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 aimed to assess 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 (84), 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* sp. (7.87%), *Trichuris* sp. (3.15%) and *Moniezia* spp. (3.15%). There was no significant association between the location and the presence of parasites ($p<0.05$), however, there was a higher prevalence and parasite variety in Luricocha. Sex and age did not have a significant association with parasitosis ($p>0.05$), except in prevalences of *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 and Eimeria spp. the need to implement strategic control and prevention programs in goats, where location and sex were found to be the most relevant risk factors for parasitosis in Ayacucho, Peru.

1. 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, 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 & 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 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 & 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 & 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 conditions for 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, the few epidemiological studies conducted on gastrointestinal parasitosis infection in goats in Ayacucho have been very limited. The present study aimed to assess the prevalence of gastrointestinal parasite species and their parasitic burden in goats raised under extensive systems in Ayacucho, Peru.

2. Materials and methods

2.1 Study area

The study was carried out in the districts of Ocaña, Colca, Pacaicasa, 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 to 3500 m.a.s.l. (PCM, 2017). According to official data, the districts of study present 270, 182, 164, and 136 goat farmers, respectively (MINAGRI, 2021).

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.

2.2 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 known populations, with an expected prevalence of 70%, a confidence level of 95%, and an absolute precision of 6% (Thrusfield, 2005). A total of 254 goats from 33 herds were randomly sampled, of which 89 samples were collected from Ocaña; 76 from Colca; 64 from Pacaycasa, and 25 from Luricocha, considering the limitations on distances and the number of animals in every herd of the goat farmers.

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 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).

2.3 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. 30407: “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.

2.4 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 minutes. 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).

2.5 Data analysis

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

3. Results

3.1 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 86.2%, followed by strongyle type eggs (STE) at 76.8%, and *Moniezia* spp. (3.1%) *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 and Fig. 2.

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

Table 2 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%). *Skrjabinema* spp. was identified in the districts of Luricocha (48.00%) and Pacaycasa (12.50%), and was not recorded in Ocaña and Colca. *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 in the districts of Luricocha, Colca, and Pacaycasa. Regarding *Eimeria* spp., the prevalences found were 100%, 98.44%, and 96.05% for Luricocha, Pacaycasa and Colca, respectively.

Table 2
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)		

Prevalence of parasites according to sex is shown in Table 3. No significant association was found between sex and the prevalence of goats from Ayacucho ($p > 0.05$).

Table 3
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)		

There was no significant association between the prevalence of *Skrjabinema* spp. and *Eimeria* spp. and age of goats ($p > 0.05$). In contrast, a significant relationship ($p < 0.05$) was found between age and the prevalence of STE, *Trichuris* spp., and *Moniezia* spp. (Table 4). The prevalence of STE was above 50% in all age categories. *Skrjabinema* spp. was the most common with a prevalence of 16.33% in goats of the 2T category. *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, not being reported in 4T and FM. The presence of *Eimeria* spp. in all age categories was higher than 80%.

Table 4
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)		

3.2 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 5. 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).

Table 5
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	0–20250		
	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	0–44250		
	Pacaycasa	64	1014.53	1069.60	0–5700		
	Luricocha	25	1490.00	1313.63	0–5850		
Sex							
STE	Female	205	1341.46	2584.94	0–20250	0.0051	0.9428
	Male	49	1403.06	2406.47	0–11650		
Eimeria spp.	Female	205	1438.44	3848.05	0–44250	0.3791	0.5381
	Male	49	795.92	893.49	0–3900		
Age							
STE	MT	67	1172.39	2087.01	0–11650	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	0–20250		
Eimeria spp.	MT	67	2229.85	6373.45	0–44250	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		

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.

4. 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). Thailand with 87.2% (Wuthijaree et al., 2022), and 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. Several environmental variables and differences in the breeding system constitute important variables that could explain the differences in the prevalence of gastrointestinal parasites in goats in free grazing systems (Bogale 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%. Similar results 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 lower prevalence (63.7%) for STE, but a higher prevalence for *Skrjabinema* spp. (12.9%) and *Trichuris* spp (4.1%). 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).

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). 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 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 & Paraud, 2012).

There was no significant correlation between the prevalence of gastrointestinal parasites and sex ($p > 0.05$), which would suggest that sex does not constitute a risk factor for parasitosis. Our findings would be related to the fact that both females and males were under the same type of management during their breeding, therefore, with the same probability of infection (Mahlehla, 2017; Mpofu et al., 2020; Dabasa et al., 2017). However, it is noteworthy the fact that the ratio of males and females sampled was 1:4. In contrast to our results, 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).

