Prevalence Of Gastrointestinal Parasites And Their Impact On The Health Status Of Small Ruminants In Tropical Farming Systems

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Abstract
Gastrointestinal parasitic infections remain one of the major constraints limiting the productivity and health of small ruminants in tropical farming systems. Favorable environmental conditions, including high temperature and humidity, facilitate parasite survival and transmission, resulting in persistent infections among grazing sheep and goats. This study aimed to determine the prevalence of gastrointestinal parasites and evaluate their impact on the health status of small ruminants raised under tropical farming systems. A cross-sectional observational study was conducted involving 150 small ruminants (75 sheep and 75 goats) selected from traditional and semi-intensive farms. Fresh fecal samples were collected and examined using flotation, sedimentation, and McMaster egg-counting techniques for parasite identification and quantification. Clinical examinations, body condition scoring, body weight measurement, and hematological analyses were performed to assess animal health. The results showed that 92 animals (61.3%) were infected with at least one gastrointestinal parasite species. The infection rate was accompanied by significant differences in body weight, body condition score, hemoglobin concentration, and packed cell volume between infected and non-infected animals ($P < 0.001$). Haemonchus contortus was the predominant parasite, followed by Trichostrongylus spp., Eimeria spp., Strongyloides spp., Moniezia spp., and Fasciola spp. Infected animals exhibited significantly lower body weight, body condition score, hemoglobin concentration, and packed cell volume than non-infected animals ($P < 0.05$). A significant negative correlation was observed between fecal egg count and health indicators, indicating that increasing parasite burdens were associated with deteriorating physiological condition. Younger animals and farms practicing continuous grazing with irregular deworming programs showed higher infection rates than adult animals and farms implementing improved management practices. The findings demonstrate that gastrointestinal parasites remain a serious health challenge in tropical small-ruminant production systems. The study contributes by combining parasite prevalence assessment with clinical, hematological, and management-related indicators within the same tropical small-ruminant production context. Integrated parasite management, including routine surveillance, targeted selective treatment, pasture rotation, improved nutrition, and farmer education, is recommended to reduce parasite transmission, improve animal health, and enhance the sustainability of livestock production in tropical regions.

Keywords: gastrointestinal parasites; small ruminants; tropical farming systems; prevalence; animal health.

INTRODUCTION

Small ruminants, particularly sheep and goats, are essential components of tropical farming systems because they contribute significantly to food security, rural livelihoods, and household income. Their adaptability to diverse agroecological conditions, relatively low production costs, and ability to utilize marginal grazing resources make them valuable livestock species for smallholder farmers across tropical and subtropical regions. In many developing countries, small ruminants provide meat, milk, fiber, manure, and financial security, thereby supporting sustainable agricultural production and poverty alleviation. However, their productivity remains constrained by numerous health challenges, among which gastrointestinal parasitic infections represent one of the most economically important diseases (FAO, 2023; Zajac & Conboy, 2022).

Gastrointestinal parasites (GIPs), including nematodes, cestodes, trematodes, and protozoa, are widely distributed in tropical environments where high temperatures, elevated humidity, and prolonged rainfall create favorable conditions for

parasite survival and transmission. Species such as *Haemonchus contortus*, *Trichostrongylus* spp., *Strongyloides* spp., *Cooperia* spp., *Moniezia* spp., and *Eimeria* spp. frequently infect grazing sheep and goats, leading to varying degrees of morbidity and production losses. The continuous contamination of pasture with infective larvae and oocysts increases the likelihood of reinfection, particularly in traditional grazing systems with inadequate pasture management and limited parasite control strategies (Taylor et al., 2016; Gilleard et al., 2021).

