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ORIGINAL ARTICLE

Prevalence and risk factors associated with infection by *Eimeria* spp. in goats and sheep in Northeastern Brazil

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Abstract *Eimeria* spp. infections lead to acute or chronic intestinal disorders in small ruminants, being responsible for important economic losses worldwide. The aim of this study was to assess the risk factors associated with *Eimeria* spp. infection in small ruminants of the microregion of Garanhuns, state of Pernambuco, Northeastern Brazil. Fecal samples (n = 822) were obtained from goats (n = 414) and sheep (n = 408) and evaluated by the modified Gordon and Whitlock technique. Risk factors were assessed through univariate analysis and logistical regression. Oocysts of *Eimeria* species were detected in 62.9% (517/822) of the animals, with 77.8% (322/414) in goats and 47.8% (195/408) in sheep. For goats, the herd size (OR = 5.52), rearing system (OR = 1.57), feeding place (OR = 2.60), absence of mineral salt in the diet (OR = 2.54), flooring type (OR = 2.83) and periodicity of cleaning (OR = 5.39) were considered risk factors. Conversely, for sheep only the herd size (OR = 3.16) and rearing system (OR = 2.45) were important factors associated with infection by *Eimeria* spp. Data herein obtained brings meaningful information on the epidemiology of coccidiosis in small ruminants in Northeastern Brazil. The knowledge of these risk factors is useful to contribute to the development of preventive measures, thereby, reducing the economic impact caused by these protozoa in small ruminant production.

Keywords Protozoan · Coccidiosis · Small ruminants · Epidemiology

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Introduction

Protozoa belonging to the genus *Eimeria* (Apicomplexa) are obligate intracellular parasites of the intestinal epithelium, responsible for an economically important parasitic disease commonly known as coccidiosis. The main species that infect goats are *Eimeria arloingi* and *Eimeria ninakohlyakimovae*, whereas sheep are mainly affected by *Eimeria ovinoidalis* and *Eimeria crandallis* (Chartier and Paraud 2012; Souza et al. 2015; Sharma et al. 2017). It is known that the main route of transmission is through ingestion of sporulated oocysts (Bakunzi et al. 2010; Hashemnia et al. 2015). After that, the hatched sporozoites invade the intestinal cells and undergo multiple generations of asexual reproduction followed by sexual reproduction, resulting in damage to the intestinal lining and consequently inadequate nutrient absorption causing a reduction in weight gain (Ozmen et al. 2012).

For a long time, attention has been paid to coccidiosis due to its economic impact on ruminant production. In fact, in the United States is estimated that the economic losses may reach 341 million dollars annually (Grilo and Carvalho 2014). In addition, a previous study conducted in Europe demonstrated that the prophylactic treatment of coccidiosis represents a cost of 4.88 USD per calf (Lassen and Østergaard 2012). The cost for small ruminant production has not been assessed, but it is believed that the losses are worldwide present, especially in young animals.

Several factors related to the host, environment and parasite are associated with the occurrence of *Eimeria* infection (Rehman et al. 2011). The age of the host is considered an important risk factor, since it is known that small ruminants become infected within the first few days after birth, eliminating oocysts in the faeces by the second week of life (Saratsis et al. 2011). Conversely, older animals are sources of infection due to the frequent elimination of low numbers of oocysts in the faeces for long time (Foreyt 1990). Similarly, post-partum females are also responsible for maintaining a high burden of oocysts in the environment, facilitating the infection of young animals (Silva et al. 2007).

Subclinical infection is the most common manifestation of the disease, which has a significant impact on herd health and production (Lopez-Osorio et al. 2019). One of the first signs is a delay in development, especially in young animals (Andrade Júnior et al. 2012). However, when clinical infection occurs, signs such as diarrhea, anorexia, weight loss and dehydration can be observed. Knowledge of the inherent aspects of the course of infection is important in defining the appropriate preventative measures, as the administration of drugs, most of the time, does not successfully control coccidiosis (Young et al. 2011).

