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DIVERSITY AND BURDEN OF GASTROINTESTINAL NEMATODES IN GOAT PRODUCTION SYSTEMS IN THE CENTRAL REGION OF VERACRUZ, MEXICO

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ABSTRACT

Goat herds (*Capra aegagrus hircus* L.) are susceptible to various diseases. One of the most economically damaging in production systems is caused by gastrointestinal nematodes (GINs), which can alter the health, production, and welfare of the animals. The objective of this study was to determine the diversity and burden of gastrointestinal parasites in goat production systems in the central region of Veracruz, Mexico. The municipalities included in the study are located in the mountainous zone (Coatepec and Jalacingo), the highlands (Perote), and the coastal plain (Medellín). A cross-sectional study was conducted, and sampling was carried out during the period from November 2021 to May 2022. Two surveys were applied to farmers. A descriptive analysis was carried out on the characteristics of the production units (PUs). The McMaster technique was used to determine the presence of eggs, and the coproculture, Baermann, and larval identification techniques were used to determine the diversity of GINs. The analysis of the data obtained in the laboratory and the individual survey was carried out with a fixed effects model to analyze the parasite load. The independent variables were the PU, breed, physiological state, and body condition, and the dependent variables were eggs per gram of feces (Epgf) and its natural logarithm (ln (Epgf+1)). Three types of production systems were found: housed, semi-stabled, and grazing. The genera and species identified were *Haemochus contortus*, *Teladorsagia* spp., *Trichostrongylus* spp., *Chabertia ovina*, *Cooperia* spp., *Oesophagostomum* spp., *Trichuris ovis*, and *Strongyloides papillosus*. The Toggenburg breed had the highest nematode load, and all PUs had high parasite loads with counts greater than 700 Epgf. A great diversity and high loads of GINs were found in the goat PUs of the central zone of Veracruz.

Keywords: gastrointestinal parasites, parasite load, goat farming.

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INTRODUCTION

In Mexico, there is a population of around 8 791 894 heads of goat, which are mainly concentrated in Puebla (15.4 %), Oaxaca (12 %), San Luis Potosí (10.5 %), Guerrero (7.9 %), and Zacatecas (6.1 %) (SADER, 2015; SIAP, 2019). Around 162 thousand liters of milk and 40 thousand Mg of carcass meat are produced annually. In the state of Veracruz, goat farming has shown gradual growth. In 2010, the estimated goat inventory was 150 306 cattle heads, and by 2021 it increased to 160 625 cattle heads (SIAP, 2022).

Goat production is located in rural communities in arid, semi-arid, mountainous, and highland areas, with little technification and government support and insufficient dissemination of the activity (Ortiz-Morales *et al*., 2021). It is an activity carried out by small farmers either as a primary productive activity or in combination with other productive species such as cattle and sheep or complementary with agricultural activities (Bedotti *et al*., 2018; Ortiz-Morales *et al*., 2021). Farmers lack the economic resources to invest in improving their facilities and accessing technologies that allow adequate zootechnical and sanitary management of their herds (Aréchiga *et al*., 2008; Ortiz-Morales *et al*., 2021).

Goats are exposed to gastrointestinal nematode (GIN) infections, which represent a limiting factor for production (Torres-Acosta and Hoste, 2008), mainly in regions with tropical and subtropical climates due to the existence of climatic and environmental conditions that favor the rapid development of the biological cycle of nematodes, especially in grazing production systems (Herrera *et al*., 2013). Goat production is often done collectively, i.e., they are not separated by age or physiological stages, which causes rapid spread of infective stages (Jiménez *et al*., 2013). GIN infections can alter animal health and welfare and the productive levels of animals. This is reflected in the economy of farmers (Zapata *et al*., 2016), showing a decrease in meat and milk production. When the infestation is very high, it is also one of the main causes of mortality in herds (Li *et al*., 2016).

Parasitosis is a frequent problem in goat production units because of poor sanitary management and reduced goat immunity to parasites, which makes them very susceptible (Mpofu *et al*., 2022). The damage caused is related to parasite-specific factors such as gender, degree of infection, and physiological stage, as well as their pathogenicity; this in turn depends on other factors such as weather conditions, vegetation, soil, type of grassland, type of production system, farm management, and characteristics directly related to the animal, such as age, breed, and physiological stage (Mpofu *et al*., 2022).

