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REGULAR ARTICLES

Seroepidemiological characterization and risk factors associated with seroconversion to *Corynebacterium pseudotuberculosis* in goats from Northeastern Brazil

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Abstract

Goat breeding in the Northeast region of Brazil plays an important socioeconomic role. However, there are significant losses caused by sanitary deficits and infectious diseases, particularly caseous lymphadenitis (CL). Although CL is considered endemic in Northeastern Brazil, a comprehensive and up-to-date study of this disease in goat herds in this region is necessary. The objective of this study was to determine the farm-level and animal-level seroprevalences for the disease and to identify the possible risk factors that characterize CL in the caprine species of five Northeastern's states (Ceará, Piauí, Rio Grande do Norte, Paraíba, and Sergipe). A total of 2744 goat serum samples from 230 farms were collected between 2010 and 2012. The diagnosis of *Corynebacterium pseudotuberculosis* infection was performed using the indirect ELISA technique. Farm-level and animal-level seroprevalences were 87.8% and 30.3%, respectively, suggesting that *C. pseudotuberculosis* is widespread in goat herds of the Northeast region. The risk factors were as follows: absence of forage silage (odds ratio = 5.39), not separating animals by sex (odds ratio = 4.16) or by age (odds ratio = 6.30), not replacing old goat breeders (odds ratio = 7.80), and non-treatment of CL lumps prior to spontaneous rupture (odds ratio = 10.34). This study supports the idea that caseous lymphadenitis is widely disseminated in goats from Northeastern Brazil and based on the risk factor analysis attention should be given to the need to establish adequate control measures, such as incision and early drainage of superficial abscesses, quarantine and elimination of affected animals, periodic inspection of the herd, non-introduction of infected animals, and early disposal of animals with recurrent CL.

Keywords Caseous lymphadenitis · Goats · Risk factors · Northeast Brazil

Introduction

Goat breeding is one of the oldest livestock practices in Brazil and is distributed across the five major regions of the country. However, it is predominantly located in the Northeast, with more than nine million goats (equivalent to 93.0% of the national herd) (IBGE 2016). Goat breeding in the Northeast of Brazil could be seen in more than one million rural establishments, and it plays an important socioeconomic role, whether directly used for food or for income (SEBRAE 2009; Teixeira 2009; Moreira and Guimarães 2011).

Evolving from previous subsistence farms, the caprine livestock production chain currently represents an economic activity of strategic importance in the Northeast, directed towards the production of leather, meat, milk, and its derivatives (SEBRAE 2009; IBGE 2016). However, the rural nature and rapid expansion of this activity in the Northeast region, which occurred in the last decade, have aggravated sanitary deficits in the production chain (Alencar et al. 2010; Seyffert et al. 2010; Guimarães et al. 2011b). High rates of morbidity and mortality of animals and losses caused by infectious diseases have been observed (Pinheiro et al. 2000; Medeiros et al.

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2005). Caseous lymphadenitis (CL), which is caused by *Corynebacterium pseudotuberculosis*, is characterized by the formation of abscesses in the superficial and internal lymph nodes as well as the internal organs of small ruminants (Faccioli-Martins et al. 2014). The losses brought by this disease are related to its high incidence, the difficulty of detection and control, and the morbidity caused by the impairment of vital functions in the affected animals, causing decreased weight gain, goat milk production, and skin integrity. The increase of treatment and disposal costs for diseased animals and their ultimate deaths also cause significant economic damages (Brown et al. 1986; Panton et al. 1994). In Brazil, it is estimated that most goats and sheep are affected (Alves et al. 2007).

In general, CL has always been endemic in the areas of Brazil where there is an increased focus in the breeding of small ruminants. Thus, the relevance of CL cannot be dismissed especially with the increased participation of goats in contributing towards products from national livestock. Consequently, the economic impact of the disease should not be minimized (Guimarães et al. 2009; Seyffert et al. 2010; Carmo et al. 2012; Faccioli-Martins et al. 2014). The increase in goat breeding in some states coupled with the lack of attention given to CL by breeders and authorities (Brown et al. 1986; Souza et al. 2011) makes this situation even more worrying. This demonstrates that a more comprehensive and current study of CL in Brazilian goats is necessary.