The impact of gastrointestinal parasitism extends beyond clinical disease, affecting nearly every aspect of animal productivity. Infected animals commonly exhibit reduced feed intake, impaired nutrient absorption, anemia, diarrhea, poor body condition, decreased weight gain, reduced reproductive performance, and increased susceptibility to secondary bacterial and viral infections. Severe infections may result in mortality, especially among young animals whose immune systems are still developing. Consequently, parasitic infections substantially reduce farm profitability through decreased production efficiency and increased veterinary treatment costs, posing a significant challenge to sustainable livestock production in tropical countries (Zajac & Conboy, 2022; Mavrot et al., 2015).

The epidemiology of gastrointestinal parasites is influenced by numerous interacting factors, including climatic conditions, host age, breed, nutritional status, grazing management, stocking density, and the implementation of parasite control programs. Tropical climates accelerate parasite life cycles and enhance the development of infective stages in the environment, often leading to year-round transmission. Furthermore, the widespread and repeated use of anthelmintic drugs has contributed to the emergence of anthelmintic resistance in many parasite populations, reducing the effectiveness of conventional control measures and emphasizing the need for integrated parasite management approaches combining strategic deworming, pasture rotation, nutritional improvement, and genetic selection for parasite resistance (Kaplan, 2020; Gilleard et al., 2021).

Numerous epidemiological studies conducted in Africa, Asia, and Latin America have reported high prevalence rates of gastrointestinal parasites among small ruminants, although infection levels vary considerably according to geographical location, season, production system, and diagnostic techniques employed. Despite the abundance of regional studies, comparative information regarding parasite prevalence and its association with animal health indicators such as body condition score, hematological parameters, and productivity remains limited in many tropical farming systems. This knowledge gap restricts the development of evidence-based control strategies tailored to local production environments and management practices (Mavrot et al., 2015; Roeber et al., 2013). In particular, studies that simultaneously assess parasite prevalence, parasite burden, clinical condition, and hematological indicators under different small-ruminant management practices remain relatively limited. Examining these factors together can provide a more practical basis for identifying animals and management conditions associated with higher infection risk.

Assessing the prevalence of gastrointestinal parasites alongside their impact on the health status of sheep and goats is therefore essential for improving animal welfare and enhancing livestock productivity. Reliable epidemiological data enable veterinarians, livestock extension officers, and farmers to identify major parasite species, determine high-risk populations, evaluate associated health consequences, and design effective prevention and control programs. Such information also supports sustainable livestock management by reducing production losses while minimizing the development of drug resistance through more targeted parasite control interventions (FAO, 2023; Kaplan, 2020).

Based on these considerations, the present study aims to investigate the prevalence of gastrointestinal parasites and evaluate their impact on the health status of small ruminants raised under tropical farming systems. Specifically, this study seeks to identify the predominant gastrointestinal parasite species, determine infection prevalence, and examine the relationship between parasite infection and selected health indicators of sheep and goats. The findings are expected to provide scientific evidence that contributes to the development of integrated parasite management strategies for sustainable small-ruminant production in tropical regions. Therefore, the contribution of this study lies not only in estimating parasite prevalence, but also in relating infection status and fecal egg burden to measurable health indicators and management practices in the same population.

LITERATURE REVIEW

Small Ruminants in Tropical Farming Systems

Small ruminants, particularly sheep and goats, play an important role in tropical agricultural systems due to their adaptability to harsh environmental conditions, efficient feed conversion, and relatively low production costs. These animals contribute significantly to household income, food security, and rural livelihoods, especially among smallholder farmers. Tropical farming systems are characterized by high temperatures, seasonal rainfall, and diverse vegetation, creating favorable conditions for both livestock production and parasite development. Despite their resilience, sheep and goats are highly susceptible to various diseases, including gastrointestinal parasitic infections, which remain one of the major constraints to productivity (Devendra, 2013).