The assessment of risk factors is pivotal, as it helps to adopt prophylactic measures, consequently reducing the occurrence of *Eimeria* infection in small ruminants (Souza et al. 2015). However, these factors are poorly investigated in many regions where the rearing of goats and sheep is an important economic activity (Carrau et al. 2018). Thus, the aim of this study was to assess the risk factors associated with infection by *Eimeria* spp. in small ruminants from Northeastern Brazil.

Materials and methods

Study area

This study was performed in sheep and goats from private farms in the Garanhuns microregion (8°53′25″ South and 36°29′34″ West), state of Pernambuco, Northeastern Brazil (Fig. 1). The climate in this area is characterized as semi-arid with an annual average of temperature of 22 °C (from 17 to 30 °C), 900 m above sea level, average rainfall of

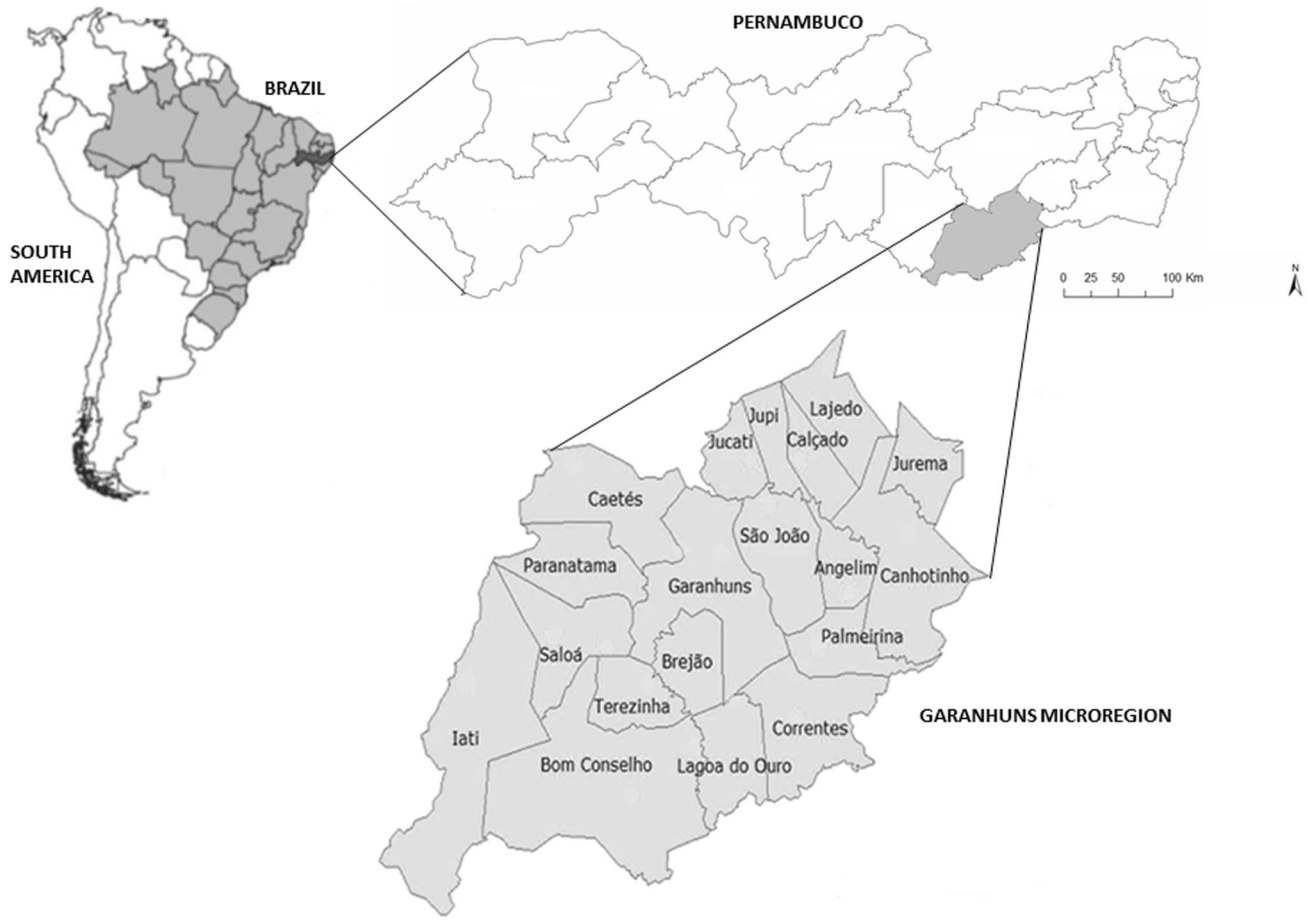

Fig. 1 Map of the Garanhuns microregion, state of Pernambuco, Northeastern Brazil

147 mm (from 25 to 295 mm), and relative humidity of 90%.

Animals, sampling and laboratorial procedures

Goat (n = 35,770) and sheep (n = 99,606) population number on the study area (IBGE 2016) was considered to define minimum sample size (n = 384) for each species. Moreover, it was considered a prevalence estimated in 50%, a confidence level of 95% and statistical error of 5% (Thrusfield 2004). The farms were randomly selected by convenience (Reis 2003). There were no exclusion criteria regarding breed, gender, age and rearing systems of the animals.

