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RESEARCH

Cross-sectional study of gastrointestinal helminthosis in goats from three ecosystems in Peru: Prevalence and associated factors

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Abstract

Gastrointestinal parasitism is a health issue in livestock, particularly in non-intensive farming systems. This research evaluated the prevalence and risk factors associated with gastrointestinal helminths in goats from three ecosystems in Peru: the Andean shrubland (Ancash), dry forest (Lambayeque), and coastal valley (Lima). The study used a cross-sectional design, with random sampling of goats from extensive production systems in each ecosystem. A total of 819 fecal samples were collected and analyzed using qualitative and quantitative parasitological methods. Additionally, coproculture was performed to identify infective larvae of nematodes. The FAMACHA© index was used to assess anemia levels, while body condition scores were recorded to evaluate the nutritional status of the animals. The highest prevalence was recorded in the Andean shrubland (74.2%), followed by the dry forest (63.1%), whereas the coastal valley had the lowest prevalence (59.3%). The most frequently identified helminths were strongyle-type eggs (49.9%) and *Skrjabinema* sp. (33.7%), while *Moniezia* sp. (5.4%) and *Fasciola hepatica* (1.1%) were detected at lower frequencies. The identification of L3 infective larvae of *Haemonchus* sp., *Trichostrongylus* sp., *Cooperia* sp., *Strongyloides* sp., *Oesophagostomum* sp., *Bunostomum* sp., and *Teladorsagia* sp. highlighted the diversity of gastrointestinal nematodes affecting goats in Peru. Multivariable analysis revealed that anemia (FAMACHA $\geq$ 3; PR = 1.14), poor body condition (BCS 1–2; PR = 1.03), and age (2–6 teeths or full dentition; PR = 1.12 and 1.08, respectively) were associated with increased infection risk. Males had lower prevalence than females (PR = 0.80), and goats raised in the dry forest and coastal valley had lower risk than those from the Andean shrubland. These findings highlight the influence of physiological status and environmental conditions on parasite burden in goat herds.

Keywords Helminths · Parasitism · Epidemiology · FAMACHA · Goat

Introduction

Goat production is a highly relevant economic activity in various regions of the world, especially in rural areas, where goats represent a resource of significant social and cultural importance for local communities, both in Peru and in other countries (Gómez-Urviola et al. 2016; Monau et al. 2017; Villagra et al. 2015). Small farmers primarily raise these animals for milk and meat production due to their adaptability to diverse environmental conditions (Peacock and Sherman 2010; Sarria et al. 2014). However, one of the main challenges for goat farming is their high susceptibility to various diseases, including parasitic diseases, which can affect the health and productivity of the animals (Matthews 2016).

Goat farming in Peru plays a vital role in the livelihoods of numerous rural families, particularly in the coastal and Andean regions. The nation's goat population is estimated at approximately 2 million, with significant concentrations in departments such as Piura, Lima, Ayacucho, Ica, Lambayeque and Ancash. (CENAGRO 2012). The activity remains largely artisanal, with low production and income

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levels. Milk production is scarce, and there is minimal production of adult goat meat, despite the potential for both products (Arroyo 2007). For instance, in the coastal valleys of Lima, goat-rearing can be classified as extensive systems with three distinct groups differentiated by management practices and their production and marketing objectives (Paredes Chocce et al. 2024). In the highlands of southeastern Peru, a lack of good management practices in goat production without genetic improvement strategies is evident, and some small-scale goat farmers produce milk and cheese only for their own consumption (Palomino-Guerrera et al. 2024). On the other hand, in the dry forest of northern Peru, goat farming is predominantly extensive, with the main purpose of selling kid goats for meat, and the food sources (grasslands) are dependent on rainfall patterns (Temoche et al. 2025).

Gastrointestinal parasites in goats represent a significant problem for farmers, as they cause considerable economic losses by reducing productive performance, increasing morbidity and mortality, and generating additional costs due to antiparasitic treatments (Junkuszew et al. 2015; Mpofu et al. 2022). In addition, some parasites have the potential to infect humans, causing zoonotic diseases and affecting the health of people who are in direct contact with animals or contaminated products (Ganter 2015). Studies on parasites in goats in Peru are scarce, although the few available have reported variable prevalences of parasitic infections, which depend on factors such as geographic area, climatic conditions, type of livestock management, and availability of veterinary services (Cieza 2012; Barriga 2013; Cáceres et al. 2021; Chávez et al. 2021; Chinga 2022; Paredes 2022; Palomino-Guerrera et al. 2024). However, in many areas of Peru, information regarding the prevalence of parasites in goats remains limited.

Epidemiological studies are essential for the implementation of effective control and prevention strategies for various pathogens, which contribute significantly to improving animal health and welfare. In this context, the objective of this study was to determine the prevalence of gastrointestinal parasites in goats from different ecosystems from Peru, as well as to evaluate the risk factors associated with the presence of parasites.

