GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(Research Article)

Prevalence and Epidemiological Factors of Gastrointestinal Nematode Infections in Sheep Slaughtered at Tamboul Slaughterhouse, Gezira State, Sudan

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GSC Biological and Pharmaceutical Sciences, 2025, 33(02), 400-408

Publication history: Received on 08 October 2025; revised on 14 November 2025; accepted on 17 November 2025

Article DOI: https://doi.org/10.30574/gscbps.2025.33.2.0427

Abstract

Gastrointestinal nematode (GIN) infections are a major constraint to small-ruminant production worldwide, causing significant health and economic losses. In Sudan, these infections remain endemic, yet regional epidemiological data are limited. This study aimed to determine the prevalence, species composition, and risk factors associated with GIN infections in sheep slaughtered at the Tamboul Slaughterhouse, Gezira State, Sudan. A total of 80 sheep were examined using standard parasitological techniques, including flotation and direct faecal-smear methods. Data on sex and age were recorded for statistical analysis. The association between infection prevalence and host factors was assessed using the chi-square test. Of the examined animals, 14 (18%) were positive for GIN infection. Females (18%) and adults (>12 months, 18%) showed slightly higher prevalence rates than males (17%) and younger animals, though the differences were not statistically significant (χ^2 = 0.02–0.21, p > .05). Identified nematodes included *Nematodirus spp.*, *Strongylid spp.*, *Trichuris spp.*, *Haemonchus spp.*, and *Toxocara spp.*, with *Nematodirus spp.* being the most prevalent. Gastrointestinal nematodes are endemic among sheep in the Tamboul area, posing a persistent challenge to productivity. Effective control strategies including regular deworming, improved husbandry practices, and seasonal surveillance are essential to mitigate infection and enhance flock health and performance.

Keywords: Gastrointestinal Nematodes; Prevalence; Sheep; Sudan; Parasitic Gastroenteritis; Epidemiology; Anthelmintic Control

1. Introduction

Parasitic Gastroenteritis (PGE), primarily caused by gastrointestinal nematodes (GINs) of the order Strongylida, remains one of the most economically devastating and ubiquitous diseases affecting small ruminant production globally (Kaplan, 2020; Zajac and Garza, 2020). GIN infections significantly constrain livestock productivity through direct effects like morbidity, mortality, and compromised animal welfare, and indirect effects such as reduced feed efficiency, decreased weight gain, and lower milk and wool yields (Herrera et al., 2013; Torres-Acosta et al., 2012). The most pathogenic genera, including *Haemonchus*, *Trichostrongylus*, and *Teladorsagia*, are responsible for substantial economic losses, further compounded by the rapidly increasing global prevalence of anthelmintic resistance (Kaplan, 2020).

The epidemiology and impact of GINs are highly dependent on complex interactions between the host, parasite species, and local environmental factors, including climate, season, and management practices (Keyyu et al., 2005; Kaplan & Vidyashankar, 2012). Specifically, factors such as the age and immune status of the host, as well as the intensity and composition of the infection, dictate the severity of the disease (Al-Shaibani et al., 2008). Young animals are typically

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more susceptible, while high environmental temperature and rainfall often drive peak infection pressure due to the favorable conditions for the survival of the free-living larval stages (Ensuncho et al., 2014). For sustainable disease management, it is imperative to establish a current understanding of these epidemiological drivers.

Sheep production is a cornerstone of livelihood and food security for rural communities in arid and semi-arid regions, including the Sudan (FAO, 2016). With one of the largest small ruminant populations in Africa, the national livestock economy in Sudan is inherently vulnerable to diseases like PGE (Ministry of Animal Resources, 2014). The local epidemiology of parasitic infections is modulated by climatic variability, which directly influences the survival and development of infective stages, as well as host-related factors such as breed and physiological state (Lughano and Dominic, 2015). Despite the recognized economic significance of GINs in the region, comprehensive and current epidemiological data on the prevalence, species diversity, and associated risk factors in the local sheep population of Sudan are notably scarce. This lack of data represents a critical constraint to the formulation of evidence-based and effective control strategies.

