.2 Ethical considerations

The study protocol was approved by the Institutional Ethics Committee of ISSMV Dalaba (approval No. 22/2023/ISSMV/D/DG, dated 4 September 2023). Prior authorisation was obtained from the Regional Livestock Directorate of Mamou before data collection. Before each interview, the objectives and procedures of the study, as well as the absence of risk associated with participation, were explained to farmers in their local language. Informed consent was obtained from each farmer, in writing or orally in the presence of a witness for illiterate participants, before administration of the questionnaire and sampling of the animals. Participants were free to decline or withdraw at any time without consequence. Data were anonymised by assigning a code to each farmer and each animal, and were used solely for research purposes. Blood samples were collected by qualified veterinarians by jugular venipuncture in accordance with current animal welfare standards. Animals were gently restrained by the farmer or an assistant during sampling to minimise stress and pain. At the end of the study, each farmer was informed of the test results of their animals and received advice on brucellosis prevention.

2.3 Study design and sampling

An analytical cross-sectional study was conducted to relate the serological status of small ruminants to their individual characteristics, the characteristics of their herds and the practices reported by farmers. The study population consisted of sheep and goats aged at least one year raised in the three prefectures of the region. In each prefecture, herds were randomly selected from the registered small ruminant herds, subject to the farmer's consent. One animal was then randomly selected in each herd, without prior selection based on sex, age or clinical history.

In total, 270 small ruminants (132 sheep and 138 goats) from 270 herds were included, with 90 animals per prefecture: 45 sheep and 45 goats in both Mamou and Dalaba, and 42 sheep and 48 goats in Pita. The KAP survey was conducted among the owners of these 270 herds, with one farmer interviewed per herd.

2.4 Blood sampling and serum preparation

After restraint, 5 mL of blood was collected from each animal by jugular venipuncture into a sterile plain tube. Tubes were kept tilted in a cool box until transport to the laboratory to promote clot retraction. They were then centrifuged at 5,000 rpm for 10-15 min, and the serum was transferred into sterile tubes labelled with the animal's code and stored at −20 °C until analysis.

2.5 Laboratory analyses and definition of serological status

Sera were tested at the Laboratoire Vétérinaire de Conakry (LVC) using the Rose Bengal plate test (RBPT; IDvet, Grabels, France), followed by an indirect ELISA (I-ELISA) using the ID Screen® Brucellosis Serum Indirect Multi-species kit (IDvet, Grabels, France), according to the manufacturer's instructions and the protocols described by Camara et al. [23], in which the serological results and the diagnostic performance of both tests were reported. The I-ELISA was used as the reference test. An animal was considered seropositive when its I-ELISA result was positive.

2.6 Knowledge, attitudes and practices survey

In each sub-prefecture, a livestock officer or a community member accompanied the field team to the farmers. The survey targeted the owners of the herds from which the animals were sampled. Each farmer was interviewed once, face-to-face, by trained enumerators using a structured questionnaire translated orally into Pular or Soussou. Data were recorded directly on smartphones using the KoboCollect application and uploaded to the KoboToolbox platform. The questionnaire comprised three sections: (i) knowledge, covering awareness of zoonoses and of brucellosis in small ruminants; (ii) attitudes, covering the use of annual brucellosis screening and the fate of females that had aborted (retained in the herd, sold or slaughtered); and (iii) practices, covering the recent introduction into the herd of animals showing clinical signs (lameness, abortion, infertility, swollen testicles), assistance to females during abortion, the handling of animal carcasses (never, rarely or often), the use of gloves during handling and the use of a mask when removing manure.

2.7 Animal and herd data

At sampling, an individual record form was completed for each animal, documenting its identification, species, sex, age and clinical history as reported by the farmer. Age was estimated by dentition, supplemented by the farmer's information, and animals were classified into three age groups: 1 to < 2 years, 2 to < 3 years and ≥ 3 years. A herd record form was also completed for each herd, documenting the prefecture, location (rural or peri-urban), herd type (agropastoral or pastoral), husbandry system and presence of a nearby watercourse.