Figure 1. Small Ruminants in Tropical Farming Systems

Gastrointestinal Parasites of Small Ruminants

Gastrointestinal parasites (GIPs) are organisms that inhabit the digestive tract of animals and derive nutrients at the expense of their hosts. In small ruminants, the most common parasites include nematodes (*Haemonchus contortus, Trichostrongylus spp., Strongyloides spp.*), cestodes (*Moniezia spp.*), trematodes (*Fasciola spp.*), and protozoa (*Eimeria spp.*). These parasites can infect animals through ingestion of contaminated feed, water, or pasture containing infective eggs, larvae, or oocysts. The prevalence and intensity of infection are influenced by environmental conditions, management practices, and host immunity (Taylor et al., 2016).

Among these parasites, *Haemonchus contortus* is considered the most pathogenic nematode affecting sheep and goats in tropical regions. It is a blood-feeding parasite that causes severe anemia, edema, reduced growth, and even death in heavily infected animals. Its high reproductive capacity and rapid development under warm and humid conditions make it a major challenge for livestock producers worldwide (Kaplan, 2020).

Figure 2. Common Gastrointestinal Parasites of Small Ruminants

Life Cycle and Transmission of Gastrointestinal Parasites

The transmission of gastrointestinal parasites generally occurs through a direct life cycle involving the shedding of eggs or oocysts in feces. Under suitable environmental conditions, these eggs develop into infective larvae that contaminate grazing areas. Livestock become infected when they consume contaminated forage or water. High humidity, warm temperatures, and poor pasture management significantly increase parasite survival and transmission rates.

In tropical environments, parasite transmission often occurs year-round because climatic conditions continuously support larval development. Overstocking, continuous grazing, and inadequate sanitation further contribute to the accumulation of infective stages in the environment, increasing the risk of infection among susceptible animals (Gilleard et al., 2021).

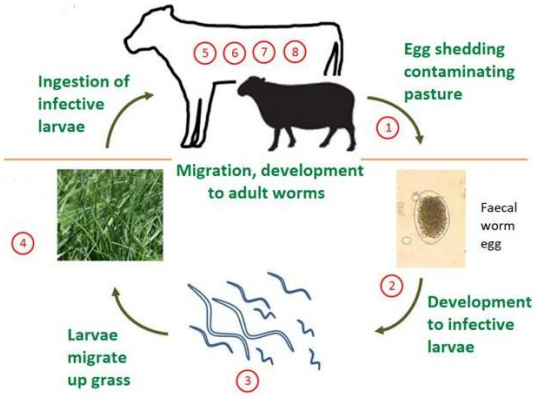

Figure 3. General Life Cycle of Gastrointestinal Nematodes

Impact of Gastrointestinal Parasites on Animal Health

Gastrointestinal parasitic infections have substantial effects on animal health and productivity. Parasites compete with the host for nutrients, damage the intestinal lining, and interfere with digestion and absorption processes. Clinical manifestations commonly include diarrhea, weight loss, anemia, dehydration, rough hair coat, reduced appetite, and poor body condition score.

The severity of infection depends on parasite species, parasite burden, host age, nutritional status, and immune competence. Young animals are generally more susceptible because of their immature immune systems. Chronic infections often result in subclinical production losses that may go unnoticed but significantly reduce growth rates and reproductive performance over time (Mavrot et al., 2015).

Several studies have reported significant associations between parasite infection and decreased hematological parameters, particularly packed cell volume (PCV), hemoglobin concentration, and red blood cell count. These indicators are commonly used to assess the health status of infected animals and evaluate the severity of parasitic disease. However, the relationship between parasite infection and animal health is not always uniform because the observed effects may depend on parasite species, infection intensity, host age, nutritional status, and immune condition. Therefore, prevalence alone may not adequately describe the health consequences of parasitism, and parasite burden should also be considered when evaluating disease impact.

Factors Affecting Parasite Prevalence

The prevalence of gastrointestinal parasites varies according to environmental, host-related, and management factors. Climatic conditions such as temperature and rainfall influence parasite development and survival. Tropical regions generally experience higher infection rates because warm and humid conditions promote rapid larval growth.