Some serological studies have been carried out in Brazil regarding diseases that affect small ruminants, but these had limited effects due to the lack of both inputs and infrastructure necessary to the realization and use of the recommendations given. As there is a need to determine epidemiological indicators of CL in goat herds of the Northeast region, the objective of this study was subsequently to determine the farm-level and animal-level seroprevalences for the disease as well as to identify the possible risk factors that characterize CL in the caprine species in five states of the Northeast region of Brazil using a planned sampling.

Material and methods

Study area

The Northeast region of Brazil covers an area of more than 1.5 million km^2 (18% of Brazil), is located below the equator, and has a predominantly semi-arid climate. It is also a typical Caatinga biome. It is divided into four sub-regions (Zona da Mata, Agreste, Sertão, and Meio-Norte) and is composed of nine states: Bahia, Ceará, Pernambuco, Paraíba, Rio Grande do Norte, Piauí, Maranhão, Alagoas, and Sergipe (ASA Brasil 2017; IBGE 2016).

Sampling

Adults and young goats of both sexes from rural farms of micro-regions with significant goat population density were used in five Northeastern States: Paraíba, Rio Grande do Norte, Ceará, Piauí, and Sergipe. The owners' provided their consent to the study. The inclusion of the farm was through probabilistic sampling: this was done through a random draw of previously listed farms, through lists provided by associations of breeders, state sanitary defense agencies, the agriculture secretariat, and Brazilian Service to Support Micro and Small Enterprises (SEBRAE). The minimum number of farms to be visited was calculated using the formula for simple random samples (Thrusfield 2007). The following parameters were considered: a farm-level expected prevalence of 98% (Seyffert et al. 2010), a sample error of 5%, and a confidence level of 95%. For these parameters, we needed a sample size of 30 farms per state; however, the final sample size consisted of 62 farms in Paraíba, 56 in Rio Grande do Norte, 37 in Ceará, 48 in Piauí, and 27 in Sergipe. The minimum number of animals to be examined within each herd was estimated in order to allow its classification as a positive farm. For this purpose, the concept of aggregate sensitivity and specificity was used (Dohoo et al. 1996). For the calculations, the following values were adopted: 93.5% and 100% (Carminati et al. 2003) for the sensitivity and specificity, respectively, of the indirect ELISA and 78.9% (Seyffert et al. 2010) for the intra-farm estimated prevalence. Herdacc version 3 software (Jordan 1995) was used during this process, and the sample size was selected so that the herd sensitivity and specificity values would be $\geq 90\%$. Therefore, 10 animals were sampled in herds with up to 99 goats; 15 animals were sampled in herds with 100 or more goats; and all animals were sampled in those with up to 10 goats. The selection of the animals within the herds was systematic, which involves the selection of sampling units at equal intervals, the first animal being selected randomly. For example, if one animal in every 100 were required, the first animal would be selected randomly from the first 100. If this were animal 63, then the sample would comprise animals, 63, 163, 263, 363, and so on (Thrusfield 2007).

Blood samples were collected from 2744 goats from 230 rural farms in 62 municipalities of the five states (Fig. 1). The samples were collected between 2010 and 2012 and between the months of May and July. Following proper animal restraint techniques and local asepsis with iodinated alcohol solution, blood samples were collected by jugular vein puncture using disposable, sterile needles, one for each animal, and placed in vacuum tubes without anticoagulant. After collection, the blood samples were sent to the Laboratory of Bacteriology of Embrapa Goats and Sheep/CNPC, Sobral, CE. Tubes with the blood samples were kept at room temperature until complete clot retraction with subsequent centrifugation was performed. Next, the samples were separated, placed in