2.8 Study variables

The outcome variable was the serological status of the animal, coded as binary (seropositive or seronegative). Explanatory variables were grouped into three categories: (i) animal-level factors, namely sex, age group and clinical history (abortion, infertility, hygroma, orchitis or no clinical signs); (ii) herd-level factors, namely prefecture, location (rural or peri-urban), herd type and presence of a watercourse; and (iii) farmers' knowledge and practices, namely awareness of zoonoses and brucellosis, introduction of animals with clinical signs, fate of females that had aborted, assistance during abortion and handling of carcasses. The husbandry system could not be evaluated because all herds were managed extensively.

2.9 Statistical analysis

Data were entered into Microsoft Excel, double-checked and, where necessary, corrected by reference to the field forms. KAP responses were described as proportions with their 95% confidence intervals (95% CI), calculated using the Wilson method, and compared between prefectures using Pearson's χ^2 test or Fisher's exact test. Seroprevalence was calculated as the proportion of I-ELISA-positive animals, with its 95% CI, by species, prefecture and herd location.

Factors associated with seropositivity were analysed separately for sheep and goats, given the differences in husbandry and susceptibility to infection between the two species. In bivariable analysis, the association between each explanatory variable and seropositivity was assessed using Pearson's χ^2 test, or Fisher's exact test when an expected count was below 5. For each category, the proportion of seropositive animals was compared with that of all other categories of the same variable, and the strength of association was expressed as an odds ratio (OR) with its 95% CI. ORs were not calculated when a cell of the contingency table contained zero.

Variables associated with seropositivity at $p < 0.20$ were entered into a multivariable logistic regression model, built separately for each species by forward stepwise selection. Only variables significant at $p \leq 0.05$ (Wald test) were retained in the final model. The association between farmers' knowledge and practices and the seropositivity of their animals was estimated as crude ORs (conditional maximum likelihood estimate with exact 95% CI and Fisher's exact test) and as Mantel-Haenszel ORs adjusted for prefecture (Cochran-Mantel-Haenszel test), in order to control for

geographical differences in seroprevalence and practices. All analyses were performed using R version 4.1.2 [28], with a significance level of 5%.

3 RESULTS

Of the 270 small ruminants tested, 29 were seropositive by I-ELISA, as previously reported [23], giving an overall seroprevalence of 10.7% (7.6-15.0).

3.1 Farmers' knowledge, attitudes and practices regarding brucellosis

Table 1 summarises the knowledge, attitudes and practices of the surveyed farmers by prefecture. Only 19.3% (15.0-24.4) of farmers were aware of zoonoses. This awareness differed markedly between prefectures, reaching 50.0% (39.9-60.1) in Pita, against 6.7% (3.1-13.8) in Dalaba and 1.1% (0.2-6.0) in Mamou. Brucellosis itself was known to only 9.6% (6.7-13.7) of farmers, with no significant difference between Dalaba (14.4% [8.6-23.2]), Mamou (8.9% [4.6-16.6]) and Pita (5.6% [2.4-12.4]). No farmer reported annual screening of their animals.

Recent introduction of animals showing clinical signs into the herd was reported by 72.6% (67.0-77.6) of farmers. The practice was nearly universal in Pita, at 98.9% (94.0-99.8), and less common in Mamou, at 74.4% (64.6-82.3), and in Dalaba, at 44.4% (34.6-54.7). Overall, 20.0% (15.7-25.2) of farmers had already assisted a female during an abortion. This proportion reached 44.4% (34.6-54.7) in Dalaba, against 13.3% (7.8-21.9) in Pita and 2.2% (0.6-7.7) in Mamou. Females that had aborted were kept in the herd by 80.7% (75.6-85.0) of farmers, whereas 11.5% (8.2-15.8) slaughtered them and 7.8% (5.1-11.6) sold them. Retention differed significantly between prefectures, from 72.2% (62.2-80.4) in Mamou to 90.0% (82.1-94.6) in Pita, with Dalaba in between at 80.0% (70.6-87.0). Slaughter was most frequent in Mamou, at 17.8% (11.2-26.9), followed by Dalaba, at 11.1% (6.1-19.3), and Pita, at 5.6% (2.4-12.4).