Host-related factors include age, sex, breed, physiological status, and immune response. Young animals frequently exhibit higher prevalence rates than adults. Nutritional deficiencies can also weaken immune function and increase susceptibility to infection. Management practices such as grazing systems, stocking density, housing sanitation, and deworming programs play critical roles in determining parasite prevalence within herds (Roeber et al., 2013).

Diagnostic Approaches for Gastrointestinal Parasites

Accurate diagnosis is essential for effective parasite control. The most commonly used diagnostic technique is fecal examination, which allows detection and quantification of parasite eggs or oocysts. Methods such as flotation, sedimentation, and McMaster egg-counting techniques are widely employed in veterinary parasitology laboratories.

Recent advances in molecular diagnostics, including polymerase chain reaction (PCR)-based methods, have improved the identification of parasite species and enhanced epidemiological investigations. However, conventional fecal

examination remains the most practical and cost-effective approach for routine diagnosis in developing countries (Roeber et al., 2013). Nevertheless, conventional microscopy may have limitations in distinguishing morphologically similar parasite species, particularly when infections involve multiple parasite groups. Molecular methods can provide greater taxonomic resolution, although their cost and laboratory requirements may limit routine application in smallholder production systems.

Control and Prevention Strategies

Effective control of gastrointestinal parasites requires an integrated management approach. Strategic deworming programs, rotational grazing, improved nutrition, selective breeding for parasite resistance, and regular monitoring of parasite burdens are recommended to reduce infection levels and minimize production losses.

The emergence of anthelmintic resistance has become a major concern worldwide. Excessive and indiscriminate use of deworming drugs has reduced their efficacy in many livestock systems. Consequently, sustainable parasite management now emphasizes targeted selective treatment and integrated parasite control strategies rather than reliance solely on chemical anthelmintics (Kaplan, 2020; Gilleard et al., 2021).

Conceptual Framework

The conceptual framework of this study assumes that environmental conditions and management practices influence the prevalence of gastrointestinal parasites, which subsequently affect the health status of small ruminants.

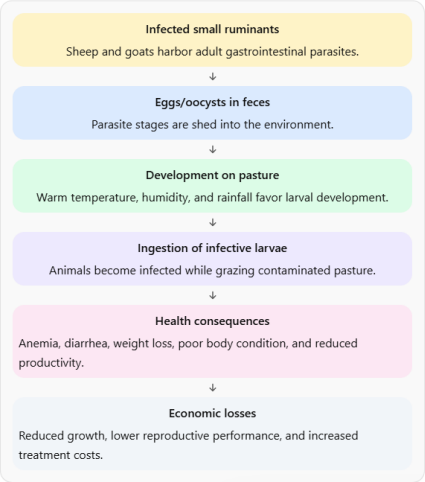

Figure 4. Research Flow

RESEARCH METHODOLOGY

Research Design

This study employed a **cross-sectional observational design** to determine the prevalence of gastrointestinal parasites and evaluate their association with the health status of small ruminants raised under tropical farming systems. A cross-sectional approach was selected because it enables simultaneous assessment of parasite infection and animal health indicators at a single point in time. The study was conducted in representative smallholder livestock farms located in tropical regions characterized by high annual rainfall, warm temperatures (25–32°C), and extensive grazing systems. Data collection was carried out during the wet season when environmental conditions favor parasite development and transmission.

Study Animals and Sampling Procedure

The study population consisted of apparently healthy and clinically suspected sheep and goats maintained under traditional and semi-intensive production systems. A total of **150 small ruminants** (75 sheep and 75 goats) of different ages and sexes were selected using a simple random sampling technique from ten livestock farms. The sampling was intended to include both sheep and goats from the available traditional and semi-intensive production systems, allowing parasite prevalence and associated health indicators to be compared across the main host and management characteristics recorded during the study. For each animal, demographic information including species, age, sex, body weight, body

condition score (BCS), deworming history, and management practices was recorded using a standardized questionnaire. Clinical examinations were performed by licensed veterinarians to assess visible signs of parasitic infection such as anemia, diarrhea, dehydration, rough hair coat, submandibular edema, and poor body condition.