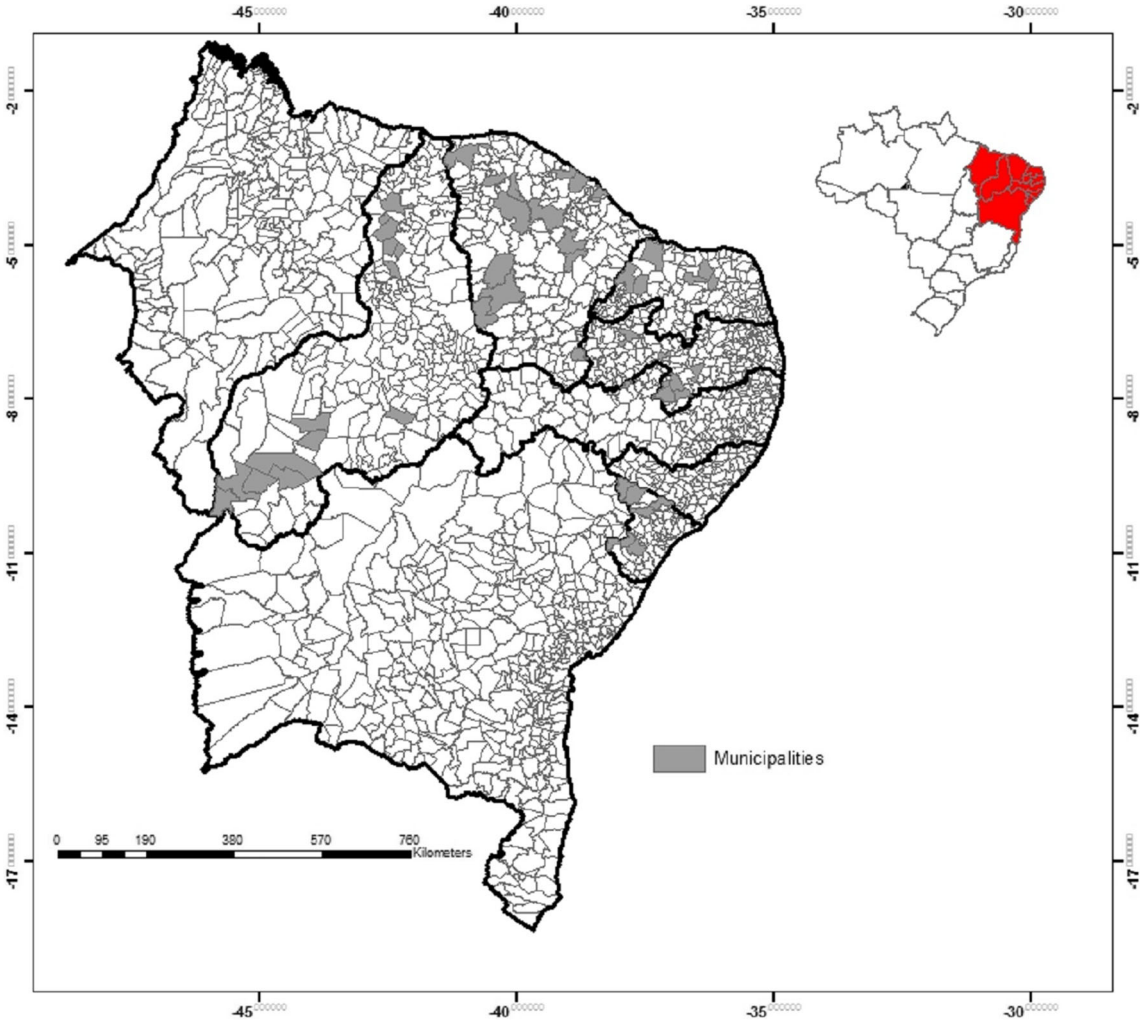

Fig. 1 Geographic distribution of investigate municipalities in five states of Northeastern Brazil (Paraíba, Rio Grande do Norte, Ceará, Piauí, and Sergipe)

microtubes previously identified, and stored at − 20 °C for later use in serological tests.

Serological diagnosis

For the indirect ELISA tests, the methodology described by Carminati (2005), with modifications developed by the Brazilian Agricultural Research Corporation (Embrapa Goats and Sheep, CNPC, Sobral, CE) was used. The antigen was produced from a culture of *C. pseudotuberculosis* of ovine strain 02/2014 (BRM 029971) steeped 72 h in brain heart infusion (BHI Broth, Acumedia®) broth added with 0.1% Tween 80 made according to Paule et al. (2004). This test had a sensitivity of 93.5% and a specificity of 99.0%.

Each 96-well flat bottom polystyrene microplate (Maxisorp®-Nunc) was sensitized with *C. pseudotuberculosis* antigen, diluted in 0.05 M carbonate/bicarbonate buffer pH 9.6, and incubated at 4 °C overnight. After two washes with a saline wash solution (NaCl, Tween 20, Sigma-Aldrich®), the microplate was blocked with blocking solution (PBS, casein 2%) (Casein-Sigma-Life Science®) then incubated at 37 °C for 45 min. The test sera were pre-diluted in 1:100 incubation buffers (PBS, Casein 0.25%, Tween 20), then added to the microplate with subsequent incubation at 37 °C for 30 min. After a five-wash washout sequence, we added rabbit immunoglobulin anti-IgG of goat (whole molecule), peroxidase-conjugated (Sigma-Aldrich®), diluted in incubation buffer, with a subsequent incubation at 37 °C for 30 min. Five washings were then performed in wash solution and incubated with revealing solution of OPD and hydrogen peroxide in pH 5.0 (OPD, P1526, Sigma-Aldrich®) citric acid solution for 15 min at room temperature and sheltered from light. The reaction was then terminated by the addition of H_2SO_4 (Exodo Cientifico®) 1:20, and the plate was afterward immediately taken to the ELISA reader (Thermo Scientific, Multiscan FC Microplate Photometer N/S 357-906416) and read using a 490-nm filter.

