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REGULAR ARTICLES

Gastrointestinal parasites in free grazing goats from Ayacucho, Peru: prevalence and risk factors associated with infection in herds

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Abstract
This study assessed the prevalence and risk factors associated with gastrointestinal parasite infection in goats in Ayacucho, Peru. Fecal samples were collected from a total of 254 goats from four districts of Ayacucho: Ocaña (89), Colca (76), Pacaicasa (64), and Luricocha (25) during the dry season; recording the location, sex, and age of the animals. The fecal samples were analyzed using the flotation technique in salt and sugar solution, and modified McMaster egg counting techniques for eggs/oocysts (epg/opg) of gastrointestinal parasites. The associations between location, sex, and age with the prevalence of gastrointestinal parasites were analyzed using the chi-square test. Fecal samples showed an overall parasite prevalence of 87.80%. The identified parasites were *Eimeria* spp. (86.22%), Strongyle type eggs (STE) (65.75%), *Skrjabinema* spp. (7.87%), *Trichuris* spp. (3.15%) and *Moniezia* spp. (3.15%). There was a significant association between the location and the presence of parasites ($p < 0.05$); where STE was more prevalent in the district of Colca (98.68%); *Trichuris* spp. in Pacaycasa (9.38%); *Skrjabinema* spp. (48.00%), *Moniezia* spp. (12.00%) and *Eimeria* spp. (100%) were more prevalent in Luricocha. Sex had a significant association with the prevalence of *Eimeria* spp., *Skrjabinema* spp. and *Moniezia* spp. ($p < 0.05$); while age had a significant association with parasitosis only for *Trichuris* spp. and *Moniezia* spp. ($p < 0.05$). The epg/opg values revealed a higher parasite burden in goats from Colca compared to the other locations ($p < 0.05$). There was also no statistical relationship between fecal egg/oocyst counts and sex or age, nevertheless, there were moderate and high parasitic burdens. The high prevalence of parasites such as nematodes, cestodes, and coccidia suggests the need to implement strategic control and prevention programs in free-grazing goats. Location and sex were the most relevant risk factors for parasitosis in Ayacucho, Peru.

Keywords Goats · Parasite burden · Nematodes · Cestodes · Coccidiosis

Introduction

Goat farming is one of the livestock activities that contribute to the socioeconomic growth of developing regions (Tumusiime et al. 2022), ensuring food security and offering economic income to smallholders in rural areas (Monau et al. 2020). In Peru, the goat population is distributed between the mountains and the coast, concentrating in the regions of Piura, Ayacucho, Ica, and Lima, where about 9.64% of the total population is located in Ayacucho (MINAGRI 2021).

Goats have the great ability to adapt to nutritional and climatic changes, in addition to contributing to the efficient management of plants and soil (Chacón-Hernández and Boschini-Figueroa 2015). However, gastrointestinal parasite infections are one of the major problems of goat farming, being responsible for economic losses due to mortality and decreased meat and milk production, reducing the incomes of small farmers (Emiru et al. 2013; Zaros et al. 2010; Income et al. 2021; Weny et al. 2017; Charlier et al. 2020).

The prevalence of gastrointestinal parasites and intensity of infections varies depending on the local environment (temperature, rainfall, humidity, and vegetation), management practices, seasonal variations, as well as age, sex, and

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breed (Belina et al. 2017; Mpofu et al. 2022). Risk factors such as age, seasonality, and body condition have been reported to exhibit a significant association with nematodes, *Moniezia* spp., and *Eimeria* spp. infections in goats (Chartier and Paraud 2012; Diop et al. 2015; Wuthijaree et al. 2022; Hussein et al. 2023). It has been reported that kids could be more susceptible to infection due to their lower level of immune response (Singh et al. 2015). Thus, there is also susceptibility in adult females when experiencing physiological stress in the reproductive and production phases (Golo et al. 2017).

Climatic factors such as temperature, relative humidity, and rainfall play an important role in parasite egg hatching, which influences the degree of infection in the animal (Dey et al. 2020). The main clinical signs and symptoms of parasitosis are anemia, diarrhea, emaciation, and rectal tenesmus (Wuthijaree et al. 2022), however, there are some animals do not show any symptoms (Besier et al. 2016). Infection of *Monieza spp*. also depends on the presence of oribatid mites, the intermediate host (Diop et al. 2015). Additionally, stress caused by dietary changes and inadequate management practices can lead to outbreaks of coccidiosis, affecting gastrointestinal health in goats (Chartier and Paraud 2012).