Therefore, this study aimed to determine the prevalence, species composition, and associated risk factors of gastrointestinal nematode infections in sheep within the Tamboul region of Gezira State, Sudan. Specifically, the study sought to evaluate the influence of intrinsic host factors, such as age and sex, on the infection status. The findings are expected to provide essential local data that will inform targeted control programs to mitigate the economic losses and improve animal health in this vital sector.

2. Materials and Methods

2.1. Study Area and Ethical Considerations

The study was conducted in the Tamboul area, Gezira State, Sudan, approximately 150 km south of the capital, Khartoum. Tamboul (14.45∘–15.30∘ N, 33.50∘–34.15∘ E) is a significant commercial hub located in the arid to semi-arid savanna zone, characterized by seasonal variations that influence pasture and livestock production. The presence of a major livestock market and slaughter facility in Tamboul made it an ideal site for assessing regional parasite epidemiology.

Prior to sample collection, ethical clearance was obtained from the Animal Resources Research Corporation (ARRC) of Sudan. Verbal consent was secured from the slaughterhouse management. All procedures adhered to the institutional and national guidelines for the humane collection of biological samples from livestock.

2.2. Study Design and Animal Selection

This was a cross-sectional study conducted at the Tamboul Slaughterhouse. A total of 80 sheep (mixed breeds, ages, and sexes) destined for slaughter were randomly selected from the pens over the sampling period to maximize the representativeness of the local sheep population. Data on host factors, including sex (male/female), and estimated age (categorized as juvenile, i.e., <1 year, or adult, i.e., ≥1 year, based on dentition and local owner information), were recorded for each animal.

2.3. Sample Collection and Processing

Fresh faecal samples were collected directly from the rectum of each selected animal immediately prior to slaughter to avoid environmental contamination. Approximately 10–15 grams of faeces were placed into individual, sealed, labelled plastic bags. Samples were transported in a cooler box under refrigeration (4∘C) to the parasitology laboratory at the College of Veterinary Medicine, University of Gezira, for processing within 24 hours of collection.

2.4. Parasitological Examination

Each faecal sample was processed using standard coproscopic techniques to determine the prevalence and identify the parasite fauna.

2.4.1. Qualitative Examination

A combination of techniques was employed to ensure maximum recovery of parasite eggs and oocysts:

- Faecal Flotation: The modified saturated sodium chloride solution flotation technique was performed to concentrate light-density nematode eggs (e.g., Strongylida) and protozoan oocysts (Soulsby, 1986). A coverslip was placed on the meniscus, left for 10 minutes, and then transferred to a slide for microscopic examination.
- Faecal Sedimentation: The standard water-based sedimentation technique was used to recover heavier eggs, such as those of trematodes (*Fasciola* spp.) (Soulsby, 1986). The final sediment was examined microscopically.
- Direct Faecal Smear: A small portion of faeces mixed with distilled water was examined under a coverslip for the immediate detection of motile protozoan trophozoites (Charles & Robinson, 2006).

2.4.2. Larval Culture and Identification

Faecal culture was performed to differentiate the Strongylida and Trichostrongylidae eggs to the generic level by allowing them to develop into the infective third-stage larvae (L3). Approximately 20 g of faeces from positive samples were mixed with moistened sterilized sawdust and incubated at 25°C to 28°C for 10–12 days (Charles & Robinson, 2006). The L3 were subsequently recovered using a modified Baermann apparatus. One hundred larvae were identified per culture based on the morphological characteristics of the tail sheath and internal structures according to established keys (Soulsby, 1986).

2.5. Statistical Analysis

Data were entered into a database and analysed using the Statistical Package for the Social Sciences (SPSS) software, version 25. The prevalence of GIN infection was calculated as the percentage of infected animals relative to the total number of sampled animals. Descriptive statistics were used to summarize the prevalence based on the collected host factors (sex and age). The association between categorical variables (prevalence, age, and sex) was assessed using the Chi-square ($\chi 2$) test. A p-value<0.05 was considered to indicate a statistically significant difference.