Materials and methods

Study area

The study was carried out in the regions of Lima, Ancash and Lambayeque in Peru, based on the distribution of three ecosystems where goat farming is described in the country, according to Sarria et al. (2014), these being the northern coast, the west of the Andes, and central coast valleys. Within these regions, the main ecosystems or land covers in which goat farming is carried out were identified based on the peruvian national ecosystems map (Ministerio del Ambiente 2019). These ecosystems were the seasonally dry hill and mountain forest, seasonally dry plain forest, coastal desert, Andean shrubland, and agricultural zone (Fig. 1). The study area was located between the coordinates 5°31′26.4" S 79°58′55.20"W and 11°36′25.2″ S 77°12′54"W. The goat populations in the study area for the regions of Ancash, Lima, and Lambayeque were 6055, 1989 and 33682 heads, respectively (CENAGRO 2012).

Study design and sample collection

As part of the mandatory activities of the Ministry of Agriculture of Peru (MINAGRI, PROCAP), the situation of parasitic infections in goat livestock from various regions of Peru was evaluated. Sampling was conducted from July to September 2023. During this period, central coastal area experienced winter weather conditions, whereas the Andes and dry forest were in the dry season.

The required sample size was calculated using a formula for estimating a proportion in a finite population, based on the estimated goat population in each region. Although farms were selected through convenience sampling, animals were randomly selected within herds prioritizing individuals from different age groups and sexes to ensure representativeness. For the coastal valley area (coastal desert and agricultural areas) in the Lima region, a total of 258 sampled animals (10 herds) were collected; for the west of the Andes (Andean shrubland) in the Ancash region, 279 animals (9 herds) were evaluated; and for the northern coastal area (seasonally dry hill and mountain forest; seasonally dry plain forest) in the Lambayeque region, 282 animals (11 herds) were evaluated (Fig. 2). A total of thirty herds were assessed throughout the sampling period. These herds were in the districts of Huaral and Aucallama in the Lima region; the districts of Antonio Raymondi, Huayllacayan, Congas, and Pararin in Ancash; and the district of Olmos in the Lambayeque region (Suppl. 1).

Due to the lack of birth records in most herds, age was estimated using dentition status, a practical and widely used method in field studies across Latin America. Goats were grouped as follows: a) milk teeth: only deciduous incisors, indicating young animals (typically < 6 months); b) Two teeth: presence of the first pair of permanent central incisors, typically indicating animals around 1 year of age; c) Four teeth: presence of two pairs (4) of permanent incisors, corresponding to animals approximately 2 years old; d) Six teeth: presence of three pairs (6) of permanent incisors, generally associated with animals around 3 years old; and e) Full mouth: presence of all eight permanent incisors, indicating animals 4 years of age or older. This method, although