GINs lodge throughout the digestive tract of ruminants to obtain nutrients for survival (Craig, 2018). Within the main gastrointestinal nematode genera identified to affect small ruminants are *Haemochus contortus*, *Trichostrongylus colubriformis*, *T. axei*, *Teladorsagia circumcincta*, *Cooperia* spp., *Oesophagostomum* spp., *Trichuris ovis*, *Strongyloides papillosus*, and *Bunostomum* spp. (Badaso and Addis, 2015).

In the state of Veracruz, there are few studies related to the diversity and impact of gastrointestinal parasitosis in goat herds. Most studies on gastrointestinal nematodes have been carried out in cattle and sheep. Under the hypothesis that gastrointestinal nematodes in the central zone of the state of Veracruz can be caused by different genera, they have an impact on goat production systems. The objective of this research was to determine the diversity and burden of gastrointestinal parasites in goat production systems in the central region of Veracruz.

MATERIALS AND METHODS

Study area

This research was conducted in four municipalities located in the central zone of the state of Veracruz, Mexico. The municipalities included in the study are located in the mountainous zone (Coatepec and Jalacingo), the highlands (Perote), and the coastal plain (Medellín de Bravo).

Study design

The study was cross-sectional. Sampling of the herds was carried out during the period from November 2021 to May 2022. Herds established in three different physiographic regions of the central zone of the state of Veracruz were considered. The production units (PUs) were selected according to the producer's availability to participate in the study. A total of 123 animals (females) with an average age of five months to eight years were sampled from 14 PUs across four municipalities (Table 1).

Table 1. Locations, number of animals, average age, and breeds of goats (*Capra aegagrus hircus* L.) evaluated in the study areas.

Municipality	Locality	PU	N of animals	Age (years)	Breed
Perote	Xaltepec	1	10	2.00–6.00	Alpine
Perote	Xaltepec	2	10	3.00–7.00	Alpine, Saanen, and Toggenburg
Perote	La Gloria	3	10	0.60–6.00	Saanen
Perote	La Gloria	4	6	0.75–6.00	Saanen
Coatepec	Pacho Viejo	5	10	0.60–7.00	Saanen and Alpine
Coatepec	Coatepec	6	10	2.00–4.00	Alpine, Saanen, Crossbreed, and Toggenburg
Coatepec	Coatepec	7	5	0.50–5.00	Crossbreed and Alpine
Perote	Frijol Colorado	8	10	3.00–4.00	Alpine, Saanen, and Toggenburg
Perote	Frijol Colorado	9	10	1.00–4.00	Saanen and Alpine
Medellín	Mata Ortiz	10	10	1.00–8.00	Crossbreed and Creole
Medellín	Palmira	11	6	1.00–9.00	Creole and Crossbreed
Coatepec	Agrosol	12	6	2.00–4.00	Saanen and Crossbreed
Jalacingo	Melchor Ocampo	13	10	0.41–3.00	Alpine, Saanen, and Toggenburg
Jalacingo	Melchor Ocampo	14	10	4	Alpine, Saanen, and Toggenburg

PU: production unit.

Data collection

To determine the characteristics of the PUs and the conditions of the animals studied, a questionnaire was used to obtain data related to animal identification, age, breed, sex, physiological state (primal, pregnant, lactating, and empty), body condition, recent diarrhea or diseases, and the last date of deworming. The McMaster test was used to obtain the variable eggs per gram of feces (Epgf), with which the intensity of infection was determined. This metric indirectly represents the intensity of infection of the animals. The breeds found in the PUs studied were Alpine (31.7 %), Saanen (43.9 %), Toggenburg (7.3 %), Crossbreed (13.8 %), and Creole (3.3 %). Body condition (BC) was scored on a scale of 1 to 5, according to Frutos and Ruiz-Mantecón (1994); for better understanding, these scores were associated with qualitative criteria such as 1 (very lean), 2 (lean), 3 (fair), 4 (good), and 5 (fat).

Sampling

Sample collection was carried out by holding the animal by the head through the cleft of the lower jaw with the hands, the trunk of the animal between the hind limbs by an assistant, and extracting the fecal samples directly from the rectum of the goats. A total of 5–10 g of feces was collected and placed in plastic bags properly identified. The samples were coded according to the municipality of origin, PU, and the progressive number of the animal. In addition, in the individual card, the earring or name and number of the animal sampled (from 1 to 10) were recorded. The samples were placed in a cooler with refrigerant for preservation until transferred to the Parasitology Laboratory at the Rancho Torreón del Molino of the Faculty of Veterinary Medicine and Animal Science of the Universidad Veracruzana (UV-FMVZ) for processing.