Figure 5. Collection of Health Data from Small Ruminants

Fecal Sample Collection and Laboratory Examination

Fresh fecal samples (approximately **10–15 g**) were collected directly from the rectum of each animal using disposable gloves to minimize environmental contamination. Samples were placed into sterile labeled plastic containers, stored in insulated cool boxes at approximately **4°C**, and transported to the Veterinary Parasitology Laboratory within 24 hours. Laboratory examination was conducted using three complementary diagnostic methods: the flotation technique for detecting nematode eggs and coccidian oocysts, the sedimentation technique for identifying trematode eggs, and the McMaster egg-counting technique to determine fecal egg counts (FEC), expressed as eggs per gram (EPG) of feces. Parasites were identified microscopically according to their morphological characteristics using standard veterinary parasitology identification keys.

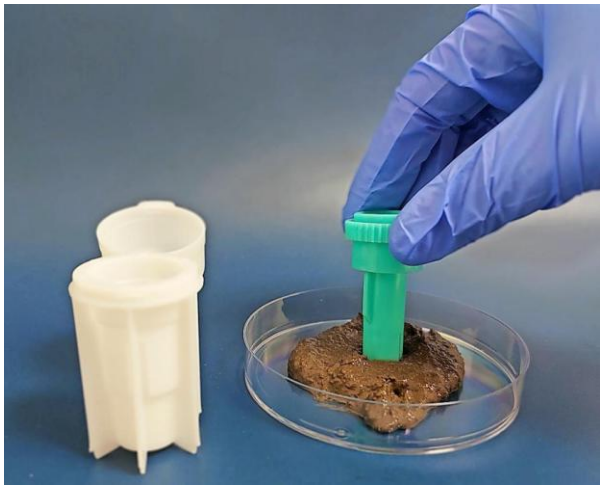

Figure 6. Laboratory Examination of Fecal Samples

Health Status Assessment

The health status of each animal was evaluated using both clinical observations and physiological measurements. Body weight was measured using a digital livestock scale, while Body Condition Score (BCS) was assessed on a five-point scoring system (1 = emaciated, 5 = obese). Blood samples (5 mL) were collected via jugular venipuncture into EDTA tubes for hematological analysis. Hemoglobin concentration (Hb), packed cell volume (PCV), red blood cell (RBC) count, and white blood cell (WBC) count were determined using an automated hematology analyzer. Animals exhibiting pale mucous membranes, low PCV values, and reduced hemoglobin concentrations were classified as having anemia. These health indicators were subsequently compared between parasite-positive and parasite-negative animals to evaluate the impact of

gastrointestinal parasitic infections. Because parasite detection and clinical assessment may be influenced by the condition of the sample and the timing of examination, standardized collection, storage, and assessment procedures were used throughout the study. Nevertheless, the cross-sectional design and reliance on conventional microscopic identification may still introduce some degree of measurement limitation.

Figure 7. Blood Collection and Hematological Analysis

Data Analysis

All data were entered into Microsoft Excel before being analyzed using **IBM SPSS Statistics version 27** (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize animal characteristics, parasite prevalence, and health indicators. Overall prevalence was calculated as the percentage of infected animals among the total examined population:

$$\text{Prevalence (\%)} = \frac{\text{Number of infected animals}}{\text{Total number of examined animals}} \times 100$$

Differences in parasite prevalence according to species, age, sex, and management system were analyzed using the **Chi-square (χ^2) test**. Independent sample **t-tests** were performed to compare hematological parameters and body condition scores between infected and non-infected animals. Pearson correlation analysis was used to determine the relationship between fecal egg count (EPG) and health indicators. Statistical significance was established at **$P < 0.05$**. The study protocol complied with institutional guidelines for animal welfare and was approved by the Institutional Animal Ethics Committee before commencement of field activities.