There was a significantly greater infection with *Trichuris* spp. (8.96%) in young animals (MT), and a higher susceptibility to *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). There were no significant differences between the prevalence of STE, *Skrjabinema* spp., and *Eimeria* spp. regarding age ($p > 0.05$). 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).

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 & Paraud, 2012). This finding could be explained by the absence of other risk factors related to clinical disease.

Most of the goat herds showed high parasite burdens, except in the groups 2T and 6T, 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, as well (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 & 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.

5. Conclusion

A high overall prevalence of gastrointestinal parasites (87.80%), including nematodes, cestodes, and *Eimeria* spp. is reported in goat herds from Ayacucho. The present study also shows that location and sex constituted risk factors for gastrointestinal parasite infection. This work is one of the first of its kind carried out in Ayacucho, Peru and it may contribute to the development of suitable deworming programs against gastrointestinal parasites in goats.

Declarations

- 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.

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.

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Ethical statement

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/legi sl ation_en.htm.

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Author Contributions

W.P.G., D.G.P. and V.F.P.: Conceptualization; W.P-G., M.R.H. and V.F.P.: Methodology; W.P.G., M.R.H. and V.F.P.: Investigation; W.P.G.: Statistical analysis; W.P.G.: Data analysis and interpretation; W.P.G.: Manuscript writing; D.G.P. and D.Z.R.: Manuscript review and edition. All authors have read and accepted the latest version for the submission of the manuscript.

References

1. Belina, D., Giri A., Mengistu, S., Eshetu A., 2017. Gastrointestinal nematodes in ruminants: the parasite burden, associated risk factors and anthelmintic utilization practices in selected districts of East and Western Hararghe, Ethiopia. J Vet Sci Techno. 8(2):433–9. https://doi.org/10.4172/2157-7579.1000433
2. Besier, R.B., Kahn, L.P., Sargison, N.D., Van Wyk, J.A., 2016. Pathophysiology, ecology, and epidemiology of Haemonchus contortus infection in small ruminants. Adv Parasitol, 93 : 95-143. https://doi.org/10.1016/bs.apar.2016.02.022v.
3. Bogale, B., Muluneh, J., & Chanie, M., 2014. Major Gastrointestinal Nematodes of Small Ruminants in Dembia District, Northwest Ethiopia. European Journal of Applied Sciences, 6(2), 30–36. https://scholar.archive.org/work/nknzuchqy5fitkwcc4fjjz3hsu/access/wayback/https://nadre.ethernet.edu.et/record/840/files/64JejawBasaznewandMe
4. Bowman, D.D., 2014. Georgis' Parasitology for Veterinarians-E-Book. 10th ed. Elsevier Health Sciences. Ithaca. New York.
5. Cabaret, J., Gasnier, N., & Jacquiet, P., 1998. Faecal egg counts are representative of digestive-tract strongyle worm burdens in sheep and goats. Parasite, 5(2), 137–142. https://doi.org/10.1051/parasite/1998052137
6. Cáceres, M. V., Pinedo, R. Y. V., & Chávez, A. V., 2021. Gastrointestinal nematodiasis in goats from Ica, Peru. Revista de Investigaciones Veterinarias Del Peru, 32(5), 21342. https://doi.org/10.15381/rivep.v32i5.21342
7. Cardoso, C. P., Cardozo, L. L., da Silva, B. F., & do Amarante, A. F. T., 2012. Gastrointestinal parasites in goats from Monte Castelo, Santa Catarina, Brazil. Revista Brasileira de Parasitologia Veterinaria, 21(2), 148–150. https://doi.org/10.1590/s1984-29612012000200014