Carcass handling was reported by 73.3% (67.8-78.3) of farmers, 46.3% (40.4-52.3) doing so rarely and 27.0% (22.1-32.6) often, with no difference between prefectures. Protective equipment was seldom used. Only 21.1% (16.7-26.4) of farmers wore gloves, a proportion that ranged significantly from 5.6% (2.4-12.4) in Mamou to 42.2% (32.5-52.5) in Dalaba, with 15.6% (9.5-24.4) in Pita. Likewise, 22.6% (18.0-27.9) of farmers wore a mask when removing manure. Mask use was significantly more frequent in Pita, at 40.0% (30.5-50.3), and Mamou, at 25.6% (17.7-35.4), than in Dalaba, at 2.2% (0.6-7.7) (Table 1).

3.2 Factors associated with *Brucella* seropositivity in sheep

Of the 132 sheep tested, 14 were seropositive (Table 2). Sheep aged 3 years or more were significantly more often seropositive than younger animals, with an OR of 3.40 [1.01-11.47] ($p = 0.039$). Both sheep with hygroma were seropositive ($p = 0.011$). Ewes with a history of abortion tended to be seropositive more often, with an OR of 9.67 [1.25-74.95] ($p = 0.056$), whereas sheep without any clinical sign had much lower odds of seropositivity, with an OR of 0.02 [0.00-0.13] ($p < 0.001$). Sex showed no significant association, the OR being 2.96 [0.63-13.89] ($p = 0.224$).

None of the herd-level variables was significantly associated with seropositivity in sheep. The OR was 1.52 [0.49-4.68] for Mamou ($p = 0.553$) and 1.22 [0.38-3.88] for Pita ($p = 0.766$), against 0.49 [0.13-1.87] for Dalaba ($p = 0.380$), and none of these differences was significant. Herd location, herd type and the presence of a nearby watercourse showed no association either ($p > 0.05$). Because all herds were managed extensively, the husbandry system could not be tested (Table 2).

Table 1: Knowledge, attitudes and practices of the surveyed farmers regarding brucellosis, by prefecture

Variable	Category	Mamou	Pita	Dalaba	Total
		n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]	n (%) [95% CI]
Awareness of zoonoses	Yes	1 (1.1) [0.2-6.0]	45 (50.0) [39.9-60.1]	6 (6.7) [3.1-13.8]	52 (19.3) [15.0-24.4]
	No	89 (98.9) [94.0-99.8]	45 (50.0) [39.9-60.1]	84 (93.3) [86.2-96.9]	218 (80.7) [75.6-85.0]
Awareness of brucellosis	Yes	8 (8.9) [4.6-16.6]	5 (5.6) [2.4-12.4]	13 (14.4) [8.6-23.2]	26 (9.6) [6.7-13.7]
	No	82 (91.1) [83.4-95.4]	85 (94.4) [87.6-97.6]	77 (85.6) [76.8-91.4]	244 (90.4) [86.3-93.3]
Annual brucellosis screening	Yes	0 (0.0) [0.0-4.1]	0 (0.0) [0.0-4.1]	0 (0.0) [0.0-4.1]	0 (0.0) [0.0-1.4]
	No	90 (100.0) [95.9-100.0]	90 (100.0) [95.9-100.0]	90 (100.0) [95.9-100.0]	270 (100.0) [98.6-100.0]
Recent introduction of animals with clinical signs (lameness, abortion, infertility, swollen testicles)	Yes	67 (74.4) [64.6-82.3]	89 (98.9) [94.0-99.8]	40 (44.4) [34.6-54.7]	196 (72.6) [67.0-77.6]
	No	23 (25.6) [17.7-35.4]	1 (1.1) [0.2-6.0]	47 (52.2) [42.0-62.2]	71 (26.3) [21.4-31.9]
	Does not know	0 (0.0) [0.0-4.1]	0 (0.0) [0.0-4.1]	3 (3.3) [1.1-9.3]	3 (1.1) [0.4-3.2]
Assistance to a female during abortion	Yes	2 (2.2) [0.6-7.7]	12 (13.3) [7.8-21.9]	40 (44.4) [34.6-54.7]	54 (20.0) [15.7-25.2]
	No	88 (97.8) [92.3-99.4]	78 (86.7) [78.1-92.2]	50 (55.6) [45.3-65.4]	216 (80.0) [74.8-84.3]
Fate of aborted females	Kept	65 (72.2) [62.2-80.4]	81 (90.0) [82.1-94.6]	72 (80.0) [70.6-87.0]	218 (80.7) [75.6-85.0]
	Sold	9 (10.0) [5.4-17.9]	4 (4.4) [1.7-10.9]	8 (8.9) [4.6-16.6]	21 (7.8) [5.1-11.6]
	Slaughtered	16 (17.8) [11.2-26.9]	5 (5.6) [2.4-12.4]	10 (11.1) [6.1-19.3]	31 (11.5) [8.2-15.8]
Use of gloves	Yes	5 (5.6) [2.4-12.4]	14 (15.6) [9.5-24.4]	38 (42.2) [32.5-52.5]	57 (21.1) [16.7-26.4]
	No	82 (91.1) [83.4-95.4]	76 (84.4) [75.6-90.5]	47 (52.2) [42.0-62.2]	205 (75.9) [70.5-80.6]
	Does not know	3 (3.3) [1.1-9.3]	0 (0.0) [0.0-4.1]	5 (5.6) [2.4-12.4]	8 (3.0) [1.5-5.7]
Handling of carcasses	Never	24 (26.7) [18.6-36.6]	21 (23.3) [15.8-33.1]	27 (30.0) [21.5-40.1]	72 (26.7) [21.7-32.2]
	Rarely	38 (42.2) [32.5-52.5]	45 (50.0) [39.9-60.1]	42 (46.7) [36.7-56.9]	125 (46.3) [40.4-52.3]
	Often	28 (31.1) [22.5-41.3]	24 (26.7) [18.6-36.6]	21 (23.3) [15.8-33.1]	73 (27.0) [22.1-32.6]
Use of a mask when removing manure	Yes	23 (25.6) [17.7-35.4]	36 (40.0) [30.5-50.3]	2 (2.2) [0.6-7.7]	61 (22.6) [18.0-27.9]
	No	67 (74.4) [64.6-82.3]	54 (60.0) [49.7-69.5]	88 (97.8) [92.3-99.4]	209 (77.4) [72.1-82.0]