Ayacucho is located in the mountainous region of Peru where goat farming is raised generally under free-grazing systems on cultivated or natural pastures in the inter-Andean valleys. The grazing areas present suitable environmental conditions (temperate climate, wet conditions, and precipitations) that favor the development of gastrointestinal parasites. Hence, it is necessary to identify the epidemiological factors that affect the presence of gastrointestinal parasites to formulate effective prevention and control measures (Income et al. 2021; Rahman et al. 2017; Chakrabortty et al. 2023). However, there is a scarcity of published epidemiological studies on gastrointestinal parasites in goats done in the Region Ayacucho. These reports have been mainly performed in districts where goat raising constitutes a secondary economic activity. Major goat producing districts in Ayacucho have not been involved in this type of study. The present study aimed to evaluate the prevalence, burden and factors associated with gastrointestinal parasitosis in goats raised under extensive systems in four districts of the Region Ayacucho, Peru; where goat raising is an important activity for several communities.

Materials and methods

Study area

The study was carried out in the districts of Ocaña, Colca, Pacaycasa, and Luricocha, located in the rangelands of the region of Ayacucho, Peru (Fig. 1), with a total land area of 85 600 ha, 6 400 ha, 5 8.00 ha, and 14 000 ha, respectively. Altitudes at the districts vary between 2470 and 3500 m.a.s.l. (PCM 2017). These districts were selected since they are the ones with the largest goat populations in the Ayacucho region (MINAGRI 2021). In addition, in the selected sectors goat raising constitutes a relevant economic activity for an important number of producers.

Temperatures range from 0.1 °C in July to 28.7 °C in November, with a monthly precipitation of 5.5 mm to 154.7 mm (SENAMHI 2018). Generally, the climate at Ayacucho rangelands of Ayacucho is characterized by being warm, and two seasons can be distinguished: the rainy season (from December to March) and the dry season (from May to October), April and October the transition months (Moncada and Willems 2020).

Animals and sample determination

The population of goats in the districts of Ocoña, Colca, Pacaycasa, and Luricocha is 24 821, 7 766, 15 700, and 10 876, respectively, representing 75.44% of the total population in Ayacucho (MINAGRI 2021). Goats are raised under a traditional grazing management, being shrubs the forage base in their diet, without any type of supplementation.

A descriptive cross-sectional study was conducted during the dry season (May to July 2023). The sample size was estimated using the formula of minimum sampling number to determine prevalence with unknown populations:

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

Where:

n = sample size,
P = expected prevalence
e = prevalence level

An expected prevalence of 60% (Cáceres et al. 2021), a confidence level of 95%, and an absolute precision of 6% (Thrusfield 2005). A total of 254 goats were randomly sampled from 33 herds: 10 herds in Ocaña ($n = 89$ goats), 12 herds in Colca ($n = 76$ goats), 6 herds in Pacaycasa ($n = 64$ goats), and 5 herds in Luricocha ($n = 25$ goats), considering the limitations of distances and the number of animals in each goat farmer's herd. For the selection of the herds, it was considered at least 1 herd from each sector/community in each district, with a minimum herd size of 10 goats.

The inclusion criteria were: animals older than six months of age with no deworming in the last three months. Location, sex, and age were recorded. Age was determined