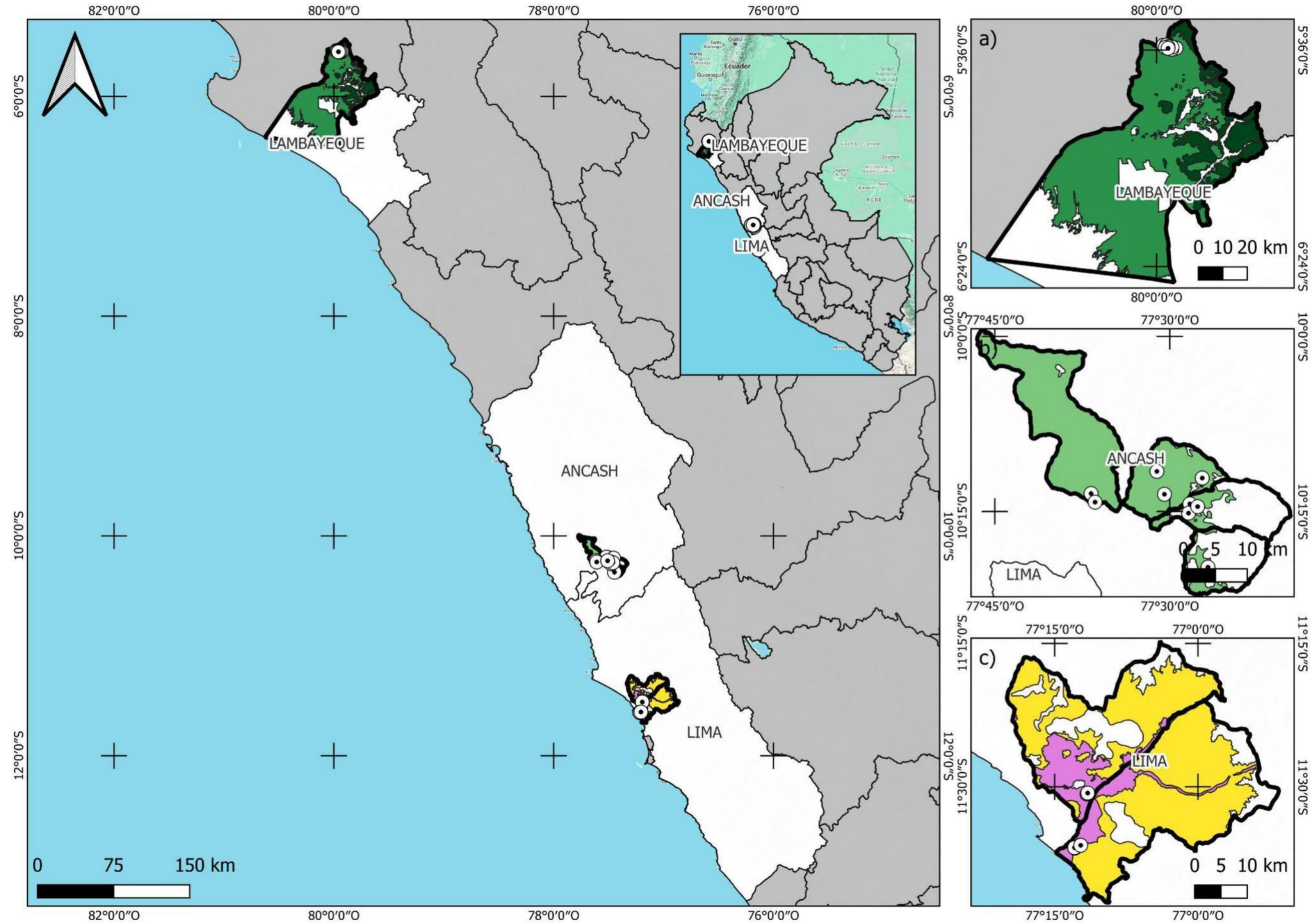

Fig. 1 Location map of study area and sampling points evaluated in the three ecosystems of Peru. **a**) Dry Forest ecosystems (Seasonal dry hill and mountain forest; seasonal dry plains forest); **b**) Andean Shrubland ecosystem (Andean shrubland); **c**) Coastal Valley (Coastal desert; Agricultural Zone). Legend: Dark green: seasonal dry hill and mountain forest; Green: seasonal dry plains forest; light green: Andean shrubland; Yellow: Coastal Desert; Violet: Agricultural zone

Fig. 2 Goat production systems of the three ecosystems: **a**) Coastal desert (Extensive based in crop stubble); **b**) Andean Shrubland (Extensive Non-transhumant); **c**) Andean Shrubland (Extensive Transhumant); **d**) Dry Forest (Extensive Non-transhumant)

less precise than chronological age, provides a field-adapted proxy.

Secondary information was recorded on the animals under study, such as age, sex, origin, body condition score (BCS), and FAMACHA© index (Malan et al. 2001). In this study, fecal samples were collected directly from the rectum of the animals (approximately 30 g per sample). These samples were stored in an isothermal box of expanded polystyrene with gel ice packs at ~ 4 °C and transported to the laboratory for analysis.

Coproparasitological analysis

The detection of parasite eggs was carried out using qualitative concentration techniques, including sedimentation tests (Valcárcel 2009) and flotation methods with Sheather solution (Taylor et al. 2016). Quantitative analysis was carried out using the modified McMaster technique (Valcárcel 2009).

The coproculture technique was used to obtain infective larvae of gastrointestinal nematodes (L3), for which an environment with humidity, temperature, and oxygenation favorable for the development and hatching of the larvae was provided (Hansen and Perry 1994). For their collection, the Baermann method was used, which is based on the migratory capacity of the larvae when they are suspended in water. The identification of the larval genus was determined using taxonomic keys based on morphological and biometric characteristics (Hansen and Perry 1994; Ueno and Gonçalves 1998).

An individual goat was considered positive for gastrointestinal helminths if at least one helminth egg was detected in the fecal sample through flotation or sedimentation techniques. This qualitative approach was adopted to maximize detection sensitivity and is consistent with standard parasitological surveillance in field settings. A farm was classified as positive if at least one of the sampled animals tested positive for gastrointestinal helminths. This conservative criterion was used to identify the presence of infection at the herd level.