Diagnostic techniques

The McMaster flotation technique was used to determine fecal counts of gastrointestinal nematodes (Figueroa-Castillo *et al*., 2015). Fecal egg counts can be classified according to their intensity. Counts of 0 Epgf are considered negative; mild PU infection is up to 200 Epgf, moderate infection is between 200 and 700 Epgf, and high infection is for counts over 700 Epgf (Prada-Sanmiguel and Plazas-Caro, 2010). To identify nematode genera, the coproculture technique was previously used to obtain the third larval stage (L3), providing the environmental conditions that the eggs would have in the grassland and thus achieving the hatching of the eggs to recover the L3 (O'Connor *et al*., 2006). The Baermann technique was used for the concentration and recovery of the L3, which were differentiated to determine the genera (Figueroa-Castillo *et al*., 2015).
The L3 larvae collected were identified according to dichotomous keys established by Niec (1968), Liébano, (2011), and van Wyk and Mayhew (2013). The main morphological characteristics were size, number, shape of intestinal cells and forelimb, termination of the larval tail, and length and shape of the sheath tail (Niec, 1968).

Statistical analysis

The information from the surveys and laboratory data were integrated in databases elaborated with the Excel program. For the analysis of the laboratory and individual survey data, a fixed effects model was used, where the variables PU, breed, and parasite egg count (Epgf) were included to evaluate the intensity of the infection. This was analyzed as a generalized linear model using SPSS 23 software (IBM Statistics). The data were transformed with the natural logarithm plus one to guarantee homogeneity of variance of the parasitic load and to improve data distribution (Díaz-Rivera *et al*., 2000). In the preliminary models, the effects of municipality and locality were not significant. Thus, they were removed from the definitive model and replaced by the PU effect. Additionally, the effect of body condition was included. The effects of age (covariate) and production system, although recorded, were not estimable under the resulting data structure. For the general survey, a descriptive analysis of the characteristics of the PUs was performed.

The following formula used was:

$$\text{Fecal egg count } (Epgf \text{ and } ln\ (Epgf + 1)) = \mu + PU_i + RZ_j + EF_k + CC_l + \varepsilon_{ijklm}$$

where *Epgf* is the number of eggs per gram of feces and the response variable; μ is the overall mean; PU_i is the effect of the *i*-th production unit; RZ_j is the effect of the *j*-th breed; EF_k is the effect of the *k*-th physiological state; CC_l is the effect of the *l*-th body condition; and ε_{ijklm} is the residual effect on each observation.

RESULTS AND DISCUSSION

Nematode diversity

The following genera, and in certain cases, genus and species of gastrointestinal parasites, were identified from the 123 samples: *Haemochus contortus*, *Teladorsagia* spp., *Trichistrongylus* spp., and *Chabertia ovina* were found in all municipalities; *Cooperia* spp. was found only in the municipality of Jalacingo; *Oesophagostomum* spp. and *Strongyloides papillosus* were found in the municipality of Medellín; and *Trichuris ovis* was found only in the municipality of Coatepec (Table 2). Of the animals sampled,

Table 2. Presence and diversity of gastrointestinal parasites in goats (*Capra aegagrus hircus* L.) in the different municipalities in the central region of Veracruz, Mexico.

Parasite genus	Coatepec	Jalacingo	Medellín	Perote
Haemochus contortus	X	X	X	X
Teladorsagia spp.	X	X	X	X
Trichostrongylus spp.	X	X	X	X
Chabertia ovina	X	X	X	X
Cooperia spp.		X		
Oesophagostomum spp.			X	
Trichuris ovis	X			
Strongyloides papillosus			X	

almost 90 % were found to be highly infected with nematodes. Likewise, all the animals sampled presented nematode associations; that is, they had the presence of more than one species of gastrointestinal nematode.

These results are consistent with Income *et al*. (2021), where samples were collected from nine goat PUs and found *Haemochus* spp. (100 %), *Trichostrongylus* spp. (91.7 %), *Oesophagostomum* spp. (29.2 %), and *Cooperia* spp. (37.5 %). These authors also detected mixed infections with more than one genus of nematodes. In a similar study conducted in sheep and goats by Herrera *et al*. (2013) in Antioquia, Colombia, a similar presence of nematodes was identified in the municipalities studied, with *H. contortus*, *Oesophagostomum* spp., *Trichostrongylus* spp., and *Ostertagia* spp. being the most frequent nematodes. Similarly, in another study in cattle and goats conducted in Quechultenango, Mexico, Figueroa-Antonio *et al*. (2018) determined a positivity of 91.8 % of one or more gastrointestinal nematodes, which is similar to the findings in this study.