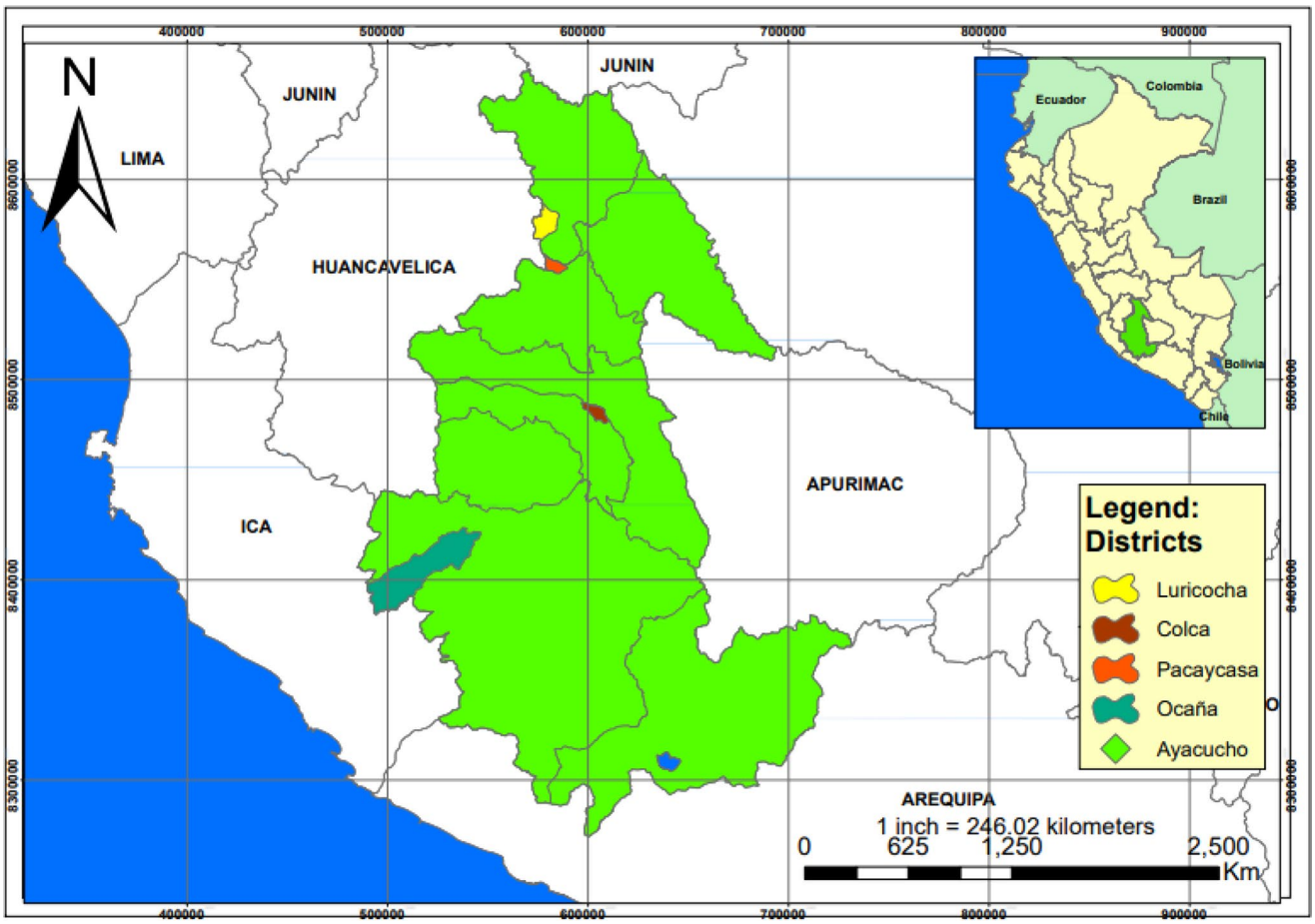

Fig. 1 Map of Ayacucho, Peru, showing the position of the districts of Ocaña, Colca, Pacaycasa, and Luricocha

by dental chronometry as follows: Milk teeth (MT: less than 12 months), two teeth (2T: from 12 to 18 months), four teeth (4T: from 18 to 24 months), six teeth (6T: from 24 to 36 months) and full mouth (FM: from 36 to 48 months) (MAPA 2019).

Sampling

A fecal sample of approximately 5 to 10 g was collected directly from the rectum, using latex gloves lubricated with mineral oil, and placed in a plastic sample container. The sample collection from goat specimens was conducted following the Peruvian National Law No. 30,407: "Animal Protection and Welfare", maintaining the required animal welfare conditions at all times. The feces were preserved in an isothermal box of expanded polystyrene with gel ice packs and transported to the Laboratory of Parasitology, at the Animal Science College, Universidad Nacional Agraria La Molina (UNALM), where they were placed under refrigeration (4 °C) until processing.

Coprological analysis

Fecal flotation technique with saturated sodium chloride was used to identify nematode and cestode eggs, as well as *Eimeria* oocyst (Urquhart et al. 1996; Navarro 2017). Briefly, 2 g of feces were homogenized in saturated saline solution, subsequently sieved, and poured into 15 ml polypropylene Falcon® tubes, forming a positive meniscus. A cover slip was placed and allowed to rest for 10 min. Then the coverslip was carefully placed on a slide and taken to the microscope (OPTICA B-292®). Positive samples were analyzed using a modified McMaster protocol (Tumusiime et al. 2022), to assess the number of eggs/oocysts per gram of feces. Intensity burdens (low, moderate, and high) were evaluated according to Taylor et al. (2007).

Data analysis

The data were processed using computer program R software version 4.3.1 (R Core Team 2023) to determine the 95% confidence interval (Hussein et al. 2023). Descriptive statistics were used to establish gastrointestinal parasite

Table 1 Prevalence of gastrointestinal parasites in goats from four districts of Ayacucho, Peru, 2023

Parasites	No. examined	No. positive	% prevalence
SET	254	167	65.75
Skrjabinema spp.	254	20	7.87
Trichuris spp.	254	8	3.15
Moniezia spp.	254	8	3.15
Eimeria spp.	254	219	86.22

prevalence, and the Chi-square test (X^2) was used to examine the association between prevalence and risk variables such as location, sex, and age. The arithmetic mean of the parasite burden was compared using the non-parametric Kruskall Wallis test and the U-Mann Whitney test.

Results

Fauna and prevalence of gastrointestinal parasites

The overall prevalence of gastrointestinal parasites in goats from Ayacucho was 87.80%. Among the identified parasites, *Eimeria* spp. was the most common, with a prevalence of 86.22%, followed by strongyle type eggs (STE) at 65.75%, *Skrjabinema* spp. (7.87%), *Trichuris* spp. (3.15%) and *Moniezia* spp. (3.15%) were also found. The parasitic fauna and prevalence by species are shown in Table 1; Fig. 2.