Fresh faecal samples (n = 822) were collected in goats (n = 414) and sheep (n = 408), from March 2017 to May 2018. Of the animals enrolled, 144 and 270 goats, and 172 and 236 sheep were classified as young ($\leq$ 12 months old) and adults (> 12 months old), respectively. Collection was performed using plastic gloves, and after that, samples were stored at 4 °C in isothermal boxes until parasitological procedures. Each sample was individually processed by the modified Gordon and Whitlock technique (Gordon and Whitlock 1939). For the analysis of the risk factors, an investigative questionnaire based on information about the herd and sanitary conditions was applied to farmers following all the ethical guidelines for research, respecting the confidentiality of the interviewed people, which read and signed an informed consent previously approved by the ethical committee (License number 06/2017).

Data analysis

Descriptive statistical analysis was performed to obtain relative and absolute frequency. In addition, the Lilliefors test was used to verify the normality of the data. The Chi-square test with Yates correction (χ^2) was used to compare the occurrence of *Eimeria* species infecting goats and sheep, as well as the occurrence of the protozoan in different ages of the small ruminants. Subsequently, for the analysis of the risk factors associated with *Eimeria* infection an univariate analysis of the variables of interest and logistic regression analysis considering as dependent variable the results of test (Gordon and Whitlock technique) was performed. Odds ratio (OR) values were obtained for each parameter assessed. The significance level was set at 5%. All analyses were carried out using the EPIINFO^{TM}7.2.2.6 software.

Results

Of all samples analyzed, 62.9% (517/822) were positive for *Eimeria* spp. oocysts, being 77.8% (322/414) of goats (mean 560,155 ± 1,485,174) and 47.8% (195/408) of

Fig. 3 Installation floor in a goat farm showing the ground type, which was considered a risk factor associated to *Eimeria* spp. infection