Quantification of infection intensity

The model and the intercept (common effect) used were significant ($p \leq 0.01$); the effect of the PU and body condition were also significant ($p \leq 0.01$). The effect of breed was significant ($p \leq 0.05$) only for the transformed variable, and the effect of the physiological state was not important for either of the two response variables (Table 3).

Table 3. Analysis of variance of nematode infection intensity in evaluated in the central region of Veracruz, Mexico.

Variable	Degrees of freedom	Epgf	ln (Epgf+1)
Model	24	25 110 296**	6208**
Intercept	1	117 247 158**	750 032**
Production unit	13	3 671 895**	2755**
Breed	4	3 689 108^{NS}	2021^{NS}
Physiological state	3	1 691 837^{NS}	997^{NS}
Body condition	4	70 466 843**	6456**
Error	98	1 774 107	1178

Epgf: eggs per gram of feces; $^{NS}p > 0.05$ (non-significant); *$p \leq 0.05$; **$p \leq 0.01$.

Differences between PUs

All PUs were found to have high infection rates, with counts higher than 700 Epgf. The PU with the highest count was AGROSOL, located in the municipality of Coatepec, with an average of 4260 Epgf (Table 4). This could be due to poor animal management, ranging from the indiscriminate use of dewormers to the coexistence of animals from different flocks and other species, like sheep. PUs with loads higher than 2500 Epgf are considered to have serious parasitism problems.

Table 4. Fecal counts of nematode eggs (mean ± standard error) in the sampled production units in the central region of Veracruz, Mexico.

Production unit	Animals sampled	Epgf	ln (Epgf+1)
4 (La Gloria, Perote)	6	765±1039 a	4.98±0.58 a
3 (La Gloria, Perote)	10	898±906 a	5.75±0.50 a
13 (Melchor Ocampo, Jalacingo)	10	906±829 a	6.21±0.46 a
9 (Frijol Colorado, Perote)	10	1079±940 a	5.38±0.52 a
8 (Frijol Colorado, Perote)	10	1090±1032 a	5.95±0.57 a
6 (Coatepec, Coatepec)	10	1201±835 a	6.02±0.46 a
5 (Pacho Viejo, Coatepec)	10	1369±796 a	6.83±0.44 a
11 (Palmira, Medellín)	6	1546±1048 a	6.68±0.58 ab
10 (Mata Ortiz, Medellín)	10	2219±932 a	6.82±0.52 ab
2 (Xaltepec, Perote)	10	3240±841 b	7.81±0.47 b
7 (Coatepec, Coatepec)	5	3351±945 b	7.87±0.52 b
1 (Xaltepec, Perote)	10	3356±1009 b	8.10±0.56 b
14 (Melchor Ocampo, Jalacingo)	10	3619±1013 b	8.08±0.56 b
12 (Agrosol, Coatepec)	6	4260±994 b	7.96±0.55 b

Epgf: eggs per gram of feces. Means with different letters within columns indicate significant differences ($p \leq 0.05$).

These results coincide with a study conducted by Income *et al*. (2021) in Kanchanaburi, Thailand, where they studied cattle and goat PUs and found that all goat PUs studied were positive for helminth eggs, presenting 100 % prevalence in the herd, and the positive goats were heavily infected. A study conducted by Cerbo *et al*. (2010) in Lombardy, Italy, showed that almost all the goats sampled were positive in the 110 PUs studied.

Fecal counts of gastrointestinal nematode eggs per breed

Goat production in Veracruz is mainly destined for milk production, which is transformed into fresh cheeses and gourmet cheeses, and therefore, has a preference for specific breeds (SADER, 2021). The results indicate that the Toggenburg breed was the most susceptible to nematode infection (Table 5). This is relevant since it would be necessary to carry out further studies to confirm the presence and susceptibility to nematodes that they maintain. This breed has a small percentage of animals in the herds studied; however, it is present in several PUs.

It is important that producers consider breed susceptibility when acquiring animals and give them special attention. Creole breeds would be thought to have greater resistance because they are animals adapted to their environment; however, they also have high parasite loads, which may be due to the management they receive. Goats, unlike other ruminants, have a weak immunity against GINs (Rossanigo, 2003).

There is scarce literature on parasitism in the Toggenburg breed. Herrera *et al*. (2013)

Table 5. Fecal counts of nematode eggs (mean ± standard error) by goat breed (*Capra aegagrus hircus* L.).