Statistical analysis

Descriptive statistics were used to summarize the characteristics of the populations evaluated in the three regions, describing the age stratum, sex, FAMACHA index, and BCS of the animals evaluated. The overall and specific prevalence of each parasite identified in the three ecosystems was determined; the CI at 95% is presented. Subsequently, the BCS variable was recategorized into two classes: healthy if the BCS was between 2.5 and 4, and health problems if the BCS was between 1 and 2, according to what was mentioned by Ghosh et al. (2019). Likewise, the FAMACHA variable was recategorized into three classes: not anemic (1 and 2), mildly anemic (3), and severely anemic (4 and 5) (Suárez et al. 2014). To identify factors associated with gastrointestinal helminth infection, we used generalized linear models (GLM) to estimate prevalence ratios (PR) and 95% confidence intervals (CI). Variables such as age, sex, FAMACHA score, and body condition score were included as explanatory variables to explore their statistical association with infection status. Analyses were conducted in STATA, with significance set at $p < 0.05$.

Results

The study evaluated 819 goats sampled from three different ecosystems: Andean shrubland (34.1%), dry forest (34.4%), and coastal valley (31.5%) in 2023, reflecting a balanced representation of goats from diverse ecological systems in Peru. In terms of age distribution, the largest proportion of goats (41.9%) fell into the full mouth category, with the second-largest group (31.4%) belonging to the milk teeth classification. In terms of sex distribution, females comprised 91.3% of the sampled population, significantly outnumbering males (8.7%). This is due to the predominant role of female goats in reproduction and their importance in milk production. The FAMACHA© scoring system, used to assess anemia levels, revealed that most goats scored 3 (56.3%), and only a small proportion of goats scored 5 (1.6%) and 1 (0.2%). The BCS results showed that most goats scored between 2.5 (38.7%) and 2 (30.2%), reflecting a relatively moderate to poor overall body condition (Table 1). In the coastal valley ecosystem, we observed a greater number of animals in condition 2.5 (40.3%), whereas the lowest was found in condition 3.5, with only one individual. Similar to other ecosystems, conditions greater than three were either not seen in any animals (Andean shrubland) or were seen in very few individuals (dry forest).

The parasitological examination revealed a high overall prevalence of gastrointestinal helminths, with 65.7% (95% CI: 62.3–68.9) of fecal samples testing positive for at least one parasitic genus. Marked variation was observed among the three ecosystems studied, with the Andean shrubland in Ancash exhibiting the highest overall prevalence (74.2%), followed by the dry forest in Lambayeque (63.1%), and the coastal valley in Lima (59.3%) (Table 2).

When disaggregated by helminth group, nematodes were by far the most frequently detected parasites. Strongyle-type eggs (STE) were present in nearly half of the total sample (49.9%), and showed significant variation across ecosystems, reaching 67.4% in the Andean shrubland, 44.2% in the coastal valley, and only 37.9% in the dry forest ($p < 0.001$). *Skrjabinema* sp., was the second most prevalent nematode overall (33.7%), with frequencies of 41.5% and 34.5% in the

Table 1 Characteristics of goats according to age, sex, FAMACHA categorize, and body condition score (BCS), in the three different ecosystems from Peru, 2023

Variables	Andean shrubland n (%)	Dry forest n (%)	Coastal valley n (%)	Total n (%)
Age				
Milk teeth	119 (42.7)	48 (17.0)	90 (34.9)	257 (31.4)
2 tooth	24 (8.6)	28 (9.9)	20 (7.8)	72 (8.8)
4 tooth	21 (7.5)	35 (12.4)	14 (5.4)	70 (8.5)
6 tooth	15 (5.4)	38 (13.5)	24 (9.3)	77 (9.4)
Full mouth	100 (35.8)	133 (47.2)	110 (42.6)	343 (41.9)
Sex				
Female	247 (88.5)	264 (93.6)	237 (91.9)	748 (91.3)
Male	32 (11.5)	18 (6.4)	21 (8.1)	71 (8.7)
FAMACHA©				
1	-	-	2 (0.8)	2 (0.2)
2	52 (18.7)	67 (23.8)	50 (19.4)	169 (20.6)
3	159 (57.0)	162 (57.4)	140 (54.2)	461 (56.3)
4	64 (22.9)	45 (16.0)	65 (25.2)	174 (21.3)
5	4 (1.4)	8 (2.8)	1 (0.4)	13 (1.6)
BCS				
1	-	-	-	-
1.5	23 (8.2)	9 (3.2)	23 (8.9)	55 (6.7)
2	77 (27.6)	108 (38.3)	62 (24.0)	247 (30.2)
2.5	101 (36.2)	112 (39.7)	104 (40.3)	317 (38.7)
3	78 (28.0)	52 (18.4)	59 (22.9)	189 (23.1)
3.5	-	1 (0.4)	9 (3.5)	10 (1.2)
4	-	-	1 (0.4)	1 (0.1)
4.5	-	-	-	-
5	-	-	-	-

BCS: body condition index

dry forest and coastal valley, respectively. Other nematodes identified included *Nematodirus* sp. (5%), *Strongyloides* sp. (3.1%) and *Trichuris* sp. (2.1%), all with significantly lower prevalence and restricted distribution.