Epidemiological questionnaires and data analysis

A structured questionnaire with 62 questions, including closed questions, was designed to obtain information on (a) management practices, (b) the technological profile of the property, (c) health aspects of the herd, and (d) herd structure and composition. The questionnaires were given for answering to the owner or person in charge of the herd by one of the study authors concurrent with the herd blood collection in farms visited. The analyzed variables and respective categories were as follows: owner's education level (up to primary school/up to secondary school/higher education), area of the farm (≤ 155 ha/> 155 ha), presence forage silage (no/yes), time of experience in raising goats (≤ 20 years/> 20 years), sale of animals (no/yes), sale of produced milk (no/yes), keeping the animals in shelter at night (no/yes), separation of animals by sex (no/yes), separation of animals by age (no/yes), replacement of old goat breeders (no/yes), purchasing of female goats (no/yes), caseous lymphadenitis present in the herd (no/yes), foot rot present in the herd (no/yes), screwworm present in the herd (no/yes), antiparasitic therapy of all animals (no/yes), cut and disinfection of the goat's navel immediately after birth (no/yes), allowing the young goat to be nursed by mother after birth (no/yes), cleaning and treating wounds of animals (no/yes), draining the lump when present (no/yes), treatment of CL lumps prior to spontaneous rupture (no/yes), using lime at the entrance of installations during winter (no/yes), performing clinical evaluation of acquired animals (no/yes), performing quarantine of acquired animals (no/yes), requesting diagnostic tests prior to animal purchasing (no/yes), vaccination of animals (no/yes), making improvements in the areas of pasture in the Caatinga of the farm (no/yes), management system (extensive/semi-intensive/intensive), animals with free access to water sources (no/yes), animal identification (no/yes).

The risk factor analysis was performed at the farm-level and conducted in two steps: univariable and multivariable analyses. The variables were organized for presentation in ascending or descending order regarding the scale of risk. When necessary, these variables were re-categorized. The lower-risk category was considered the basis for comparison for the other categories. An initial exploratory analysis of the data (univariable) was conducted for selection of variables with $P \leq 0.2$ by the chi-square test or Fisher's exact test (Zar 1999); subsequently, the variables that passed this cut-off were utilized for logistic regression (Hosmer and Lemeshow 2000). The fit of the final model was verified with the Hosmer and Lemeshow test, and collinearity between independent variables was verified by a correlation analysis; for those variables with a strong collinearity (correlation coefficient > 0.9), one of the two variables was excluded from the multiple analysis according to the biological plausibility (Dohoo et al. 1996). Confounding was assessed by monitoring the changes in the model parameters when adding new variables. If substantial changes (i.e., higher than 20%) were observed in the regression coefficients, this was considered as indicative of confounding. The calculations were performed by using SPSS software version 20.0. A chi-square test with a significance level of 5% was used to compare the seropositivity frequencies among the categories of animals (breeders, matrices, and young). The analyses were carried out with the BioEstat 5.03 program (Ayres et al. 2007).

Results

According to data obtained in the present study, 202 (87.8%; 95% CI = 82.9–91.4) of the 230 investigated farms had at least one goat seropositive for *C. pseudotuberculosis*. The prevalence by state is presented in Table 1. Of the 2744 goats evaluated, 832 (30.3%; 95% CI = 28.6–32.0%) were seropositive for CL. Among the states, there were no significant differences in seropositivity frequencies between matrices and breeders, at 41.6% and 37.3%, respectively. Nevertheless, the frequencies for young goats were lower than those obtained for adults ($P < 0.001$) (Table 2).