Table 2 shows the prevalence of mixed infections in the herds studied. Mixed infection STE + *Eimeria* spp. had the highest prevalence (59.45%), followed by mixed infection *Eimeria* spp. + *Skrjabinema* spp. (7.48%), STE + *Skrjabinema* spp. (5.51%), and STE + *Skrjabinema* spp. + *Eimeria* spp. (5.51%). Regarding the other mixed infections, between 0.39 and 3.15% were registered.

Table 2 Prevalence of mixed infections with gastrointestinal parasites in goats from Ayacucho, Peru

Mixed infection	*N*° positive	% prevalence
STE	1	0.39
Eimeria spp.	16	6.30
Monieza spp.	2	0.79
STE + *Skrjabinema* spp.	14	5.51
STE + *Trichuris* spp.	7	2.76
STE + *Moniezia* spp.	6	2.36
STE + *Eimeria* spp.	151	59.45
Eimeria spp. + *Skrjabinema* spp.	19	7.48
Eimeria spp. + *Trichuris* spp.	8	3.15
Eimeria spp. + *Moniezia* spp.	8	3.15
Trichuris spp. + *Skrjabinema* spp.	1	0.39
Trichuris spp. + *Moniezia* spp.	1	0.39
Moniezia spp. + *Skrjabinema* spp.	3	1.18
STE. + *Skrjabinema* spp. + *Trichuris* spp.	1	0.39
STE + *Skrjabinema* spp. + *Moniezia* spp.	1	0.39
STE + *Skrjabinema* spp. + *Eimeria* spp.	14	5.51
STE + *Skrjabinema* spp. + *Trichurs* spp. + *Eimeria* spp.	1	0.39
Total	**254**	**100.00**

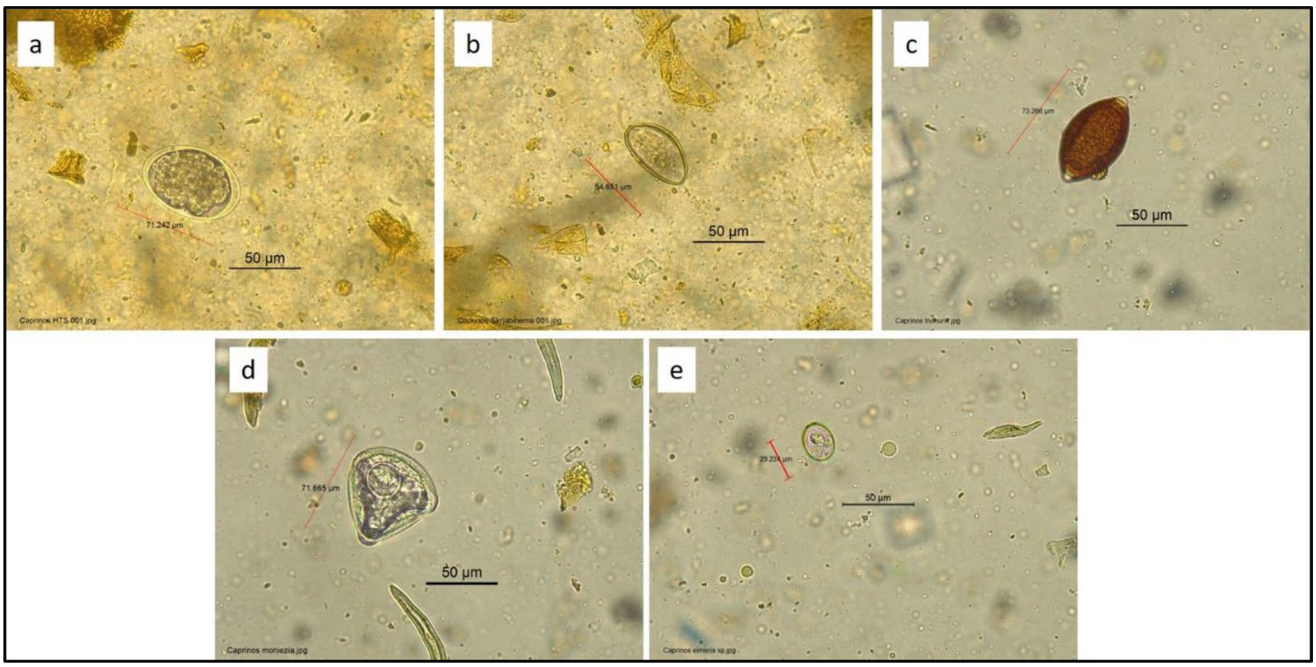

Fig. 2 Gastrointestinal parasite eggs/oocysts found in goats from districts of Ayacucho, Peru. (**a**) Strongyle type eggs (STE), (**b**) *Skrjabinema* spp., (**c**) *Trichuris* spp., (**d**) *Moniezia* spp. and (**e**) *Eimeria* spp