Regarding cestodes, *Moniezia* sp. was detected in 5.4% of samples, with the highest prevalence observed in the dry forest (7.8%), suggesting favorable intermediate host conditions in that environment. Trematode infection was infrequent overall. *Fasciola* sp., the causative agent of fasciolosis, was observed in only 1.1% of goats, and was almost exclusively detected in the Andean shrubland, aligning with the known altitudinal distribution of the intermediate snail host in Peru.

In addition to egg detection (Fig. 3) via sedimentation and flotation, coproculture and Baermann techniques enabled the identification of infective third-stage larvae (L3) of several important gastrointestinal nematodes, including *Strongyloides* sp., *Cooperia* sp., *Haemonchus* sp., *Trichostrongylus* sp., *Oesophagostomum* sp., and *Teladorsagia* sp. The presence of these genera confirms ongoing transmission cycles and supports the need for targeted control measures.

Regarding the parasite load, the highest proportion of animals had a low number of eggs (< 50 epg) for all the nematodes or parasitic forms found. In addition, a statistically significant difference was found between the type of ecosystem and the STE load ($p < 0.001$); in this sense, a higher load of STE (> 550 epg) was found in the Andean shrubland (Table 3).

The analysis revealed notable variations by age and sex. Table 4 shows the prevalence of gastrointestinal helminths according to age and sex. Contrary to typical expectations, the youngest goats (with milk teeth) had the lowest prevalence (52.1%), while intermediate-aged goats (2–6 permanent teeth) and adults with full dentition showed significantly higher prevalences of 72.6% and 71.4%, respectively.

Table 2 Prevalence of gastrointestinal helminths in goats from three different ecosystems in Peru, 2023

Helminths	Andean shrubland Prevalence (95% CI)	Dry forest Prevalence (95% CI)	Coastal valley Prevalence (95% CI)	p-value	Total Prevalence (95% CI)
Nematodes					
STE	67.4 (61.5—72.9)	37.9 (32.3—43.9)	44.2 (38.0—50.5)	< 0.001*	49.9 (46.5—53.4)
Skrjabinema sp.	25.1 (20.1—30.6)	41.5 (35.7—47.5)	34.5 (28.7—40.6)	< 0.001*	33.7 (30.5—37.1)
Trichuris sp.	2.9 (1.2—5.6)	1.4 (0.4—3.6)	1.9 (0.6—4.5)	0.476*	2.1 (1.2—3.3)
Strongyloides sp.	5.0 (2.8—8.3)	3.9 (2.0—6.9)	0	0.002*	3.1 (2.0—4.5)
Nematodirus sp.	5.0 (2.8—8.3)	0	0	< 0.001^	5.0 (2.8—8.3)
Cestod					
Moniezia sp.	2.2 (0.8—4.6)	7.8 (5.0—11.6)	6.2 (3.6—9.9)	0.009*	5.4 (3.9—7.1)
Trematoda					
Fasciola sp.	2.2 (0.8—4.6)	0	1.2 (0.2—3.4)	0.027^	1.1 (0.5—2.1)
Total	74.2 (68.6—79.2)	63.1 (57.2—68.8)	59.3 (53.0—65.4)	0.001*	65.7 (62.3—68.9)

*Chi Square Test, ^Fisher Exact Test, 95% CI: 95% Confidence Interval

STE: Strongylid-type eggs

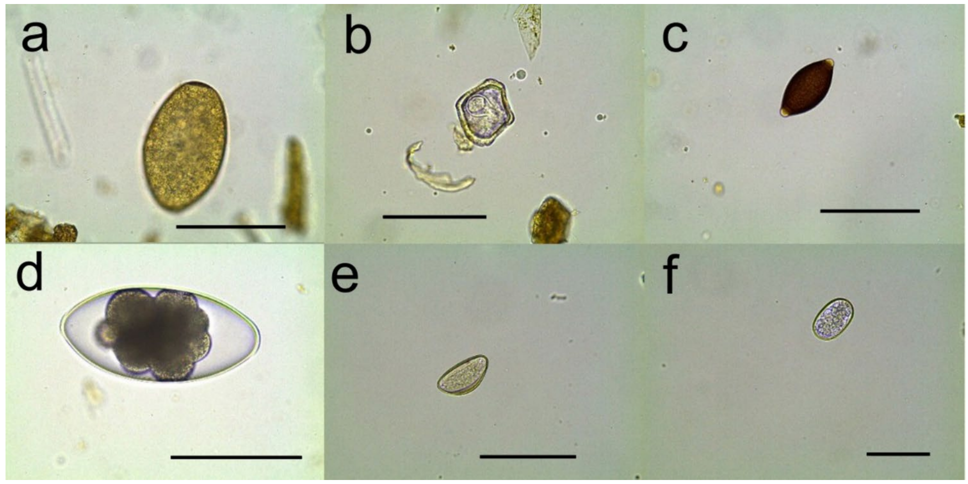

Fig. 3 GIP eggs found in goats from three ecosystems of Peru: **a**) *Fasciola hepatica*; **b**) *Moniezia* sp.; **c**) *Trichuris* sp.; **d**) *Nematodirus* sp.; **e**) *Skrjabinema* sp.; **f**) *Strongyloides* sp. (scale = 100 µm)