8. Chacón-Hernández, P., & Boschini-Figueroa, C., 2015. Crecimiento del ganado caprino en una finca del Valle Central de Costa Rica. Agronomía Mesoamericana, 27(1), 159. https://doi.org/10.15517/AM.V27I1.21895
9. Chakrabortty, M., Shohana, N. N., Begum, N., Dey, A. R., Rony, S. A., Akter, S., & Alam, M. Z., 2023. Diversity and prevalence of gastrointestinal parasites of Black Bengal goats in Natore, Bangladesh. Journal of Advanced Veterinary and Animal Research, 10(1), 80–87. https://doi.org/10.5455/javar.2023.j655
10. Charlier, J., Rinaldi, L., Musella, V., Ploeger, H. W., Chartier, C., Vineer, H. R., Hinney, B., von Samson-Himmelstjerna, G., Băcescu, B., Mickiewicz, M., Mateus, T. L., Martinez-Valladares, M., Quealy, S., Azaizeh, H., Sekovska, B., Akkari, H., Petkevicius, S., Hektoen, L., Höglund, J., Claerebout, E., 2020. Initial assessment of the economic burden of major parasitic helminth infections to the ruminant livestock industry in Europe. Preventive Veterinary Medicine, 182. https://doi.org/10.1016/J.PREVETMED.2020.105103
11. Chartier, C., & Paraud, C., 2012. Coccidiosis due to Eimeria in sheep and goats, a review. Small Ruminant Research, 103(1), 84–92. https://doi.org/10.1016/j.smallrumres.2011.10.022
12. Chinga, M., 2022. Prevalencia de parásitos gastrointestinales en caprinos (Capra aegagrus hircus) del Distrito de Querecotillo, Provincia de Sullana, Departamento de Piura – Perú. – 2021 [Universidad Nacional Hermilio Valdizán]. http://repositorio.unheval.edu.pe/handle/20.500.13080/7981
13. Dabasa, G., Shanko, T., Zewdei, W., Jilo, K., Gurmesa, G., Abdela, N., 2017. Prevalence of small ruminant gastrointestinal parasites infections and associated risk factors in selected districts of Bale zone, South Eastern Ethiopia. J. Parasitol. Vector Biol. 9(6):81–88 https://doi.org/10.5897/JPVB2017.0286.
14. Dey, A. R., Begum, N., Alim, M. A., Malakar, S., Islam, M. T., & Alam, M. Z., 2020. Gastro-intestinal nematodes in goats in Bangladesh: A large-scale epidemiological study on the prevalence and risk factors. Parasite Epidemiology and Control, 9. https://doi.org/10.1016/j.parepi.2020.e00146
15. Diao, N. C., Zhao, B., Chen, Y., Wang, Q., Chen, Z. Y., Yang, Y., Sun, Y. H., Shi, J. F., Li, J. M., Shi, K., Gong, Q. L., & Du, R., 2022. Prevalence of Eimeria Spp. Among Goats in China: A Systematic Review and Meta-Analysis. Frontiers in Cellular and Infection Microbiology, 12. https://doi.org/10.3389/fcimb.2022.806085
16. Diop, G., Yanagida, T., Hailemariam, Z., Menkir, S., Nakao, M., Sako, Y., Ba, C.T., Ito A., 2015. Genetic characterization of Moniezia species in Senegal and Ethiopia. Parasitol Int, 64(5):256-60. https://doi.org/10.1016/j.parint.2015.02.008 Epub 2015 Mar 6. PMID: 25752566.
17. Egbe-Nwiyi, T. N., Paul, B. T., & Cornelius, A. C., 2019. Coprological detection of equine nematodes among slaughtered donkeys (Equus asinus) in Kaltungo, Nigeria. Veterinary World, 12(12), 1911–1915. https://doi.org/10.14202/vetworld.2019.1911-1915
18. Emiru, B., Amede, Y., Tigre, W., Feyera, T., & Deressa, B., 2013. Epidemiology of gastrointestinal parasites of small ruminants in Gechi District, Southwest Ethiopia. Adv Biol Res, 7(5), 169-174. https://doi.org/10.5829/idosi.abr.2013.7.5.74176
19. Figueroa, A., Pineda, S., Godínez, F., Vargas, D., & Rodriguez, E., 2018. Parásitos gastrointestinales de ganado bovino y caprino en Quechultenango. Agroproductividad, 11(6), 97–104. http://www.revista-agroproductividad.org/index.php/agroproductividad/article/view/438