95% CI: 95% confidence interval (Wilson method).

Table 2: Factors associated with *Brucella* seropositivity (I-ELISA) in sheep in the Mamou region

Variable	Category	Animals tested (n = 132) n (%)	Seropositive (n = 14) n (%)	OR (95% CI)	p-value
Age	1 to < 2 years	31 (23.48)	1 (7.14)	0.23 (0.03-1.80)	0.186
	2 to < 3 years	41 (31.06)	3 (21.43)	0.57 (0.15-2.18)	0.548
	≥ 3 years	60 (45.45)	10 (71.43)	3.40 (1.01-11.47)	0.039*
Sex	Female	91 (68.94)	12 (85.71)	2.96 (0.63-13.89)	0.224
	Male	41 (31.06)	2 (14.29)	0.34 (0.07-1.58)	
Clinical history	Abortion	4 (3.03)	2 (14.29)	9.67 (1.25-74.95)	0.056
	Infertility	1 (0.76)	1 (7.14)	NC	0.106
	Hygroma	2 (1.52)	2 (14.29)	NC	0.011*
	Orchitis	1 (0.76)	1 (7.14)	NC	0.106
	No clinical signs	124 (93.94)	8 (57.14)	0.02 (0.00-0.13)	< 0.001***
Prefecture	Mamou	45 (34.09)	6 (42.86)	1.52 (0.49-4.68)	0.553
	Dalaba	45 (34.09)	3 (21.43)	0.49 (0.13-1.87)	0.380
	Pita	42 (31.82)	5 (35.71)	1.22 (0.38-3.88)	0.766
Herd location	Rural	114 (86.36)	12 (85.71)	0.94 (0.19-4.60)	1.000
	Peri-urban	18 (13.64)	2 (14.29)	1.06 (0.22-5.19)	
Herd type	Agropastoral	100 (75.76)	11 (78.57)	1.19 (0.31-4.58)	1.000
	Pastoral	32 (24.24)	3 (21.43)	0.84 (0.22-3.21)	
Husbandry system	Extensive	132 (100.00)	14 (100.00)	NC	-
Nearby watercourse	Yes	90 (68.18)	9 (64.29)	0.82 (0.26-2.62)	0.766
	No	42 (31.82)	5 (35.71)	1.22 (0.38-3.88)	