Table 3 Nematodes load according to the McMaster Technique by ecosystem in Peru, 2023

Nematode load by ecosystem	STE n (%)	*Skrjabinema* sp. n (%)	*Trichuris* sp. n (%)	*Strongyloides* sp. n (%)	*Nematodirus* sp. n (%)
Andean shrubland					
< 50 epg	80 (42.6)	48 (68.6)	8 (100.0)	12 (85.7)	14 (100.0)
50–550 epg	73 (38.8)	21 (30.0)	-	2 (14.3)	-
> 550 epg	35 (18.6)	1 (1.4)	-	-	-
Dry forest					
< 50 epg	90 (84.1)	86 (73.5)	2 (50.0)	10 (90.9)	-
50–550 epg	17 (15.9)	30 (25.6)	2 (50.0)	1 (9.1)	-
> 550 epg	-	1 (0.9)	-	-	-
Coastal valley					
< 50 epg	79 (69.3)	61 (68.5)	4 (80.0)	-	-
50–550 epg	28 (24.6)	28 (31.5)	1 (20.0)	-	-
> 550 epg	7 (6.1)	-	-	-	-
Total					
< 50 epg	249 (60.9)	195 (70.7)	14 (82.3)	22 (88.0)	14 (100.0)
50–550 epg	118 (28.9)	79 (28.6)	3 (17.7)	3 (12.0)	-
> 550 epg	42 (10.2)	2 (0.7)	-	-	-

epg: eggs per gram

STE: Strongylid-type eggs

Males exhibited a lower prevalence (53.5%) compared to females (66.8%).

Multivariable analysis revealed that age, anemia status, body condition, sex, and ecosystem were associated with helminth infection. Goats with 2–6 permanent incisors and those with full dentition had significantly higher risk compared to young goats with only milk teeth (PR = 1.12 and 1.08, respectively; $p < 0.001$). Anemic goats (FAMACHA ≥ 3) had over 1.14 times the prevalence compared to non-anemic animals. Those in poor body condition (BCS = 1–2) were also at increased risk (PR = 1.03, $p < 0.001$). Males had significantly lower prevalence compared to females (PR = 0.80, $p = 0.029$). Finally, goats raised in dry forest and coastal valley ecosystems had significantly lower risk than those in Andean shrubland (PR = 0.66 and 0.64 respectively, both $p < 0.001$).

Discussion

This study shows that goats from three ecosystems in Peru have a high prevalence of gastrointestinal helminths (over 65%). This prevalence is comparable to findings from the central coastal region (Ica department), where Cáceres et al. (2021) reported a 67.6% prevalence of gastrointestinal nematodes. However, the prevalence observed in our study was lower compared to previous reports in South America. Zapata-Salas et al. (2016) documented a 78.7% prevalence

Table 4 Risk factors associated with gastrointestinal helminth infection in goats from three Peruvian ecosystems: bivariate and multivariate analysis using prevalence ratios (PR)

Variables	n (%)	OR crude	p-value	OR adjusted	p-value
Age					
Milk teeth	134 (52.1)	ref		ref	
2–6 tooth	159 (72.6)	2.4	< 0.001	2.2	< 0.001
Full mouth	245 (71.4)	2.3	< 0.001	1.7	0.021
Sex					
Female	500 (66.8)	ref		ref	
Male	38 (53.5)	0.6	0.025	0.8	0.356
FAMACHA©					
Not anemic (1–2)	80 (46.8)	ref		ref	
Mild anemic (3)	317 (68.8)	2.5	< 0.001	2.0	0.001
Severe anemic (4–5)	141 (75.4)	3.5	< 0.001	2.4	0.001
BCS					
Healthy (2.5–4)	312 (60.4)	ref		ref	
Health problem (1–2)	226 (74.8)	2.0	< 0.001	1.3	0.126
Ecosystem					
Andean shrubland	207 (74.2)	ref		ref	
Dry forest	178 (63.1)	0.6	0.005	0.5	< 0.001
Coastal valley	153 (59.3)	0.5	< 0.001	0.5	< 0.001
BCS: body condition index, OR: odds ratio					

Age categories were based on dental eruption:

Milk teeth = deciduous incisors only

2–6 teeth = 2 to 6 permanent incisors

Full mouth = 8 permanent incisors

of gastrointestinal nematodes in Colombia, while Radavelli et al. (2014) reported an 88.9% prevalence of gastrointestinal parasites in Brazil. These differences may be attributed to variations in environmental conditions, management practices, or parasite control strategies across regions.