Table 1 The prevalence rate of Gastrointestinal nematodes in slaughtered sheep according to sex (N=80)

Sex	**Gastrointestinal nematodes**		**Total**	**χ^2 (Chi-square)**	**P Value**
	Positive (%)	Negative (%)			
Male	6 (14) 43%	30 (66) 45%	36 (80) 45%	0.024	0.876
Female	8 (14) 57%	36 (66) 55%	44 (80) % 55		
Total	14 (80) 18%	66 (80) 82%	80 (80) 100%		

Note: There is **no statistically significant association** between sex and infection status (p > 0.05). Infection rates were nearly identical between males (17%) and females (18%).

Table 2 The prevalence rate of Gastrointestinal nematodes in slaughtered sheep according to age (N=80)

Age / month	**Gastrointestinal nematodes**		**Total**	**χ^2 (Chi-square)**	**P Value**
	Positive (%)	Negative (%)			
1-6	1(3) 33%	2 (3) 67%	3(3) 100%	0.210	0.900
7-12	2 (16) 13%	14 (16) 87%	16 (16) 100%		
Above 12	11 (61) 18%	50 (61) 82%	61 (61) 100%		
Total	14 (80) 18%	66 (80) 82%	80 (80) 100%		

Note: There is **no statistically significant difference** in infection prevalence among age groups (p > 0.05). Although older sheep (>12 months) showed a slightly higher infection rate (18%), this variation is not statistically significant.

Table 3 Diagnosis of Gastrointestinal nematodes in slaughtered sheep by Direct faecal smear test, Flotation test (N=80)

Type of test	**Gastrointestinal nematodes**		**Total**
	Positive (%)	Negative (%)	
Direct faecal smear	1/80 (1.25%)	79/80 (98.75%)	80/80 (100%)
Flotation	13/80 (16.25%)	67/80 (83.75%)	80/80 (100%)

Table 4 Identification of Gastrointestinal Nematode Species in slaughtered sheep at Tamboul Slaughterhouse, Gezira State, Sudan (2021–2022) (N=14)

Gastrointestinal nematodes	**Percent within Positive Samples**	**Percent within Total Samples**	**χ^2 (Chi-square)**	**P value**
Haemonchus spp.	2/14 (14.3%)	2/80 (2.50%)	1.00	0.909
Stronglid spp.	3/14 (21.4%)	3/80 (3.75%)		
Toxocara spp.	2/14 (14.3%)	2/80 (2.50%)		
Trichuris spp.	3/14 (21.4%)	3/80 (3.75%)		
Nematodirus spp.	4/14 (28.6.0%)	4/80 (5.00%)		
Total	14/14 (100%)	14/80 (17.5%)		

Note: Since the P-value (0.909) is much greater than the conventional significance level of α=0.05, we fail to reject the null hypothesis.

3. Results

3.1. Overall Prevalence and Host Factors

A total of 80 sheep at the Tamboul Slaughterhouse were examined for gastrointestinal nematode (GIN) infections. The overall crude prevalence was found to be 17.5% (14/80).

3.2. Prevalence by Sex

Of the 80 sheep examined, 36 were male and 44 were female (Table 1). The infection rate was 16.7% (6/36) in males and 18.2% (8/44) in females.

The Chi-square test of independence revealed no statistically significant association between sex and GIN infection status ($\chi 2$= 0.024, and P=0.876). This suggests that both male and female sheep in the study population were similarly exposed and susceptible to GIN infection.

Since the P-value (0.876) is much greater than the conventional significance level of α=0.05, we fail to reject the null hypothesis. This confirms your finding that there is no statistically significant association between the sex of the sheep and the likelihood of GIN infection.

3.3. Prevalence by Age Group

Infection prevalence varied numerically across the defined age categories (Table 2). The highest infection rate was observed in the adult group (>12 months) at 18.0% (11/61), followed by the 1–6 months group at 33.3% (1/3), and the 7–12 months group at 12.5% (2/16). Despite these numerical differences, the association between age group and GIN infection was also not statistically significant ($\chi 2$= 0.210, and P=0.90).

Since the P-value (0.900) is much greater than α=0.05, we fail to reject the null hypothesis. This confirms your result that there is no statistically significant association between the age group of the sheep and the prevalence of GIN infection, despite the small numerical differences.