20. Golo, D., Wubishet, Z., Tadelle, S., Kula, J., Gete, G., & Garu, L., 2017. Composition, prevalence and abundance of Ixodid cattle ticks at Ethio-Kenyan Border, Dillo district of Borana Zone, Southern Ethiopia. Journal of Veterinary Medicine and Animal Health, 9(8), 204–212. https://doi.org/10.5897/jvmah2017.0589
21. Hossain, M., Sultana, N., Akter, S., Labony, S., & Anisuzzaman, A., 2021. A Retrospective Survey of Gastrointestinal Parasites in Livestock of Hilly Areas in Mymensingh. Journal of Bangladesh Agricultural University, 19(3), 332. https://doi.org/10.5455/jbau.93883
22. Hussein, H. A., Abdi, S. M., Ahad, A. A., & Mohamed, A., 2023. Gastrointestinal nematodiasis of goats in Somali pastoral areas, Ethiopia. Parasite Epidemiology and Control, 23, e00324. https://doi.org/10.1016/j.parepi.2023.e00324
23. Hoste, H., Torres-Acosta, J. F. J., & Aguilar-Caballero, A. J., 2008. Nutrition-parasite interactions in goats: Is immunoregulation involved in the control of gastrointestinal nematodes? In Parasite Immunology (Vol. 30, Issue 2, pp. 79–88). Parasite Immunol. https://doi.org/10.1111/j.1365-3024.2007.00987.x
24. Income, N., Tongshoob, J., Taksinoros, S., Adisakwattana, P., Rotejanaprasert, C., Maneekan, P., & Kosoltanapiwat, N., 2021. Helminth Infections in Cattle and Goats in Kanchanaburi, Thailand, with Focus on Strongyle Nematode Infections. Veterinary Sciences, 8(12). https://doi.org/10.3390/VETSCI8120324
25. Mahlehla M., 2017. Evaluating the Prevalence, Faecal Egg Count and Control Methods of Gastrointestinal Parasites of Merino Sheep in Lesotho. Lesotho: Master of Sciences (Animal Science) Dissertation, National University of Lesotho.
26. Mendoza Chauca, M., 2023. Prevalence of gastrointestinal parasites in Creole goats during the rainy season in the district of Pacaycasa. Veterinary doctor thesis.. https://repositorio.unsch.edu.pe/bitstream/UNSCH/5558/1/TESIS%20MV206_Men.pdf (accessed 23 January 2023).
27. MINAGRI., 2021. Ministerio Nacional de Agricultura y Riego. Servicio de Información Estadística Agrarian. Lima, Perú; https://siea.midagri.gob.pe/portal/siea_bi/index.html (accessed 23 August 2023).
28. Monau, P., Raphaka, K., Zvinorova-Chimboza, P., & Gondwe, T., 2020. Sustainable Utilization of Indigenous Goats in Southern Africa. Diversity 2020, Vol. 12, Page 20, 12(1), 20. https://doi.org/10.3390/D12010020
29. Mpofu, T. J., Nephawe, K. A., & Mtileni, B., 2022. Prevalence and resistance to gastrointestinal parasites in goats: A review. Veterinary World, 15(10), 2442. https://doi.org/10.14202/vetworld.2022.2442-2452.
30. Mpofu, T. J., Nephawe, K. A., & Mtileni, B., 2020. Prevalence of gastrointestinal parasites in communal goats from different agro-ecological zones of South Africa. Veterinary World, 13(1), 26–32. https://doi.org/10.14202/vetworld.2020.26-32
31. Navarro, A., 2017. Optimización de técnicas coprológicas para el diagnóstico parasitario en el mono vervet (chlorocebus pygerythrus) [Universidad CEU - Cardenal Herrera]. https://dialnet.unirioja.es/servlet/tesis?codigo=298425&info=resumen&idioma=SPA
32. Nisa R.U., Tantray A.Y., Kouser N., Allie K.A., Wani S.M., Alamri S.A., Alyemeni M.N., Wijaya L., Shah A.A., 2021. Influence of ecological and edaphic factors on biodiversity of soil nematodes. Saudi J. Biol. Sci. 28:3049–3059. https://doi.org/10.1016/j.sjbs.2021.02.046