The results across three ecosystems in our study reveal distinct parasitic prevalence, which might be attributed to both environmental factors and management practices. The highest parasite prevalence was found in the Andean shrubland ecosystem of Ancash (74.2%); however, it was lower than the reported prevalence in the central highlands (Ayacucho department, with similar conditions), with rates between 87.8% and 100% (Palomino-Guerrera et al. 2024; Mendoza 2023). Nevertheless, these prevalence rates included general gastrointestinal parasites, such as protozoa, and nematodes. In the dry forest ecosystem of Lambayeque, a lower prevalence was observed (63.1%), where the reduced precipitation and semi-arid conditions may limit the development and survival of free-living stages of gastrointestinal nematodes, particularly those with high moisture requirements for larval development. This environmental constraint has been documented as a limiting factor for genera such as Haemonchus and Trichostrongylus, whose infective third-stage larvae (L3) are highly dependent on humid microclimates and moderate temperatures for survival and migration from feces to pasture (O'Connor et al. 2006; Kaplan and Vidyashankar 2012; Khadijah et al. 2013). For instance, a comparable study conducted in the similar ecosystem in Piura (Chinga 2022) found a prevalence of 37.5% for gastrointestinal parasites in goats. On the other hand, the coastal valley ecosystem in Lima showed the lowest prevalence of helminths (59.3%). A related study in Pachacamac, Lima found Strongylus type eggs with 10.6% as the most prevalent parasite, followed by *Trichuris* sp. (5.6%), and *Skrjabinema ovis* (4.0%) (Paredes 2022).

The identification of L3 infective larvae of gastrointestinal nematodes such as *Strongyloides* sp., *Cooperia* sp., *Haemonchus* sp., *Trichostrongylus* sp., *Oesophagostomum* sp., and *Teladorsagia* sp. in this study highlighted the diversity and complexity of parasitic infections affecting goats in Peru. These findings are consistent with previous studies (Cáceres et al. 2021), where similar larvae were identified in the Ica region. However, the presence of *Oesophagostomum* and *Strongyloides* were not reported. On the other hand, the presence of *Chabertia* sp., a genus not identified in our study, was documented. The presence of genera such as *Haemonchus* and *Trichostrongylus* is particularly concerning because of their significant impact on goat health and productivity, causing anemia and substantial economic loss (Arsenopoulos et al. 2021). The detection of these infective larvae highlights the need for specific control and prevention programs to reduce the damage these infections cause to goat production. These programs should include integrated management strategies and regular monitoring of gastrointestinal parasite loads across different ecological regions and underscore the importance of region-specific surveillance and control strategies.

In addition to nematodes, *Moniezia* sp. and *Fasciola hepatica* were detected, but with lower prevalences. The overall prevalence of *Moniezia* sp. was 5.4%, with a higher occurrence in dry forests (7.8%) compared to Andean shrublands (2.2%). This pattern may be related to the distribution and activity of oribatid mites, which act as intermediate hosts for Anoplocephalidae tapeworms such as Moniezia spp. Previous studies have shown that oribatid mite communities are influenced by environmental factors like moisture and temperature (Gergócs and Hufnagel 2009), which vary between these ecosystems. The presence of *F. hepatica* in goats was low (1.1%), with no cases detected in the dry forest ecosystem, likely due to the lack of *Lymnaea* spp. snails, the required intermediate host, which are typically found in humid environments. In another study, Cieza (2012) reported a higher prevalence of *F. hepatica* (14.2%) in the Huaura Sayán Valley, where wetland conditions favor the life cycle of the parasite. Contrasting these results, Paredes (2022) did not find *F. hepatica* cases in Pachacamac (coastal Lima), further supporting the hypothesis that fasciolosis is geographically restricted to areas with permanent water sources. The low number of cestodes and trematodes in our study and that of Paredes (2022) suggests that these parasites have more restricted ecological requirements, contrasting with the widespread presence of nematodes. This highlights the need for parasite-specific ecological assessments when designing control programs, considering not only the prevalence of each parasite but also the environmental factors that drive their transmission.

Our study identified multiple risk factors associated with gastrointestinal helminth infections in goats, highlighting the influence of age, sex, anemia status (FAMACHA index), and body condition score on parasite prevalence. Age was a significant determinant, with goats in the 2–6 tooth age group and those with full mouth having a higher risk of nematode infection. In this study, age classification was based on dental eruption, a method widely used in field conditions across Latin America due to its practicality. Although international guidelines often rely on precise chronological age, dentition provides a reliable proxy where birth records are unavailable. The higher prevalence observed in older goats likely reflects cumulative exposure to infective stages in contaminated grazing environments. This pattern may reflect cumulative exposure over time or delayed deworming practices, which can lead to sustained parasite burdens in adult animals. Similarly, females exhibited a higher prevalence of infection (66.8%) compared to males (53.8%).