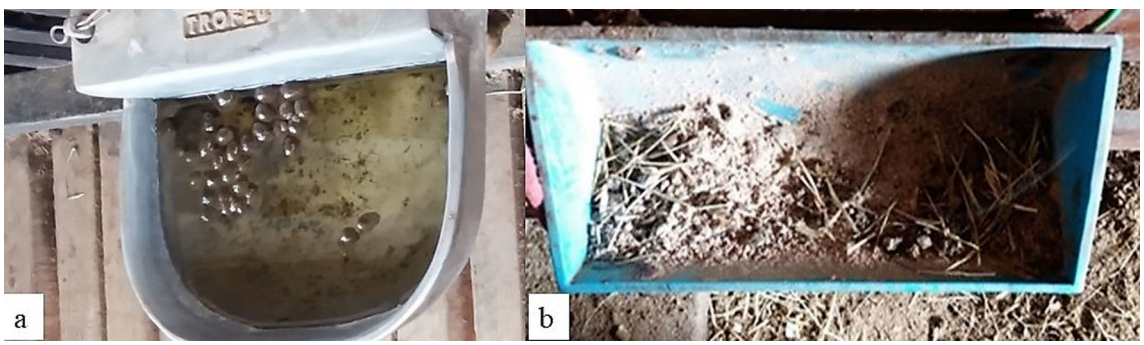

Fig. 2 Fecal contamination of water (**a**) and food (**b**)

Table 1 Univariate analysis of risk factors associated with infection by *Eimeria* spp. in goats of Northeastern region of Brazil

Variable	N	OoPG positive	Univariate analysis OR (CI 95%)	*p* value
Age (months)				
≤ 12	144	112 (77.78%)		
> 12	270	210 (77.78%)	1.00 (0.60–1.68)	0.546
Gender				
Male	61	50 (81.97%)		
Female	353	272 (77.05%)	1.35 (0.65–3.01)	0.250
Herd size (animals)				
> 50	244	206 (84.43%)		
≤ 50	170	116 (68.24%)	2.52 (1.53–4.17)	0.00008*
Rearing system				
Intensive	108	80 (74.07%)	–	
Semi-intensive	237	194 (81.86%)	1.57 (0.87–2.80)	0.022*
Extensive	69	48 (69.57%)	0.50 (0.26–0.98)	
Place of supply (food)				
Others	224	191 (85.32%)		
Trough	190	131 (68.95%)	2.60 (1.57–4.35)	0.00005*
Mineral salt				
Not	253	213 (84.19%)		
Yes	161	109 (67.70%)	2.54 (1.54–4.19)	0.00007*
Installation floor				
Cemented	121	81 (66.94%)	–	
Ground	175	149 (85.14%)	2.83 (1.55–5.18)	0.0002*
Ripped	118	92 (77.97%)	0.617 (0.32–1.18)	
Periodicity of cleaning				
Daily	158	102 (64.56%)	–	
Weekly	130	118 (90.77%)	5.39 (2.66–11.63)	0.00000007*
Monthly	126	102 (80.95%)	0.43 (0.18–0.95)	

N Total samples; *OR* Odds Ratio; *CI* Confidence interval

*p < 0.05, significant association

sheep (mean 166,769 ± 1,478,003) (χ^2 = 77,881, p = 0.0000). No statistical difference was observed between the positivity and age of both species (χ^2 = 1.027; p = 0.3109).

The univariate analysis associated only the herd size and rearing system as risk factors for the infection by *Eimeria* spp. in sheep. Conversely, in goats, the herd size, rearing system, feeding place (Fig. 2), absence of mineral salt in the diet, flooring type (Fig. 3) and periodicity of cleaning were considered risk factors (Tables 1 and 2).

Discussion

This study describes risk factors associated with infection by *Eimeria* spp. in small ruminants reared in Northeastern region of Brazil. The overall prevalence herein obtained (i.e., 77.8% for goats and 47.8% for sheep) revealed high parasitism by *Eimeria* spp. in both animal species. Currently, coccidiosis is one of the most important threats for small ruminant production (Souza et al. 2015; Carrau et al. 2018).

Several risk factors have been associated with infection by *Eimeria* species in ruminants, especially in bovines (Makau et al. 2017; Lopez-Osorio et al. 2019). Less data regarding small ruminants (i.e., goats and sheep) have been produced worldwide. However, this study identifies some risk factors associated with infection by these protozoans. It is known that the age is considered an important risk factor for infection by *Eimeria* species, however, in this study animals of different ages were equally exposed to *Eimeria* spp., differing from other studies in which young animals were more affected (Carrau et al. 2018; Squire et al. 2019).