33. Owusu, M., Sekyere, J.O., Adzitey, F., 2016. Prevalence and burden of gastrointestinal parasites of Djallonke sheep in Ayeduase, Kumasi, Ghana. Vet. World. 9(4):361–364. https://doi.org/10.14202/vetworld.2016.361-364.
34. PCM., 2017. Cajamarca: información territorial - Campañas - Presidencia del Consejo de Ministros - Plataforma del Estado Peruano. https://www.gob.pe/institucion/pcm/campañas/4224-ayacucho-informacion-territorial (accessed 17 December 2023).
35. Rabbi, A., Islam, A., Anisuzzaman, M., Majumder, S., & Rahman, M., 2013. Does Feeding System Influence Parasitism in Black Bengal Goats in Bangladesh Progressive Agriculture, 22(1–2), 85–95. https://doi.org/10.3329/pa.v22i1-2.16470
36. Rahman, M. A., Labony, S. S., Dey, A. R., & Alam, M. Z., 2017. An epidemiological investigation of gastrointestinal parasites of small ruminants in Tangail, Bangladesh. Journal of the Bangladesh Agricultural University, 15(2). https://doi.org/10.3329/JBAU.V15I2.35071
37. Ratanapob, N., Arunvipas, P., Kasemsuwan, S., Phimpraphai, W., & Panneum, S., 2012. Prevalence and risk factors for intestinal parasite infection in goats raised in Nakhon Pathom Province, Thailand. Tropical Animal Health and Production, 44(4), 741–745. https://doi.org/10.1007/s11250-011-9954-6
38. Salgado, J. A., & Santos, C. de P., 2016. Panorama da resistência anti-helmíntica em nematoides gastrointestinais de pequenos ruminantes no Brasil. In Revista Brasileira de Parasitologia Veterinaria (Vol. 25, Issue 1, pp. 3–17). Rev Bras Parasitol Vet. https://doi.org/10.1590/S1984-29612016008
39. SENAMHI., 2018. National Service of Meteorology and Hydrology of Peru. Ministerio del ambiente. https://www.senamhi.gob.pe/?&p=monitoreo-hidrologico (accessed 23 August 2023)
40. Singh, A. K., Das, G., Roy, B., Nath, S., Naresh, R., & Kumar, S., 2015. Prevalence of gastro-intestinal parasitic infections in goat of Madhya Pradesh, India. Journal of Parasitic Diseases : Official Organ of the Indian Society for Parasitology, 39(4), 716–719. https://doi.org/10.1007/S12639-014-0420-Z
41. Sorobetea, D., Svensson-Frej, M., Grencis, R., 2018. Immunity to gastrointestinal nematode infections. Mucosal. Immunol. 11(2):304–315. https://doi.org/10.1038/mi.2017.113
42. Storey, B. E., 2015. Fecal egg counts: uses and limitations. What works with worms at: Pretoria, South Africa, 1-9.
43. Taylor M., Coop R., Wall R., 2007. Blackwell Publishing; Oxford, UK. Veterinary Parasitology. 3rd ed. https://books.google.com.pe/books/about/Veterinary_Parasitology.html?id=tPpEofdsZ5gC&redir_esc=y (accessed 15 December 2023)
44. Thrusfield, M., 2005. Veterinary epidemiology. Oxford, England: Ed Blackwell Science. 592 p
45. Tumusiime, M., Ndayisenga, F., & Ntampaka, P., 2022. Prevalence of Gastrointestinal Nematodes, Cestodes, and Protozoans of Goats in Nyagatare District, Rwanda. Veterinary Medicine: Research and Reports, Volume 13, 339–349. https://doi.org/10.2147/vmrr.s389336
46. Urquhart, G. M., Armour, J., Duncan, J. L., Dunn, A. M., & Jennings 2nd, F. W., 1996. Veterinary Parasitology. United Kingdom, 307.
47. Verma, R., Sharma, D. K., Paul, S., Gururaj, K., Dige, M., Saxena, V. K., Rout, P. K., Bhusan, S., & Banerjee, P. S., 2018. Epidemiology of common gastrointestinal parasitic infections in goats reared in semi-arid region of India. Journal of Animal Research, 8(1), 39–45. https://doi.org/10.30954/2277-940X.2018.00150.07
48. Weny, G., Okwee-Acai, J., Okech, S. G., Tumwine, G., Ndyanabo, S., Abigaba, S., & Goldberg, T. L., 2017. Prevalence and Risk Factors Associated with Hemoparasites in Cattle and Goats at the Edge of Kibale National Park, Western Uganda. The Journal of Parasitology, 103(1), 69–74. https://doi.org/10.1645/16-33
49. Windsor, P. A., Nampanya, S., Putthana, V., Keonam, K., Johnson, K., Bush, R. D., & Khounsy, S., 2018. The endoparasitism challenge in developing countries as goat raising develops from smallholder to commercial production systems: A study from Laos. Veterinary Parasitology, 251, 95–100. https://doi.org/10.1016/j.vetpar.2017.12.025
50. Wuthijaree, K., Tatsapong, P., & Lambertz, C., 2022. The prevalence of intestinal parasite infections in goats from smallholder farms in Northern Thailand. Helminthologia (Poland), 59(1), 64–73. https://doi.org/10.2478/helm-2022-0007
51. Zanzani, S. A., Gazzonis, A. L., Di Cerbo, A., Varady, M., & Manfredi, M. T., 2014. Gastrointestinal nematodes of dairy goats, anthelmintic resistance and practices of parasite control in Northern Italy. BMC Veterinary Research, 10. https://doi.org/10.1186/1746-6148-10-114
52. Zaros, L. G., Coutinho, L. L., Sider, L. H., de Medeiros, H. R., das Neves, M. R. M., Benvenuti, C. L., Navarro, A. M. do C., & Vieira, L. da S., 2010. Evaluation of reference genes for real-time PCR studies of Brazilian Somalis sheep infected by gastrointestinal nematodes. Genetics and Molecular Biology, 33(3), 486–490. https://doi.org/10.1590/S1415-47572010000300018.