These observations are consistent with previous studies that have identified age, sex, anemia status, and body condition as significant risk factors for gastrointestinal parasite infections in goats. For instance, a study in Zimbabwe reported that host factors such as age and sex significantly influenced the prevalence of gastrointestinal nematodes (Zvinorova et al. 2016). Similarly, research in Thailand found that sex and age were significant factors influencing susceptibility to gastrointestinal parasite infections, with clinical indicators such as anemia and poor body condition associated with higher infection rates (Rerkyusuke et al. 2024). Furthermore, a study in Malaysia observed that females were more at risk of strongyle infections than males (Paul et al. 2020). This sex-related difference in susceptibility has been widely documented and may be explained by the physiological and immunological changes occurring around parturition. In particular, the periparturient period is characterized by a temporary suppression of immune function in females, often referred to as the periparturient relaxation of immunity (PPRI), which can increase susceptibility to gastrointestinal nematodes (González-Garduño et al. 2021). In goats, Hernández-Castellano et al. (2019) demonstrated that periparturient does experience changes in immune parameters, with reduced leukocyte counts and altered cytokine profiles, likely due to the combined hormonal, metabolic, and energetic demands of late pregnancy and early lactation. These findings support the idea that females, especially around parturition, are more vulnerable to parasitic infections. Collectively, these findings underscore the importance of considering host-related factors when developing and implementing control strategies for gastrointestinal helminth infections in goats.

The main limitations of the study were related to the distribution of the samples per herd, which was unbalanced mainly due to the availability of animals at the time of sampling in the field. The milk teeth and full mouth (male) categories had a lower proportion of sampled individuals than adult animals. This low proportion was due to two factors: the productive objective of the breeding system and the sampling period. The first factor of the production system is milk production, so the permanence of female animals is prioritized over that of males, which are eliminated before 30 days of age, leaving one to two animals as breeders for the following campaign. Regarding the second factor, the sampling period did not correspond to the calving season of the animals in many of the herds; therefore, the number of MT animals available for sampling was lower than expected.

This study employed a cross-sectional design, which limits the ability to establish temporal or causal relationships between risk factors and the presence of gastrointestinal helminths. Consequently, variables such as anemia status or body condition score may represent either predisposing factors for infection or clinical consequences of parasite burden. While associations were identified, reverse causality cannot be ruled out. Moreover, variables like age and sex were included in the analysis due to their biological relevance, despite being potential confounders. These variables were adjusted in the multivariable model to better isolate the effect of other explanatory variables. Future longitudinal studies are warranted to clarify the directionality of these associations and better understand the underlying mechanisms.

Based on the results obtained, it is necessary to implement parasite control programs in goat populations, considering the ecosystem variations, age, and physiological status of the animals. Parasite control strategies should include pasture rotation, deworming, and improved goat nutrition. Future studies are necessary to evaluate the economic impact of helminthosis on goat production, as well as to evaluate anthelmintic resistance.

Conclusions

This study reports a high prevalence of gastrointestinal parasites in goats across three different ecosystems in Peru. The Andean shrubland ecosystem in Ancash exhibited the highest frequency of parasitism by helminths (74.2%), highlighting the environmental influence on parasitic loads. Strongyle-type eggs were the most frequently identified parasitic form (49.9%), followed by *Skrjabinema* sp. (33.7%). Anemic goats, based on FAMACHA© scores, showed a higher prevalence of infection: mildly anemic goats (score 3) had an adjusted PR of 1.14 ($p < 0.001$), while severely anemic animals (scores 4–5) had a PR of 1.15, indicating a consistent trend between anemia severity and infection risk. Similarly, goats with poor body condition (BCS 1–2) had a higher prevalence compared to healthy individuals (BCS 2.5–4), with an adjusted PR of 1.03 ($p < 0.001$). Ecosystem differences were notable, goats in dry forest and coastal valley areas had lower prevalence ratios compared to those in Andean shrubland, with adjusted PRs of 0.66 and 0.64, respectively (both $p < 0.001$). The identification of infective L3 larvae, including *Bunostomun* sp., *Haemonchus* sp., *Trichostrongylus* sp., *Cooperia* sp., *Strongyloides* sp., *Oesophagostomum* sp., and *Teladorsagia* sp., indicates the need for effective parasite control strategies. These findings highlight the importance of implementing region-specific parasite management programs. Likewise, further studies are necessary to evaluate the economic impact of parasitism on goat production in affected regions.

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Data availability The datasets analysed during the current study are available from the corresponding authors on reasonable request.

Declarations

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