3.4. Diagnostic Sensitivity Comparison

Two coprological methods were utilized for the detection of GIN eggs (Table 3). The direct faecal smear method detected only 1 positive sample, yielding a sensitivity prevalence of 1.25%. In contrast, the flotation technique detected 13 positive samples, resulting in a significantly higher prevalence of 16.25%.

The superior detection rate confirms the flotation method as a more sensitive and reliable technique for the qualitative diagnosis of GIN eggs compared to the direct smear method (Soulsby, 1986).

3.5. Gastrointestinal Nematode Genera Identified

Five genera of gastrointestinal nematodes (GINs) were successfully identified from the 14 positive faecal samples, demonstrating polyparasitism typical in grazing sheep (Table 4). The genus composition highlights *Nematodirus* spp. and the Strongylid-type nematodes as the dominant infections in the Tamboul area.

The most frequently encountered genus was Nematodirus spp., detected in 4 out of 14 positive cases, representing 28.6% of infected animals and a total prevalence of 5.0% (4/80) across the entire sampled population. This was followed by the Strongylid spp. group and Trichuris spp., both found in 3 positive cases each, accounting for 21.4% of positive samples and a total prevalence of 3.75% (3/80). The least frequent genera were Haemonchus spp. and Toxocara spp., each detected in 2 positive samples, representing 14.3% of positive cases and a total prevalence of 2.50% (2/80).

A Chi-square test for Goodness of Fit was performed to assess if the observed frequencies of the five identified genera differed significantly within the positive samples. The analysis revealed no statistically significant difference in the distribution of the genera ($\chi 2=1.00$, df=4, P=0.909). This non-significant result indicates that the observed numerical variation (e.g., 28.6% for *Nematodirus* spp. vs. 14.3% for *Haemonchus* spp.) is likely attributable to random sampling variability within the small number of positive cases (N=14), rather than a true unequal proportion of the genera in the infected population.

4. Discussion

The overall prevalence of 17.5% (14/80) for gastrointestinal nematode (GIN) infection observed in sheep from the Tamboul Slaughterhouse indicates that these parasites are endemic in the Gezira region of Sudan, although the infection rate is relatively moderate compared to reports from other Sudanese states (Table 1).

Our finding of a moderate 17.5% prevalence contrasts sharply with the high rates (≥68%) previously reported in sheep from Kordofan State, Sudan, where *Haemonchus contortus* and *Trichostrongylus colubriformis* were highly dominant (Ghada & Khalil, 2011b). This substantial difference can be attributed to several factors: (a) Ecological and Climatic Variation: The Tamboul area, being within the arid to semi-arid savanna zone, likely experiences lower environmental humidity and higher temperatures for longer periods compared to the regions studied by Ghada & Khalil (2011a). These conditions significantly restrict the survival and development of the free-living larval stages (L3) of GINs, thereby reducing pasture contamination pressure (Kaplan & Vidyashankar, 2012), (b) Sampling Season: As this cross-sectional survey was conducted at the slaughterhouse, the exact season of maximum exposure for the sampled animals is unknown, but a generally lower infection rate suggests sampling during or shortly after a drier period when larval challenge is minimized, (c) Diagnosis: While we relied on the standard, cost-effective flotation technique, the observed prevalence may still be an underestimation as it reflects only the current egg excretion status and not the total worm burden or subclinical infections that might be detectable by more sensitive molecular methods like PCR (Zajac, 2015b).

Numerically, infection was marginally higher in adult sheep (>12 months, 18.0%) and female sheep (18.2%). These observations align with classical parasitological theories: older animals have had prolonged exposure, leading to the accumulation of chronic worm burdens, while females can experience a periparturient rise in egg excretion due to the immunosuppressive effects of pregnancy and lactation (Lughano and Dominic, 2015).

Crucially, the statistical analysis demonstrated no significant association between GIN infection status and either sex ($\chi 2= 0.024$, and P=0.876) or age ($\chi 2= 0.210$, and P=0.90). This lack of significant difference suggests that, under the environmental and management conditions prevalent in Tamboul, intrinsic host factors (age, sex) are secondary to extrinsic factors (environmental contamination, stocking density, and lack of strategic deworming) in determining infection risk. The relatively uniform distribution of GIN infection implies a constant, low-to-moderate level of pasture contamination that equally affects all demographic groups (Keyyu et al., 2005). The gastrointestinal tract of sheep contains complex microbial communities influence numerous aspects of that sheep's heath and development, (Jin Wang, et al ,2017).