CI: confidence interval; NC: not calculable; OR: odds ratio. p-values: χ^2 test, or Fisher's exact test when an expected count was < 5. **p < 0.05; **p < 0.01; ***p < 0.001.*

3.3 Factors associated with *Brucella* seropositivity in goats

Of the 138 goats tested, 15 were seropositive, all of them females, so that sex was significantly associated with seropositivity (p = 0.011) (Table 3). A history of abortion was strongly associated with seropositivity, with an OR of 26.97 [6.97-104.32] (p < 0.001), and 8 of the 13 does that had aborted tested positive. Goats without clinical signs, in contrast, had markedly lower odds, with an OR of 0.05 [0.01-0.16] (p < 0.001). Infertility, with an OR of 8.71 [0.52-147.15] (p = 0.206), and orchitis (p = 1.000) were not significantly associated with seropositivity. Likewise, no age group differed significantly from the others, the OR being 0.21 [0.03-1.68] for goats aged 1 to < 2 years (p = 0.191), 1.29 [0.43-3.86] for those aged 2 to < 3 years (p = 0.653) and 1.67 [0.57-4.90] for those aged ≥ 3 years (p = 0.347).

As in sheep, no herd-level factor reached significance. The OR was 1.44 [0.48-4.32] for Mamou (p = 0.565), 0.93 [0.30-2.90] for Pita (p = 0.901) and 0.73 [0.22-2.42] for Dalaba (p = 0.773). Goats from rural herds had an OR of 2.25 [0.28-18.20] compared with those from peri-urban herds (p = 0.692), a difference that was not significant. Herd type and the presence of a nearby watercourse were not associated with seropositivity (p > 0.05), and the husbandry system could not be tested (Table 3).

Table 3: Factors associated with *Brucella* seropositivity (I-ELISA) in goats in the Mamou region

Variable	Category	Animals tested (n = 138) n (%)	Seropositive (n = 15) n (%)	OR (95% CI)	p-value
Age	1 to < 2 years	32 (23.19)	1 (6.67)	0.21 (0.03-1.68)	0.191
	2 to < 3 years	48 (34.78)	6 (40.00)	1.29 (0.43-3.86)	0.653
	≥ 3 years	58 (42.03)	8 (53.33)	1.67 (0.57-4.90)	0.347
Sex	Female	101 (73.19)	15 (100.00)	NC	0.011*
	Male	37 (26.81)	0 (0.00)	NC	
Clinical history	Abortion	13 (9.42)	8 (53.33)	26.97 (6.97-104.32)	< 0.001***
	Infertility	2 (1.45)	1 (6.67)	8.71 (0.52-147.15)	0.206
	Orchitis	2 (1.45)	0 (0.00)	NC	1.000
	No clinical signs	121 (87.68)	6 (40.00)	0.05 (0.01-0.16)	< 0.001***
Prefecture	Mamou	45 (32.61)	6 (40.00)	1.44 (0.48-4.32)	0.565
	Dalaba	45 (32.61)	4 (26.67)	0.73 (0.22-2.42)	0.773
	Pita	48 (34.78)	5 (33.33)	0.93 (0.30-2.90)	0.901
Herd location	Rural	120 (86.96)	14 (93.33)	2.25 (0.28-18.20)	0.692
	Peri-urban	18 (13.04)	1 (6.67)	0.45 (0.05-3.61)	
Herd type	Agropastoral	92 (66.67)	10 (66.67)	1.00 (0.32-3.12)	1.000
	Pastoral	46 (33.33)	5 (33.33)	1.00 (0.32-3.12)	
Husbandry system	Extensive	138 (100.00)	15 (100.00)	NC	-
Nearby watercourse	Yes	90 (65.22)	10 (66.67)	1.07 (0.35-3.35)	0.901
	No	48 (34.78)	5 (33.33)	0.93 (0.30-2.90)	

CI: confidence interval; NC: not calculable; OR: odds ratio. p-values: χ^2 test, or Fisher's exact test when an expected count was < 5. **p < 0.05; **p < 0.01; ***p < 0.001.*