Table 3 shows the variables considered for the univariable analysis of risk factors associated with seroconversion for *C. pseudotuberculosis* ($P \leq 0.2$). The final logistic regression model revealed that the absence of forage silage (odds ratio = 5.39, 95% CI = 1.36–21.26, $P = 0.016$), not separating animals by sex (odds ratio = 4.16, 95% CI = 1.21–14.23, $P = 0.023$) or by age (odds ratio = 6.30, 95% CI = 1.60–24.72, $P = 0.008$), not replacing old goat breeders (odds ratio = 7.80, 95% CI = 1.31–46.36, $P = 0.024$), and non-treatment of CL lumps prior to spontaneous rupture (odds ratio = 10.34, 95% = 1.26–84.60, $P = 0.029$), were identified as risk factors associated with the CL occurrence in the herds (Table 4). The final model presented good fit (the Hosmer and Lemeshow chi-square = 2.575; degrees of freedom = 4; $P = 0.630$).

Discussion

The high frequency of seropositive farms (87.8%; 202/230) shows that CL is widespread in goat herds in the Brazilian Northeast, with all the five states presenting a very high CL occurrence. The questionnaire analysis revealed that 89.5% of the farmers reported CL as present in the herd. More than half of the breeders (52.2%) claim to routinely treat this disease in their herds. However, animals with pathognomonic signs for CL were observed to be inadequately treated. Disease identification, abscess treatment by surgical incision, drainage, and cauterization with 10% iodine tincture, adequate animal isolation until total wound healing, and subsequent elimination of the recurrent CL animals are all essential conditions towards

Table 1 Occurrence of positive farms (foci) and seropositive animals for *Corynebacterium pseudotuberculosis* infection in goats from Northeastern Brazil

State	Occurrence by herd			Occurrence by animals		
	No. of herds	No. of positive farms (%)	95 CI (%)	No. of animals	No. of positive animals (%)	95 CI (%)
Piauí	48	41 (85.4)	72.8–92.7	582	209 (35.9)	32.1–39.8
Rio Grande do Norte	56	52 (91.2)	83.0–97.1	675	225 (33.3)	29.8–36.9
Paraíba	62	59 (95.1)	86.7–98.3	741	216 (29.1)	26.0–32.5
Sergipe	27	21 (77.7)	59.2–89.3	311	69 (22.1)	17.9–27.1
Ceará	37	29 (78.3)	62.8–88.6	435	113 (25.7)	22.1–30.3
Total	230	202 (87.8)	82.9–91.4	2744	832 (30.3)	28.6–32.0

the control of the disease. The haphazard elimination of the caseous contents of abscesses in the environment is the main way of transmission of *C. pseudotuberculosis*. In addition, the presence of carrier animals is the main source of herd reinfection (Alves et al. 2007; Faccioli-Martins et al. 2014).

The information provided by the owners in the epidemiological questionnaire regarding the presence of the disease in the herds agrees with the serology occurrence obtained from the farms. This demonstrates that owners are aware of the presence of CL in their herds, but generally do not implement methods of effective prevention and control of this disease. The absence of a specific CL control program, together with deficiencies of information and education in the breeders, has negatively influenced their knowledge and competence with regard to controlling *C. pseudotuberculosis* spread in the herds (Guimarães et al. 2009). This creates a serious issue as workers who deal directly with these animals ignore their risk of contamination. By ignoring the zoonotic potential of *C. pseudotuberculosis*, there is a greater risk of spreading the disease.

Of the goats evaluated, 832 were positive for *C. pseudotuberculosis* resulting in a seroprevalence of 30.3%. The occurrence in adult animals was much higher than that obtained in young goats ($P < 0.001$), 41% and 9.4%, respectively, with a higher occurrence of positive matrices in relation to breeders, 41.6% compared to 37.3% (Table 2). This situation can be explained by females residing longer in the herds, due to their milk production and reproductive activity. Further, the lower concentration of males in the herds can be explained by the fact that they are usually slaughtered young, with only a few animals selected for breeding. The incubation period of *C. pseudotuberculosis* is long, as it may take up to 180 days (Nassar 2009; Ribeiro 2009). Because of this, most of the young male population may be slaughtered before the expression of pathognomonic signs of CL. The adults kept on the property, on the other hand, are more predisposed to CL because of their longer exposure time to the agent. As observed in Seyffert et al. (2010) and Guimarães et al. (2009), it is important to control the population of older animals in small ruminant livestock to prevent CL occurrence.