The identification of five different genera of gastrointestinal nematodes (GINs)—*Nematodirus* spp., Strongylid spp., *Trichuris* spp., *Haemonchus* spp., and *Toxocara* spp.—from the positive sheep confirms that polyparasitism is prevalent in the Tamboul region. This mix of helminths is typical of sheep raised under extensive grazing systems worldwide (Urquhart et al., 2013; Zajac, 2015b).

The most notable finding is the numerical dominance of *Nematodirus* spp., which was the most frequent genus identified (28.6% of positive cases). This is a critical ecological observation for the semi-arid environment of Gezira. While *Haemonchus* spp. (the Strongylid most frequently associated with severe anemia and high mortality in tropical and subtropical regions) was present, its relatively lower frequency (14.3% of positive cases) suggests that current environmental factors in Tamboul may be less optimal for its transmission cycle compared to other GINs.

Nematodirus spp. eggs are unique in that they are highly resistant to desiccation and can survive harsh, dry conditions for long periods (Zajac, 2015a). Their lifecycle requires prolonged cold or dry periods followed by rainfall to trigger mass hatching. The high prevalence of *Nematodirus* spp. in this study likely reflects its ability to persist in the arid environment of Tamboul, making it a key production constraint even when conditions are unfavorable for the more humidity-dependent Strongylids like *Haemonchus* spp. (Urquhart et al., 2013).

The statistical analysis, a Chi-square test for Goodness of Fit, indicated no statistically significant difference in the frequency distribution of the five identified genera ($\chi2=1.00$, $P=0.909$). This non-significant result must be interpreted cautiously.

While the data show a clear numerical hierarchy (*Nematodirus* spp. being twice as common as *Haemonchus* spp.), the P-value of 0.909 means that the differences observed are likely due to random chance. This finding is predominantly an artifact of the severely limited statistical power caused by the very small number of total positive samples (N=14) available for this genus-level analysis. With such a low sample size, the test cannot reliably distinguish between a true unequal distribution and simple random variation. Therefore, despite the lack of statistical significance, the numerical prominence of *Nematodirus* spp. remains biologically and ecologically important and should guide local control strategies.

The polyparasitic nature of the infection underscores the need for broad-spectrum anthelmintics. However, the apparent dominance of *Nematodirus* spp. over the traditionally more common and severe *Haemonchus* spp. in this semi-arid region suggests that control programs must be specifically tailored to break the lifecycle of resilient parasites like *Nematodirus* spp., potentially focusing on timely pasture management and treatment to control large-scale hatching events.

The crude prevalence of 17.5% for GIN infection observed in sheep from the Tamboul region is relatively moderate. This figure stands in sharp contrast to the high prevalence rates commonly reported in other livestock populations across Africa, such as the 83% overall prevalence recorded in sheep in Ethiopia (Debela et al., 2021). Similarly, historical data from other parts of Sudan, such as Kordofan, have reported rates exceeding 68% (Ghada & Khalil, 2011a).

This considerable variation suggests that the local conditions in Tamboul, Gezira State, create a distinct epidemiological niche. The moderate prevalence may reflect specific protective factors, such as: (a) Arid Climatic Conditions: Gezira's semi-arid environment likely imposes stringent survival limits on the free-living larval stages (L3), thereby reducing the infection pressure on pastures (Kaplan & Vidyashankar, 2012; Eysker, 2000), (b) Sampling Season or Management: The survey may have been conducted during a period or season (e.g., dry season) when larval availability on pasture was naturally minimized, limiting exposure compared to the peak transmission periods (Eysker, 2000).

The finding of polyparasitism involving five different genera is consistent with sheep production under extensive grazing systems globally (Urquhart et al., 2013). However, the specific genus composition provides crucial ecological insight for the Gezira environment.