3.4 Association between farmers' knowledge and practices and *Brucella* seropositivity in small ruminants

Among the practices examined, carcass handling showed the strongest association with seropositivity (Table 4). Seroprevalence reached 13.6% (27/198) in animals of farmers who handled carcasses, whether rarely or often, against 2.8% (2/72) in animals of farmers who never did so, giving an OR of 5.50 [1.32-49.01] (p = 0.013). This association remained significant after adjustment for prefecture, with an adjusted OR of 4.45 [1.19-16.70] (p = 0.017). Seropositivity was also more frequent when farmers had recently introduced animals with clinical signs, with an OR of 3.61 [1.05-19.21] (p = 0.028), or kept aborted females in the herd, with an OR of 7.04 [1.10-295.08] (p = 0.038). Conversely, it was less frequent when farmers had assisted a female during abortion, the OR being 0.13 [0.00-0.81] (p = 0.014). None of these three associations remained significant after adjustment for prefecture, the adjusted ORs being 3.02 [0.89-10.21] (p = 0.059), 3.93 [0.90-17.16] (p = 0.050) and 0.29 [0.07-1.31] (p = 0.082), respectively.

Farmers' awareness of zoonoses and of brucellosis was not associated with the serological status of their animals, the ORs being 0.64 [0.16-1.99] (p = 0.618) and 1.09 [0.20-4.01] (p = 0.749), respectively (Table 4).

Table 4: Association between farmers' knowledge, attitudes and practices and *Brucella* seropositivity (I-ELISA) of small ruminants in the Mamou region

Variable	Category	Animals n (%)	Seropositive n (%)	Crude OR (95% CI)	p-value	Prefecture-adjusted OR (95% CI); p
Awareness of zoonoses	Yes	52 (19.26)	4 (13.79)	0.64 (0.16-1.99)	0.618	0.74 (0.23-2.35); p = 0.607
	No	218 (80.74)	25 (86.21)	1.55 (0.50-6.43)		
Awareness of brucellosis	Yes	26 (9.63)	3 (10.34)	1.09 (0.20-4.01)	0.749	1.18 (0.33-4.24); p = 0.802
	No	244 (90.37)	26 (89.66)	0.91 (0.25-5.08)		
Annual brucellosis screening	Yes	0 (0.00)	0 (0.00)	NC	-	NC
	No	270 (100.00)	29 (100.00)	NC		
Recent introduction of animals with clinical signs	Yes	196 (72.59)	26 (89.66)	3.61 (1.05-19.21)	0.028*	3.02 (0.89-10.21); p = 0.059
	No / does not know	74 (27.41)	3 (10.34)	0.28 (0.05-0.95)		
Assistance to a female during abortion	Yes	54 (20.00)	1 (3.45)	0.13 (0.00-0.81)	0.014*	0.29 (0.07-1.31); p = 0.082
	No	216 (80.00)	28 (96.55)	7.86 (1.24-328.77)		
Retention of aborted females in the herd	Yes	218 (81.04)	27 (96.43)	7.04 (1.10-295.08)	0.038*	3.93 (0.90-17.16); p = 0.050
	No (sold or slaughtered)	51 (18.96)	1 (3.57)	0.14 (0.00-0.91)		
Handling of carcasses	Rarely or often	198 (73.33)	27 (93.10)	5.50 (1.32-49.01)	0.013*	4.45 (1.19-16.70); p = 0.017*
	Never	72 (26.67)	2 (6.90)	0.18 (0.02-0.76)		

CI: confidence interval; NC: not calculable; OR: odds ratio. Crude OR: conditional maximum likelihood estimate with exact 95% CI; p-value: Fisher's exact test. Prefecture-adjusted OR: Mantel-Haenszel method; p-value: Cochran-Mantel-Haenszel test. **p < 0.05; **p < 0.01; ***p < 0.001*.

3.5 Multivariable analysis of risk factors for brucellosis in sheep and goats

Forward stepwise selection retained a single variable in each model. In sheep, animals aged 3 years or more had higher odds of seropositivity than younger animals, with an OR of 3.40 [1.01-11.47] (p = 0.048). In goats, does with a history of abortion had an OR of 26.97 [6.97-104.32] (p < 0.001). No other candidate variable remained significant once entered into the models (Table 5).