Breed	Goats sampled	Epgf	ln (Epgf+1)
Crossbreed	17	853±959 a	6.12±0.53 a
Saanen	54	1613±415 a	6.73±0.23 a
Alpine	39	1856±514 a	6.19±0.28 a
Creole	4	2034±1542 ab	7.27±0.86 a
Toggenburg	9	3965±763 b	7.4±0.42 b

Epgf: eggs per gram of feces. Means with different letters within each column show significant differences ($p \leq 0.05$).

studied goats of the Alpine, Saanen, Crossbreed, Toggenburg, Anglonubian, and La Mancha breeds. The Saanen and Alpine were more susceptible, and the Toggenburg breed was the most resistant. It is worth mentioning that the Toggenburg breed specimens were fewer in number, as well as in this study. In another study conducted by Rossanigo and Colomer (1993) in Argentina, gastrointestinal parasitism had an important effect on the production of Creole goats, which is similar to this study since Creole goats also have high parasite loads.

Susceptibility of animals to infection depends on the breed. The sources of variation depend on natural defense mechanisms. The resistance they exhibit is based on immunological strategies acquired or present in their genetic code and their resilience, which allow the animals to be parasitized, recover, and adapt to the infection, plus the type of management and herd factors (Aguilar-Caballero *et al*. 2008). Some studies describe the susceptibility of high-producing dairy goats to GIN infections (Beasley *et al*., 2010), and Alpine and Sannen breeds are considered resistant (Baker *et al*., 2001). However, evidence on the resistance of goat breeds to GINs is limited, which should be considered since the livestock used in the Veracruz are mainly dairy goats.

In relation to the physiological status, it was not possible to detect differences between the statuses analyzed in this study, probably due to the limited number of animals sampled. On the other hand, although there could be an interaction between physiological state and breed, no interactions were included in this study, due to the same limitation as above. The egg counts for each body condition level (Table 6) show that body condition 1 was associated with high gastrointestinal nematode loads, while conditions 2, 3, and 5 had an intermediate load, and the lowest values were observed in animals with body condition 4.

These results suggest that animals with a lower body condition are associated with high loads of gastrointestinal nematodes, while the other conditions seem to have a higher resilience to these parasites. Similarly, Aguilar-Caballero *et al*. (2019) found that goats with poorer body conditions showed the highest loads of GIN.

Table 6. Fecal nematode egg counts (mean ± standard error) by body condition in goats (*Capra aegagrus hircus* L.) in the central region of Veracruz, Mexico.

Body condition	Number of goats sampled	Epgf	ln (Epgf+1)
1(Very lean)	11	7533±508.4 a	8.478±0.41 a
2 (Lean)	34	1976±371.7 b	6.784±0.30 c
3 (Fair)	16	1895±493.9 b	7.230±0.40 b
4 (Good)	58	978±315.4 c	6.480±0.26 c
5 (Fat)	4	1507±904.4 b	6.160±0.74 c

Means with different letters within each column show significant differences ($p \leq 0.05$).

Characterization of the PUs

Fourteen PUs were evaluated, including stabled, semi-stabled, and grazing production systems. Three PUs belonged to the stabled system (17.1 %), four used only grazing (29.3 %) and seven had a semi-stabled system (53.7 %). The age of the animals ranged from 5 months to 8 years, with an average age of 4 years. The effect of age was not analyzed in this study; however, Rojas-Hernández *et al*. (2007) found no effect by age group in a study on the prevalence of GIN in sheep. Stabled PUs should also be considered, since they could be acquiring GINs through the cut grass provided as feed.

Some PUs deworm every 2–3 months, while others do so every 3–6 months or every 6–12 months. The most commonly used products are fenbendazole, ivermectin, closantel, levamisole, and albendazole. The dosage used is the one indicated by the product. The cleaning of the facilities varies from daily to monthly. The feces are used for composting, and some farmers sell them. In almost all PUs, farmers carry out the dosage of the deworming agent, which coincides with what was found by Cáceres *et al*. (2021) in Peru, where producers also dose according to their own criteria, without technical orientation and varying the administration every 3–12 months, and the most used product was albendazole. Inadequate practices lead to resistance to anthelmintics, especially albendazole and ivermectin (Ratanapob *et al*., 2022).

CONCLUSIONS

The main nematodes found in the study area were *Haemochus contortus*, *Teladorsagia* spp., *Trichostrongylus* spp., and *Chabertia ovina*, since they were found in all municipalities. The intensity of infection found in all production units was high, and most of the animals presented combined infections of different nematodes; therefore, it is important to develop better and integrated strategies for the control of gastrointestinal nematodes. Improved management practices, especially grazing and parasite control, are recommended to reduce the high infections present in the studied areas. Farmers should take special care due to the high fecal counts of gastrointestinal nematode eggs.

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