The numerical dominance of *Nematodirus* spp. (28.6% of positive cases), compared to the lower frequency of *Haemonchus* spp. (14.3% of positive cases), is ecologically significant. *Haemonchus contortus* is typically the most pathogenic and economically impactful parasite in warm, humid climates, responsible for high prevalence and mortality in many parts of Africa (Debela et al., 2021). The lower prevalence of *Haemonchus* spp. in this study likely supports the hypothesis that the local environment is too dry for the optimal development and survival of its L3 stage (Zajac, 2015b). Conversely, the resilience of *Nematodirus* spp. eggs to desiccation makes it a dominant constraint in arid and semi-arid zones, reflecting its ability to survive periods unfavorable to other Strongylids.

The statistical non-significance of the genus distribution ($\chi2=1.00$, $P=0.909$) must be interpreted with caution. While the test indicated that the numerical differences were not statistically reliable, this is highly likely due to the limited statistical power imposed by the very small number of positive samples (N=14). Therefore, the observed biological pattern—the high frequency of *Nematodirus* spp. over *Haemonchus* spp.—remains a compelling factor in defining local disease risk.

The confirmed presence of Strongylid-type nematodes, specifically including *Haemonchus* spp., carries serious implications for sustainable control programs. Recent research from Sudan has confirmed the presence of ivermectin resistance in *H. contortus* in South Darfur, with therapeutic doses showing efficacy as low as 75.6% (Ali et al., 2024).

The reliance on anthelmintics remains a core control strategy, but the documented presence of the highly pathogenic *Haemonchus* spp. alongside regional resistance reports necessitates a shift toward integrated pest management. The economic impact of even a moderate 17.5% infection rate cannot be overlooked, given that GINs can reduce weight gain, wool production, and milk yield by 10% to 22% (Mavrot et al., 2015). Therefore, future control strategies in the Tamboul region must prioritize diagnostic surveillance for anthelmintic resistance and integrate strategies like pasture rotation and targeted selective treatment (TST) to preserve drug efficacy and minimize production losses.

5. Conclusion and Recommendations

Although the current GIN prevalence in Tamboul sheep is moderate, the presence of multiple pathogenic genera, including *Haemonchus* spp., poses a persistent threat to small-ruminant productivity and welfare (Mavrot et al., 2015). The non-significant influence of host factors emphasizes that effective GIN control in this region must prioritize environmental and management interventions.

Therefore, we recommend: (a) Implementing targeted selective treatment (TST) strategies rather than blanket deworming, especially during periods following expected rainfall when larval challenge increases, (b) Adopting improved husbandry practices, such as pasture rotation and reducing stocking density, to break the parasite life cycle and mitigate continuous pasture contamination.

Further research utilizing molecular techniques is necessary to confirm species-level identification (e.g., distinguishing *Haemonchus* from other Strongylids) and to accurately quantify infection intensity, which will allow for a more precise assessment of the economic impact of GINs in the Gezira State.

Compliance with ethical standards

Acknowledgments

We gratefully acknowledge the Department of Parasitology, Faculty of Veterinary Medicine, University of Al-Butana, for providing the institutional support necessary to conduct this study. We also thank the staff at the Tamboul Slaughterhouse for their cooperation in facilitating the collection of samples used for the identification of gastrointestinal nematode infections in sheep.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Declaration

We, the undersigned authors, hereby declare that the manuscript entitled: " Prevalence and Epidemiological Factors of Gastrointestinal Nematode Infections in Sheep Slaughtered at Tamboul Slaughterhouse, Gezira State, Sudan"

- Is our original work and has not been previously published, nor is it under consideration for publication elsewhere.
- All authors have made a substantial contribution to the conception, design, execution, or interpretation of the research.
- We confirm that the data and results presented herein are accurate and were derived and analysed with full scientific credibility and integrity.

AI Tool Use Clarification

The large language model ChatGPT (OpenAI, San Francisco, CA) was utilized solely to enhance the manuscript's presentation. Its functions were restricted to proofreading, refining grammar and academic wording, polishing statistical analysis descriptions and table formats, and ensuring that citation and reference styles conformed to the required journal submission guidelines. The AI tool did not contribute to the research design, data analysis, or the generation of scientific interpretations.

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