Table 5: Multivariable logistic regression of risk factors for *Brucella* seropositivity in sheep and goats in the Mamou region

Species	Variable	Category	OR (95% CI)	p-value
Sheep	Age	≥ 3 years	3.40 (1.01-11.47)	0.048*
Goats	Clinical history	Abortion	26.97 (6.97-104.32)	< 0.001***

CI: confidence interval; OR: odds ratio. Forward stepwise logistic regression (entry at p < 0.20 in bivariable analysis; retention at p ≤ 0.05); a single variable was retained in each model. **p < 0.05; **p < 0.01; ***p < 0.001*.

4 DISCUSSION

Farmers in the Mamou region knew little about brucellosis and frequently engaged in practices that favour its spread, while the seropositivity of their animals depended more on individual characteristics than on herd characteristics. Fewer than one farmer in five had heard of zoonoses, and only about one in ten knew of brucellosis, whatever the prefecture. These figures are lower than those reported by Wubaye et al. [14] in the Chiro and Burka Dhintu districts of Ethiopia, where 24.1% of small ruminant owners had heard of brucellosis and 21.5% of them knew it could be transmitted to humans. Poor knowledge has also been documented among livestock owners in Jordan [15] and small-scale dairy farmers in Tajikistan [16]. The contrast between Pita, where half of the farmers were aware of zoonoses, and Mamou and Dalaba, where fewer than 7% were, may reflect unequal access to veterinary services or awareness campaigns. This general awareness, however, did not translate into better knowledge of brucellosis. That no farmer screened their animals is hardly surprising, since brucellosis does not appear in the animal health records of the region and no national surveillance programme targets small ruminants [21].

Several of the reported practices offer obvious routes of transmission, both between animals and to humans. Nearly three-quarters of farmers, and almost all of those in Pita, had recently brought animals with clinical signs into their herds, an efficient way of introducing infection into uninfected flocks. Matope et al. [29] had already linked the purchase of animals of unknown origin to the introduction of brucellosis into smallholder herds in Zimbabwe, and Natesan et al. [11] found in India that buying animals at markets increased the odds of seropositivity by a factor of 1.70 in sheep and 3.50 in goats. Most farmers also kept females that had aborted. These females can shed *Brucella* at later parturitions and contaminate pastures, water and other animals [30]. Farmers themselves are exposed when they assist abortions or handle carcasses with little use of gloves or masks, a situation also described in Ethiopia, where 74.0% of farmers assisted parturition without protective equipment [14].

Carcass handling stood out as the practice most strongly associated with seropositivity, and it was the only one to remain significant after adjustment for prefecture, with an adjusted OR of 4.45. Animals whose owners handled carcasses had a seroprevalence nearly five times higher than those whose owners never did (13.6% vs. 2.8%). Carcasses, aborted foetuses and foetal membranes carry large quantities of *Brucella* and are a major source of environmental and pasture contamination [5, 30], so handling them without precautions can readily spread the bacterium within the herd. The introduction of animals with clinical signs and the retention of aborted females were also associated with seropositivity, but not after adjustment. Since these practices were unevenly distributed between prefectures, part of their apparent effect probably reflects other differences between study areas. The same reasoning applies to the inverse association with assistance during abortion: this practice was reported mainly in Dalaba, the least affected prefecture, and the association vanished after adjustment, so it should not be read as a protective effect. Finally, awareness of zoonoses or brucellosis made no difference to the serological status of the animals, which suggests that general awareness alone does not change the way farmers manage their herds.

In sheep, age was the only factor retained in the multivariable model, animals aged 3 years or more having 3.40-fold higher odds of seropositivity than younger ones. Natesan et al. [11] also observed that sheep older than 8 months had 2.52-fold higher odds of seropositivity, and Wubaye et al. [14] found that adult small ruminants had 5.6-fold higher odds of seropositivity than young animals. Older animals have been exposed for longer and have entered reproductive life, when the genital tract and udder become preferred sites of *Brucella* multiplication [5]. In goats, abortion dominated the picture, with an OR of 26.97 and 8 of the 13 does that had aborted being seropositive. Natesan et al. [11] reported an association of similar strength in goats, with an OR of 52.12, which exceeded the OR of 8.73 observed in sheep. This link is supported by the molecular results obtained in the same animals, in which 90% of the seropositive animals that had aborted were positive by IS*711* PCR, mostly for *B. abortus* [23]. The two sheep with hygroma, both seropositive, fit the same pattern, as hygroma is a classic sign of *B. abortus* infection [5]. All seropositive goats were female, in line with Wubaye et al. [14], who reported 3.4-fold higher odds in females than in males. This finding nevertheless calls for caution, because sex and abortion are confounded and the absence of seropositive males prevented sex from being entered into the multivariable model.