Table 3 shows the results of the prevalence of gastrointestinal parasites for each district. The prevalence of parasites had a significant relationship with the location ($p < 0.05$). The highest prevalence of STE was reported in the district of Colca (98.68%), followed by Luricocha (88.00%), Pacaycasa (53.21%) and Ocaña (40.45%). *Skrjabinema* spp. was identified in the districts of Luricocha (48.00%) and Pacaycasa (12.50%). *Trichuris* spp. were only recorded in the districts of Pacaycasa (9.38%) and Luricocha (8.00%) with a very low prevalence. *Moniezia* spp. was detected with the highest prevalence in the district of Luricocha (12.00%), followed by Colca (3.95%) and Pacaycasa (3.12%). Regarding *Eimeria* spp., the prevalences found in the districts of Luricocha (100%), Pacaycasa (98.44%), and Colca (96.05%) was higher than Ocaña (65.17%).

The prevalence of parasites according to sex is shown in Table 4. No significant association was found between sex and the prevalence of STE and *Trichuris* spp ($p > 0.05$), however, there were associations with the prevalence of *Skrjabinema* spp., *Moniezia* spp., and *Eimeria* spp. ($p < 0.05$).

There was no significant association between the age of goats and the prevalence of STE, *Skrjabinema* spp. and *Eimeria* spp. ($p > 0.05$). In contrast, a significant relationship ($p < 0.05$) was found between age and the prevalence of *Trichuris* spp., and *Moniezia* spp. (Table 5). The prevalence of STE was above 50% in all age categories. *Skrjabinema* spp. had a higher prevalence in goats with 2T (16.33%) than in other categories. *Trichuris* spp. had the highest prevalence in the MT category (8.96%), followed by 2T (2.04%) and 4T (1.97%). No presence of parasites was recorded in the 6T and FM age categories. Prevalence of *Moniezia* spp. was showed in 6T (11.11%), MT (5.97%), and 2T (4.08%) age categories. The presence of *Eimeria* spp. in all age categories was higher than 80%.

Table 3 Prevalence of gastrointestinal parasites in goats from Ayacucho, Peru, in different locations of the study

Parasites	Location	% prevalence	X^2	*p*-valor
STE	Ocaña	40.45 (26/89)	71.928	< 0.001
	Colca	98.68 (75/76)		
	Pacaycasa	53.12 (34/64)		
	Luricocha	88.0 (22/25)		
Skrjabinema spp.	Ocaña	-	71.480	< 0.001
	Colca	-		
	Pacaycasa	12.5 (8/64)		
	Luricocha	48.0 (12/25)		
Trichuris spp.	Ocaña	-	15.425	0.001
	Colca	-		
	Pacaycasa	9.38 (6/64)		
	Luricocha	8.00(8/25)		
Moniezia spp.	Ocaña	-	9.473	0.023
	Colca	3.95 (3/76)		
	Pacaycasa	3.12 (2/64)		
	Luricocha	12.0 (3/25)		
Eimeria spp.	Ocaña	65.17 (58/89)	51.419	< 0.001
	Colca	96.05 (73/76)		
	Pacaycasa	98.44 (63/64)		
	Luricocha	100.0 (25/25)		

Table 4 Prevalence of gastrointestinal parasites and its association with sex in goats from Ayacucho, Peru

Parasites	Sex	% prevalence	X^2	*p*-valor
STE	Female	66.34 (136/205)	0.0576	0.8103
	Male	63.27 (31/49)		
Skrjabinema spp.	Female	7.80 (16/205)	0.0000	< 0.001
	Male	8.16 (4/49)		
Trichuris spp.	Female	1.95 (4/205)	3.1730	0.0748
	Male	8.16 (4/49)		
Moniezia spp.	Female	2.93(6/205)	0.0000	< 0.001
	Male	4.08 (2/49)		
Eimeria spp.	Female	86.34 (177/205)	0.0000	< 0.001
	Male	85.71 (42/49)		

Parasitic burden measured by fecal egg count (FEC)

The results of fecal egg counts (FEC's) expressed in eggs/oocysts per gram of feces (epg/opg) are shown in Table 6. The results were compared with the classification established by Taylor et al. (2007), where FEC's from 50 to 500, >500–1000, and >1000 per gram of feces are considered as light, moderate, and heavy infections, respectively. The differences between the FEC of STE and *Eimeria* spp. were highly significant between the districts ($p < 0.05$). STE FEC was the highest in Colca (3334.87 ± 3631.82), and moderate in Ocaña (743.82 ± 1523.47), with low FEC's in Luricocha (454.00 ± 424.24) and Pacaycasa (199.22 ± 320.40). *Eimeria* spp. FECwas high in Colca (2423.03 ± 6054.68), Luricocha (1490.00 ± 1313.63), and Pacaycasa (1014.53 ± 1069.60), and moderate in Ocaña (534.27 ± 814.28).