The absence of forage silage as a risk factor suggests the importance of auxiliary strategic control methods against CL to reduce environmental contamination by the agent. It is in extensive conventional grazing that small ruminants are more exposed to *C. pseudotuberculosis*, which is spread from the abscesses of carriers. Under these conditions, feeding the herd with silage would help to limit the infection of these animals, as this restricts their contact with the bacterial agent during grazing. Possible entry ports for the agent, such as superficial lesions caused by typical vegetation in the region (Caatinga), and oral cavity lesions caused by ingestion of coarser fodder may favor the endemic maintenance of CL in the region

Table 2 Occurrence of positive farms (foci) and seropositive animals for *Corynebacterium pseudotuberculosis* infection in goats from Northeastern Brazil, according to animal categories

States	Breeders			Matrices			Young		
	Total	Positive (%)	95% CI (%)	Total	Positive (%)	95 CI (%)	Total	Positive (%)	95 CI (%)
Piauí	94	38 (40.4)	31.7–50.5	302	150 (49.6)	44.0–55.2	186	21 (11.2)	7.5–16.6
Rio Grande do Norte	87	40 (45.9)	35.9–56.4	346	163 (47.1)	41.9–52.3	242	22 (9.0)	6.1–13.3
Paraíba	63	19 (30.1)	20.2–42.3	451	172 (38.1)	33.7–42.7	227	25 (11.0)	7.5–15.7
Sergipe	22	8 (36.3)	19.7–57.0	150	51 (34.0)	26.9–41.9	139	10 (7.1)	3.9–12.7
Ceará	42	10 (23.8)	13.4–38.5	260	93 (35.7)	30.9–31.9	133	10 (7.5)	4.1–13.2
Total	308	115 (37.3)	32.7–42.8	1509	629 (41.6)	39.2–44.1	927	88 (9.4)	7.7–11.5

Table 3 Univariable analysis of risk factors associated with infection by *Corynebacterium pseudotuberculosis* in goats raised in Northeastern Brazil

Variables	Exposed/ negatives	Exposed/ positives	*P**
Owner's education level—up to primary school	10/28	112/202	0.013
Area of the farm (≤ 155 ha)	17/28	156/202	0.096
Absence of forage silage	21/28	195/202	< 0.001
Time of experience in raising goats (≤ 20 years)	18/28	162/202	0.095
To sale animals	10/28	119/202	0.034
To sale the produced milk	20/28	197/202	< 0.001
Keep the animals in shelter at night	18/28	178/202	0.003
Not separating animals by sex	12/28	182/202	< 0.001
Not separating animals by age	14/28	188/202	< 0.001
No replacing old goat breeders	26/28	155/202	0.088
No purchasing of female goats	10/28	144/202	< 0.001
Caseous lymphadenitis is present in the herd	21/28	185/202	0.015
Foot rot is present in the herd	16/28	152/202	0.072
Screwworm is present in the herd	16/28	184/202	< 0.001
To perform antiparasitic therapy of all animals	27/28	168/202	0.090
Cut and disinfect the goat's navel immediately after birth	23/28	111/202	0.011
Not allowing young goat to be nursed by the mother after birth	9/28	144/202	< 0.001
Not cleaning and treating wounds of animals	8/28	110/202	0.018
Drain the lump when present	19/28	102/202	0.128
Non-treatment of CL lumps prior to spontaneous rupture	27/28	122/202	< 0.001
Not using lime at the entrance of installations during winter	16/28	180/202	< 0.001
Not performing clinical evaluation of acquired animals	8/28	139/202	< 0.001
Not performing quarantine of acquired animals	14/28	154/202	0.007
Not requesting diagnostic tests prior to animal purchasing	21/28	194/202	0.001
Not vaccinating animals	16/28	195/202	< 0.001
Not making improvements in the areas of pasture in the Caatinga of the property	23/28	193/202	0.017
Extensive management system	22/28	197/202	0.001
Animals with free access to water sources	9/28	151/202	< 0.001
Not using animal identification	13/28	142/202	0.021

*Variables selected and used in the multivariable analysis ($P \leq 0.2$)

(Ashfaq and Campbell 1979; Alves et al. 2007). Access to safe feeding free from contamination of exudates from abscesses of CL animals may be a favorable condition in the prevention of *C. pseudotuberculosis* infection.

Not separating animals by sex or by age were variables pointed out in the logistic regression as CL risk factors. Most of the herds evaluated were managed via the semi-intensive/extensive system, which is without segregation by sex or

Table 4 Logistic regression of risk factors associated with infection by *Corynebacterium pseudotuberculosis* in goats raised in Northeastern Brazil.