No herd-level factor was associated with seropositivity. Prefecture, herd location and herd type did not significantly change the odds of infection, unlike in the study by Natesan et al. [11], where rural sheep flocks had 6.37-fold higher odds of seropositivity. The uniformity of husbandry in the region, where all herds are kept extensively and frequently share pastures, may explain this result. The small number of seropositive animals in each species (14 sheep and 15 goats) also limited statistical power, as reflected in the width of the confidence intervals.

Some limitations should be acknowledged. The cross-sectional design does not allow causal inference. Clinical histories relied on farmers' declarations and may be affected by recall bias, and too few animals showed clinical signs to estimate ORs for infertility, hygroma and orchitis. These limitations do not alter the main message: widespread risky practices,

poor knowledge of the disease and a strong link between abortion and seropositivity call for farmer education, screening of introduced animals and safe disposal of abortion products in the Mamou region.

5 CONCLUSION

Small ruminant farmers in the Mamou region know very little about brucellosis and never screen their animals for it. Many of their routine practices, such as introducing animals with clinical signs, keeping aborted females, handling carcasses and rarely using protective equipment, favour transmission between animals and to humans. Knowledge and practices also differed markedly between Mamou, Pita and Dalaba.

Carcass handling was the practice most strongly associated with seropositivity, regardless of prefecture. At the individual level, age of 3 years or more in sheep and a history of abortion in goats were the main factors associated with infection, whereas no herd-level factor emerged in this uniformly extensive system. Three priorities follow for a One Health response: (i) educating farmers on how brucellosis spreads and on the safe handling of carcasses and abortion products, including the use of protective equipment; (ii) screening animals before they join a herd, especially those with a history of abortion; and (iii) managing abortion products and aborted females safely.

COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgements

The authors thank the General Directorate of the Institut Supérieur des Sciences et de Médecine Vétérinaire (ISSMV) de Dalaba for its institutional support, and the Laboratoire Vétérinaire de Conakry (LVC) for providing access to its facilities for the serological analyses. They are also grateful to the Regional Livestock Directorate of Mamou, to the livestock officers of the prefectures of Dalaba, Mamou and Pita, and to the farmers who agreed to take part in the study.

Funding information

This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Disclosure of conflict of interest

The authors declare that they have no competing or conflicting interests.

Authors' contributions

The original study was conducted by A.O.D.C., A.S.S., L.W.S. and A.O.S.D., who also supplied the data. The study was conceptualised by A.O.D.C. and A.S.S. Data were collected by A.O.D.C., A.S.S., N.K., A.C., F.D.M. and T.E.O. Laboratory analyses were performed by A.O.D.C., N.K. and L.K. Statistical analyses were performed by A.S.S. A.O.D.C. and A.S.S. drafted the manuscript. A.O.S.D., Y.K., C.D.K. and L.W.S. provided critical revision of the manuscript for important intellectual content. All authors have read and approved the final submitted manuscript.

Statement of ethical approval

This study was approved by the Institutional Ethics Committee of ISSMV Dalaba (No. 22/2023/ISSMV/D/DG, dated 4 September 2023). Prior authorisation was also obtained from the Regional Livestock Directorate of Mamou. Following this approval, farmers were contacted and the objectives and scope of the study were explained to them in their local language. They were free to accept or decline participation, with no negative consequences for their activities. Blood samples were collected by qualified veterinarians in accordance with current animal welfare standards.

Statement of informed consent

This study involved human participants in the form of a questionnaire survey administered to small ruminant farmers. Informed consent was obtained from each participant, in writing or orally in the presence of a witness for illiterate participants, before questionnaire administration and blood sample collection. Farmers were informed of the objectives and scope of the study beforehand and were free to accept or decline participation.

Availability of data

All relevant data generated during the study are included in this article. The datasets are available from the corresponding author upon reasonable request.

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