There was no significant association between sex and STE and *Eimeria* spp. FEC's ($p > 0.05$). STE FEC's in males and females were high and for *Eimeria* spp. in females were high and moderate in males. Likewise, no significant differences were found between STE and *Eimeria* spp. FEC's with the age of the animals. STE FEC's values revealed a moderate intensity in 2T goats (706.12 ± 1542.07) compared to MT (1172.39 ± 2087.01), 4T (1406.25 ± 2049.97), 6T (1819.44 ± 2415.46) and FM (1860.94 ± 3707.62) goats, who showed high FEC's. On the other hand, *Eimeria* spp. FEC was high in goats from MT (2229.85 ± 6373.45), 4T (1180.89 ± 1514.12), and FM (1070.31 ± 1422.63), compared to goats from 2T (792.86 ± 1031.23) and 6T (611.11 ± 621.09), who had a moderate intensity.

Table 5 Prevalence of gastrointestinal parasites and its association with age in goats from Ayacucho, Peru

Parasite	Age	% prevalence	X^2	*p*-valor
STE	MT	65.67 (44/67)	3.6625	0.4536
	2T	55.10 (27/49)		
	4T	71.43 (40/56)		
	6T	72.22 (13/18)		
	FM	67.19 (43/64)		
Skrjabinema spp.	MT	5.97 (4/67)	8.3272	0.0803
	2T	16.33 (8/49)		
	4T	3.57 (2/56)		
	6T	-		
	FM	0.38 (6/64)		
Trichuris spp.	MT	8.96 (6/67)	10.609	0.0313
	2T	2.04 (1/49)		
	4T	1.97 (1/56)		
	6T	-		
	FM	-		
Moniezia spp.	MT	5.97 (4/67)	9.5296	0.0236
	2T	4.08 (2/49)		
	4T	-		
	6T	11.11 (2/18)		
	FM	-		
Eimeria spp.	MT	89.55 (60/67)	2.2467	0.6905
	2T	81.63 (40/49)		
	4T	89.29 (50/56)		
	6T	84.38 (15/18)		
	FM	89.55 (54/64)		

Discussion

In the present study, infection with gastrointestinal nematodes, cestodes, and protozoa was determined in goats from four districts of Ayacucho, Peru. A general prevalence of 87.80% for gastrointestinal parasites was obtained. This result was higher than those previously reported in other regions of Peru such as Ica, where an overall prevalence of 67.6% was reported (Cáceres et al. 2021) or 37.5% reported for northern Peru (Chinga 2022). Likewise, the prevalence reported here is higher than those found in other regions of the globe, such as Bangladesh, with 62.1% for gastrointestinal nematodes (Dey et al. 2020). Ethiopia with 54.17%. (Hussein et al. 2023).On the other hand, our results are somehow lower than those reported in Brazil with a global prevalence of 94.57% (Cardoso et al. 2012), and in Rwanda with a prevalence of 100% (Tumusiime et al. 2022). Regarding previous studies carried out in the area of Ayacucho, Mendoza (2023) found a prevalence of 100% in creole goats from the district of Pacaycasa, Ayacucho, during the rainy season; while this study was carried out during the dry season. Climate and season, along with differences in the breeding system, are important factors that could explain the differences in the prevalence of gastrointestinal parasites in goats in free-grazing systems (Bogale et al. 2014).

Parasite infection in goats is influenced by several environmental variables such as temperature, precipitation, and other ecological conditions that promote the development and transmission of infective stages; the host species, by their affinity; and the type of diagnostic test used for the detection of parasitic forms in feces (Hussein et al. 2023; Nisa et al. 2021; Zanzani et al. 2014).

STE, *Skrjabinema* spp, *Trichuris* spp, *Moniezia* spp., and *Eimeria* spp. were the parasites found in our study. *Eimeria* spp. had a higher prevalence with 86.22%, followed by STE with 65.75%. Other parasite prevalence studies have been reported in Piura, (Northern Peru), with prevalences of 15.48% and 5.36%, for STE and *Eimeria* spp., respectively (Chinga 2022), which are low when compared with the present study. Cáceres et al. (2021) reported also a similar prevalence (63.7%) for STE and *Trichuris* spp (4.1%), but a higher prevalence for *Skrjabinema* spp. (12.9%). In other countries such as Thailand, it is reported a prevalence of 76.8% for STE, 48.8% for *Eimeria* spp., and 14.2% for *Moniezia* spp. (14.2%) (Wuthijaree et al. 2022); while, in South Africa, prevalences were determined for STE (59.6%), *Eimeria* spp. (30.8%), *Moniezia* spp. (36.6%), and *Trichuris* spp. (26.4%). According to all these works, there is a high prevalence of STE in goat herds worldwide, which can be explained due to the high biotic potential of nematodes represented by this egg type, and their short generation interval, which allow them to proliferate and contaminate the pastures (Mpofu et al. 2022; Bowman 2014).