Risk factor	Coefficient of logistic regression	Standard error	Wald	Degrees of Freedom	Odds ratio	CI 95%	*P*
Absence of forage silage	1.68	0.70	5.80	1	5.39	1.36–21.26	0.016
Not separating animals by sex	1.42	0.62	5.16	1	4.16	1.21–14.23	0.023
Not separating animals by sex	1.84	0.69	6.96	1	6.30	1.60–24.72	0.008
No replacing old goat breeders	2.05	1.07	4.74	1	7.80	1.31–46.36	0.024
Non-treatment of CL lumps prior to spontaneous rupture	2.55	0.83	9.44	1	10.34	1.26–84.60	0.029

The Hosmer and Lemeshow chi-square = 2.575; degrees of freedom = 4; $P = 0.630$

age, and with animals being kept in the same shelter at night. The agglomeration of animals in the herds is a well-known condition for the dissemination of biological agents to the susceptible ones, with the increasing possibilities of infection as the number of animals and the time of exposure increase in these populations (Medeiros et al. 2005; Nóbrega Jr. et al. 2005; Riet-Correa et al. 2013). In these conditions, the absence of segregation, together with goat agglomeration in the same shelter at night, favors the spread of infection among animals through direct contact among them as well as the contaminated equipment and environment as caseous exudates from *C. pseudotuberculosis* abound on the premises. It is worth noting that the presence of young animals together with adults under these conditions is a possible risk factor for early CL exposure.

No replacing old goat breeders demonstrates the importance of this category in the dissemination of *C. pseudotuberculosis*. Breeding animals, for the most part, remain on the farm for at least 2 years or until considered too old by their owners, at which point they are discarded and replaced. Consequently, the longer the breeding time on the farm, the greater the chances of acquiring the infection. Similar conditions were observed by Seyffert et al. (2010), which related that the greater the length of goats staying in the herd, the greater was their exposure to *C. pseudotuberculosis*. The loan of breeders among farms was also a common practice reported by breeders: no precautions were being done to prevent the spread of CL, such as inspecting the presence of lumps in these animals to be purchased. According to Guimarães et al. (2011a), the absence of periodic animal inspections may be due to practical limitations, due to the large number of animals to be inspected in the system of property creation (extensive/semi-intensive) and the lack of knowledge of breeders. However, the identification and disposal of the animals with this disease are the most effective method for CL control but this is made difficult to achieve because periodic clinical inspection of these animals still cannot reveal subclinical carriers (Alves et al. 2007). Breeders with high levels of contamination may aggravate this situation as under these conditions, the possibility of CL diffusion among goat herds in the Northeast region is magnified through both clinical and subclinical carriers of *C. pseudotuberculosis*.

The non-treatment of CL lumps prior to spontaneous rupture reveals the owners' lack of expertise in CL management. The absence of adequate treatment of affected goats prior to the spontaneous rupture of abscesses makes it impossible to effectively implement CL control measures, since *C. pseudotuberculosis* retains its viability for long periods in the areas of abscess drainage (from 5 to 8 months). This is favorable to the agent because of the lack of control measures necessary to prevent its spread Nairn and Robertson 1974, Brown and Olander 1987). Although few owners report some concern about CL control in their herds, they do not demonstrate adequate precautions, such as complying with the sanitary registry of the affected animals, or properly treating lumps in symptomatic animals when possible. Furthermore, 93.4% of owners declared that they did not discard goats with signs of CL in the herd. These conditions are unfavorable to the control of the agent. As a result, its diffusion, spread, and permanence persist in the areas studied. Guimarães et al. (2011a) reported on the danger of human infection under these conditions, especially considering the risks of contamination of the handlers when treating CL-affected animals.

Conclusions

It is concluded that the caseous lymphadenitis is widely disseminated in goats from Northeastern Brazil. Based on the risk factor analysis, attention should be given to the need to establish adequate control measures such as the use of forage silage, separation of animals by sex and age, replacement of old goat breeders, and treatment of CL lumps prior to spontaneous rupture.

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Compliance with ethical standards

The project was approved by the Research Ethics Committee (CEP) of the Rural Health and Technology Center (CSTR) of Federal University of Campina Grande (UFCG), Patos, Paraíba, Brazil, under code number 125/2016.

Conflict of interest The authors declare that they have no conflict of interest.

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