Figures

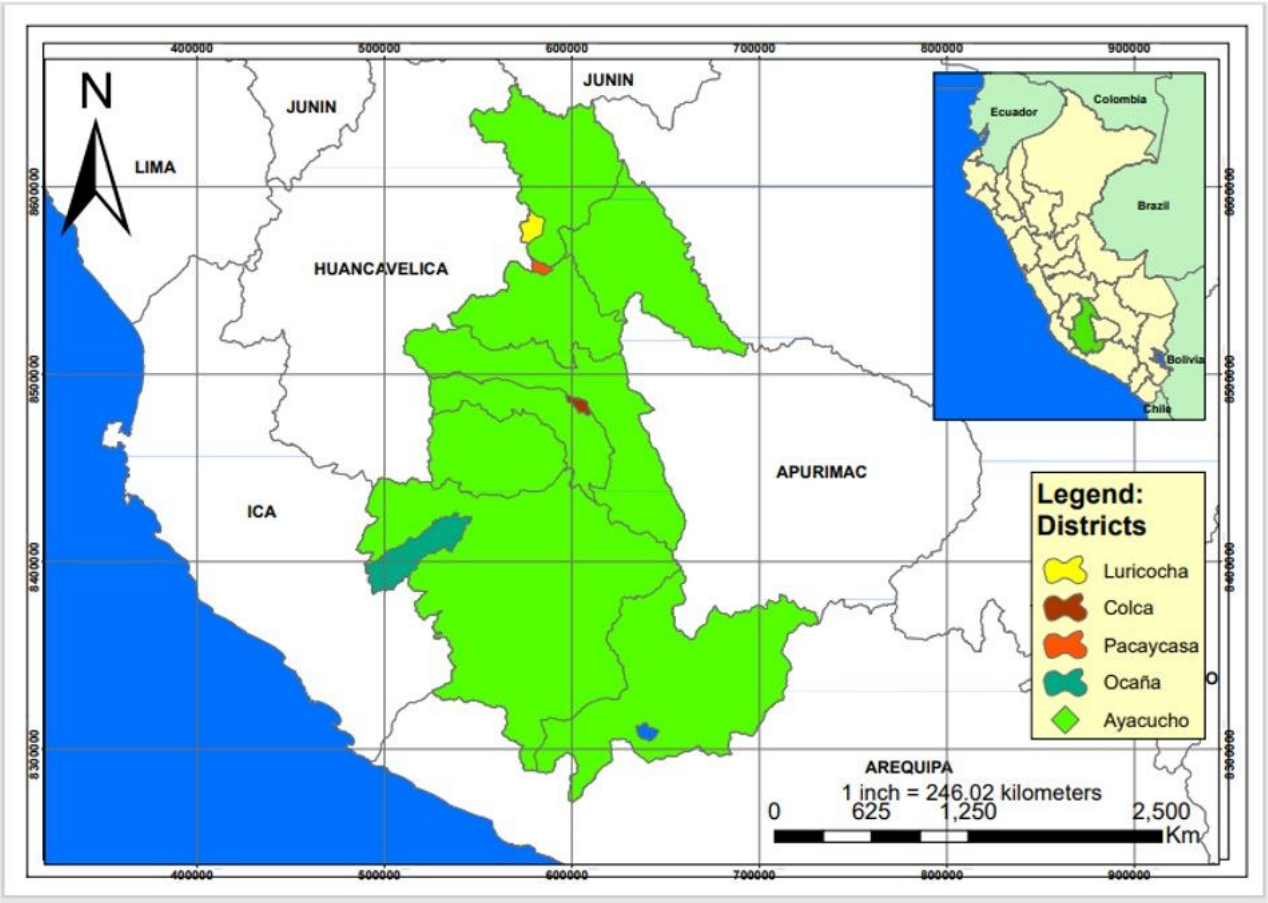

Figure 1

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

Figure 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.