Low parasite burden, the amount of feces collected, and the physiological condition of the animal can also influence the result of finding gastrointestinal parasite eggs in the collected samples (Storey 2015; Dey et al. 2020). It is worth mentioning that a negative coprological result does not necessarily indicate that the animal tested is free of parasites, since fecal examinations cannot determine immature stages of the parasite. Thus, the results of coprological tests have a margin of error that points out the possibility of variations in positive cases that have not been identified.

According to the location, Ocaña district showed a reduced parasitic fauna (only STE and *Eimeria* spp.) with a low prevalence (< 65.17%) when compared to the other three districts (Colca, Luricocha and Pacaycasa), where more than three types of parasites (STE, *Skrjabinema* spp., *Trichuris* spp., *Moniezia* spp. and *Eimeria* spp.) were identified, showing high percentages of infection (53.12 – 100%). These dissimilarities would be probably related to differences in health management among the goat herds. For instance, goat farmers in Ocaña district use a health plan calendar in which they consider deworming their animals one to two times a year. In contrast, farmers in the districts

Table 6 Fecal egg counts (FEC's) of eggs/oocysts per gram of feces (epg/opg) of gastrointestinal parasites in goats according to location, sex, and age, in Ayacucho, Peru

Parasite	Variables	N° of examined	EPG			X^2	*p*-value
			Arithmetic mean	SD	Range		
Location							
STE	Ocaña	89	743.82	1523.47	0–8300	107.9500	< 0.001
	Colca	76	3334.87	3631.82	0–20,250		
	Pacaycasa	64	199.22	320.40	0–1400		
	Luricocha	25	454.00	424.24	0–1500		
Eimeria spp.	Ocaña	89	534.27	814.28	0–4200	38.3860	< 0.001
	Colca	76	2423.03	6054.68	0–44,250		
	Pacaycasa	64	1014.53	1069.60	0–5700		
	Luricocha	25	1490.00	1313.63	0–5850		
Sex							
STE	Female	205	1341.46	2584.94	0–20,250	0.0051	0.9428
	Male	49	1403.06	2406.47	0–11,650		
Eimeria spp.	Female	205	1438.44	3848.05	0–44,250	0.3791	0.5381
	Male	49	795.92	893.49	0–3900		
Age							
STE	MT	67	1172.39	2087.01	0–11,650	9.2325	0.0555
	2T	49	706.12	1542.07	0–7850		
	4T	56	1406.25	2049.97	0–7750		
	6T	18	1819.44	2415.46	0–8900		
	FM	64	1860.94	3707.62	0–20,250		
Eimeria spp.	MT	67	2229.85	6373.45	0–44,250	3.2634	0.5148
	2T	49	792.86	1031.23	0–5850		
	4T	56	1180.89	1514.12	0–7400		
	6T	18	611.11	621.09	0–1950		
	FM	64	1070.31	1422.63	0–8850		

of Colca, Pacaycasa, and Luricocha do not adopt any type of sanitary management, there is overcrowding of animals with reduced resting areas, no sanitary measures are applied and they were not aware of any proper deworming calendars (Chakrabortty et al. 2023). Moreover, these districts have mostly mixed herds (along with sheep) which creates conditions for greater exposure (Chartier and Paraud 2012).

There was a significant correlation between the prevalence of *Skrjabinema* spp., *Moniezia* spp., and *Eimeria* spp. and sex ($p < 0.05$), which would suggest that sex constitutes a risk factor for parasitosis. Our findings would be related to the fact the ratio of males and females sampled was 1:4. Thuswise, there were significant differences in the prevalence of gastrointestinal parasites between males and females in a study performed in Ica, central Peru (Cáceres et al. 2021) and northern Peru (Chinga 2022), as well as in other countries such as Bangladesh (Chakrabortty et al. 2023), South Africa (Mpofu et al. 2020) and Thailand (Wuthijaree et al. 2022); where females showed to be more susceptible to parasitosis. This was attributed to the physiological status of females during pregnancy, parturition, and lactation, where the level of stress is higher so that the animal's immunity declines, increasing the probability of infection (Golo et al. 2017; Owusu et al. 2016).