Interestingly the herd size and rearing system were risk factors for the infection of both species. It has already been

Table 2 Univariate analysis of risk factors associated with infection by *Eimeria* spp. in sheep of Northeastern region of Brazil

Variable	N	OoPG positive	Univariate analysis OR (CI 95%)	*p*-value
Old (months)				
≤ 12 meses	172	45 (51.16%)		
> 12 meses	236	107 (45.34%)	1.26 (0.83–1.90)	0.143
Gender				
Male	116	56 (48.28%)		
Female	292	139 (47.60%)	1.02 (0.65–1.61)	0.494
Herd size (animals)				
< 50	365	164 (44.93%)		
≥ 50	43	31 (72.09%)	3.16 (1.51–6.97)	0.0005*
Rearing system				
Semi-intensive	231	89 (38.53%)		
Intensive	155	94 (60.65%)	2.45 (1.58–3.81)	0.00001*
Extensive	22	12 (54.55%)	0.77 (0.28–2.15)	
Place of supply (food)				
Others	395	188 (47.59%)		
Trough	13	7 (53.85%)	0.77 (0.21–2.76)	0.434
Mineral salt				
Not	266	124 (46.62%)		
Yes	142	71 (50.00%)	0.87 (0.56–1.34)	0.291
Installation floor				
Ground	281	137 (48.75%)		
Ripped	77	38 (49.35%)	1.02 (0.59–1.75)	0.514
Cemented	50	20 (40.00%)	0.68 (0.31–1.49)	
Periodicity of cleaning				
Daily	232	117 (50.43%)		
Weekly	75	29 (38.67%)	0.62 (0.33–1.14)	
Monthly	101	49 (47.46%)	1.49 (0.78–2.87)	0.125

N Total samples; *OR* Odds Ratio; *CI* Confidence interval

*p < 0.05, significant association

indicated that intensive and semi-intensive breeding systems, where high population density occurs, contribute to the propagation of coccidia species (Sharma et al. 2017). A common practice adopted in the farms herein studied was the partial confinement (usually at night) of animals. This data demonstrates that in the present study the semi-intensive rearing system and the high density of animals might have directly influenced infection by *Eimeria* spp. in goats and sheep.

Other risk factors such as feeding place, type of floor, absence of mineral salt in the diet and periodicity of cleaning were observed only for goats. It is important to note, that all factors mentioned above (except the use of mineral salt) are related to hygiene. Faecal contamination of water and food is important for the transmission of many protozoa, especially in places where animals are fed directly over the soil, favoring the ingestion of sporulated oocysts (Sharma et al. 2017). Precarious hygiene conditions (e.g., uncemented floor) associated with overcrowding in intensive rearing systems result in high levels of infection (Squire et al. 2019). Therefore, it is important to highlight that the place and conditions of food supply are fundamental, since proximity with the soil favors faecal contamination and consequent animal infection. A routine practice adopted in some farms enrolled in the present study was the usage of mineral salt. The absence of mineral salt in the diet of goats has also been considered a risk factor in the studied area. Currently, it is known that many formulations of mineral salt contain coccidiostatic compounds (e.g., decoquinate and monensin) that are used for the prophylaxis of coccidiosis (Andrade Júnior et al. 2012).

It is noteworthy that this study was the first to identify risk factors for infection by *Eimeria* spp. in goats and sheep in the study area. The data herein presented are important for understanding the factors that influence the occurrence of the infection by this protozoan. Accordingly, knowledge

of these parameters is of great importance for the development of prophylactic strategies suitable for the different conditions and to minimize the economic losses for small ruminant production.

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Compliance with ethical standards

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

Ethical statement This study was approved by the Ethics Committee for Animal Experimentation (ECAE) of the *Universidade Federal Rural de Pernambuco* under the license number: 06/2017. All applicable international, national, and/or institutional guidelines for the care and use of animals enrolled in the present study were followed.

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