In this study, there were no significant differences between the prevalence of STE, *Skrjabinema* spp., and *Eimeria* spp. and age ($p > 0.05$). Goats of all ages (MT, 2T, 4T, 6T, and FM) presented the highest susceptibility to STE and *Eimeria* spp. This could also be explained because all animals, regardless of age, are raised under the same husbandry practices and graze in the same pastures, therefore, having the same probability of infection with gastrointestinal parasites. However, other authors have reported significant differences related to age (Cáceres et al. 2021; Dey et al. 2020; Hossain et al. 2021; Mpofu et al. 2020), stating that adults would have greater acquired immunity, through continuous previous infections, which in turn increases the probability of eliminating parasites during an infection (Mpofu et al. 2020; Sorobete et al. 2018). Otherwise, there was a higher susceptibility to *Skrjabinema* spp. (16.33%) in young animals (2T), as well as *Trichuris* spp. (8.96%) in MT goats, unlike *Moniezia* spp. (11.11%) in adult animals (6T). The prevalence of *Trichuris* spp. in kids could be attributed to a nutritional deficit resulting from poor grazing practices (Hoste et al. 2008), an inefficient immune response (Cáceres

et al. 2021; Hossain et al. 2021) and/or the post-weaning stress (Verma et al. 2018), together with weather conditions that benefit the survival of parasites (Ratanapob et al. 2012). However, the relative prevalence of *Moniezia* spp. observed in category 6T, could be also related to the reduced number of animals sampled in that category, regardless of the influence of other factors (Rabbi et al. 2013).

The parasite burden, expressed in FEC, constitutes an indicator of the intensity of infection and the level of contamination in grasslands (Cabaret et al. 1998; Egbe-Nwiyi et al. 2019). The FEC in Colca district turned out to be higher (3334.87 ± 3631.82) than those recorded in the districts of Ocaña, Luricocha, and Pacaycasa. This high value observed in Colca could be a consequence of the level of susceptibility of the herds (Cabaret et al. 1998), specific environmental and/or geographical conditions (Rabbi et al. 2013; Ratanapob et al. 2012), and the lack of anthelmintic usage (Chakrabortty et al. 2023). The FEC for *Eimeria* spp. in all four districts showed to be moderate to high. These values could be related to seasonality (dry season) (Figueroa et al. 2018; Mpofu et al. 2020), or the lack of control programs for *Eimeria* spp. infection (Windsor et al. 2018), such as the use of anticoccidial drugs (Diao et al. 2022). However, it is noteworthy to mention that goats infected in most of the herds sampled do not present any clinical signs related to coccidiosis (Chartier and Paraud 2012). This finding could be explained by the absence of other risk factors related to clinical disease.

Regarding age, most goats showed high burdens of STE and *Eimeria* spp., except in the groups 2T for STE and *Eimeria* spp., and the groups 6T for *Eimeria* spp., where the FEC's were moderate ($p > 0.05$). According to sex, the FEC was high in both females and males, with no significant differences ($p > 0.05$). These high levels of infection could potentially lead to anemia, malnutrition, and gastroenteritis which in turn could increase mortality (Wuthijaree et al. 2022). On the other hand, there are reports where females showed higher FEC's of STE on Strongyles, but low values for *Eimeria* spp. (Wuthijaree et al. 2022). Other studies did not find significant differences between females and males (Chakrabortty et al. 2023).

Finally, our results showing moderate to high prevalence of parasitosis and variable levels of parasitic burden in goat herds should lead to tailor-made deworming programs, with optimized strategies, taking into account the risk factors for disease (Salgado and Santos 2016; Wuthijaree et al. 2022). It is important to highlight that these results were obtained during the dry season, when climate conditions are not suitable for the development of infective stages in the grasslands, nevertheless, the results of prevalence and parasitic burden could prove the great capacity of adaptation exhibited by gastrointestinal parasites which allow them to continue its life cycle even under harsh conditions.

Conclusion

A high overall prevalence of gastrointestinal parasites (87.80%), including nematodes, cestodes, and coccidia is reported in goat herds free grazing from Ayacucho. The present study also shows that location constituted a risk factor for gastrointestinal parasite infection. In addition, some parasites were significantly associated with sex (*Skrjabinema* spp., *Monieza* spp. and *Eimeria* spp.) and age (*Trichuris* spp. and *Monieza* spp.). This work is one of the first of its kind carried out in Ayacucho, Peru and it may contribute to the development of suitable and sustainable deworming programs against gastrointestinal parasites in goats, avoiding anthelmintic resistance.

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Data availability The data sets generated and/or analyzed during the present study are not publicly available due to the confidentiality maintained by the research institution which has funded the study but can be obtained from the corresponding author upon reasonable request.

Declarations

Ethical approval Verbal consent was obtained from animal owners for the collection of feces from the rectum of their goats. The authors declare that the research work was carried out following the Code of Ethics for experiments with animals, as reflected in the regulations: http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm.

Competing interests The authors declare that they have no relevant financial or non-financial interests to disclose. The authors declare that they have no competing interests to declare for the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or nonfinancial interest in the subject matter discussed in this manuscript.

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