RESULTS AND DISCUSSION

Prevalence of Gastrointestinal Parasites

A total of **150 small ruminants**, consisting of 75 sheep and 75 goats, were examined for gastrointestinal parasites using flotation, sedimentation, and McMaster fecal egg count techniques. Overall, **92 animals (61.3%)** were found to be positive for at least one gastrointestinal parasite species, indicating that parasitic infections remain highly prevalent under tropical farming conditions. The warm and humid environment typical of tropical regions provides favorable conditions for the survival and transmission of infective larvae, thereby increasing the likelihood of continuous pasture contamination and reinfection. The prevalence observed in the present study is consistent with previous reports conducted in tropical countries, where prevalence rates commonly exceed 50% because of extensive grazing systems and inadequate parasite control programs (Taylor et al., 2016).

Among the identified parasites, **Haemonchus contortus** was the predominant species, accounting for **35.9%** of all positive samples, followed by **Trichostrongylus spp. (19.6%)**, **Strongyloides spp. (14.1%)**, **Moniezia spp. (8.7%)**, **Fasciola spp. (6.5%)**, and **Eimeria spp. (15.2%)**. The predominance of *H. contortus* reflects its remarkable reproductive capacity and adaptation to tropical climatic conditions, where high temperature and humidity accelerate larval development. Blood-feeding nematodes such as *H. contortus* are recognized as one of the most pathogenic gastrointestinal parasites because they directly reduce erythrocyte counts and induce severe anemia in infected animals.

Table 1. Prevalence of Gastrointestinal Parasites in Small Ruminants

Parasite Species	Positive Animals (n)	Prevalence (%)
Haemonchus contortus	33	35.9
***Trichostrongylus* spp.**	18	19.6
***Strongyloides* spp.**	13	14.1
***Eimeria* spp.**	14	15.2
***Moniezia* spp.**	8	8.7
***Fasciola* spp.**	6	6.5
Total Positive	**92**	**61.3**

The relatively high prevalence of nematode infections may be attributed to continuous grazing practices implemented by most smallholder farmers. Animals are repeatedly exposed to contaminated pastures where infective larvae accumulate over time. Moreover, interviews with farmers revealed that deworming was often irregular and performed without fecal examination or veterinary supervision. Such management practices facilitate persistent parasite transmission and may contribute to the emergence of anthelmintic resistance, which has become an increasing concern in tropical livestock production systems.

Health Status of Infected and Non-Infected Animals

Clinical examination demonstrated clear differences between parasite-positive and parasite-negative animals. Most infected animals exhibited reduced body condition scores, rough hair coats, mild diarrhea, pale conjunctival mucous membranes, and decreased body weight. These clinical manifestations were particularly evident among animals harboring *Haemonchus contortus*, which is known to consume blood from the abomasal mucosa, resulting in progressive anemia and reduced productivity. Similar findings have been reported in previous epidemiological studies indicating that gastrointestinal parasitism substantially compromises animal health and production efficiency.

Hematological analysis further confirmed the negative impact of parasite infection on animal health. Parasite-positive animals showed significantly lower hemoglobin concentrations, packed cell volume (PCV), and red blood cell counts compared with non-infected animals (**$P < 0.05$**). Conversely, white blood cell counts were slightly elevated among infected animals, reflecting activation of the host immune response against parasitic invasion. These physiological alterations demonstrate that gastrointestinal parasites not only impair nutrient absorption but also induce systemic pathological changes that reduce animal performance.

Table 2. Comparison of Health Indicators Between Infected and Non-Infected Animals

Health Indicator	Infected (n = 92)	Non-Infected (n = 58)	P-value
Body Weight (kg)	24.6 ± 4.2	29.3 ± 3.8	<0.001
Body Condition Score	2.31 ± 0.45	3.41 ± 0.39	<0.001
Hemoglobin (g/dL)	8.9 ± 1.2	11.6 ± 0.9	<0.001
Packed Cell Volume (%)	25.8 ± 3.5	33.7 ± 2.8	<0.001
Fecal Egg Count (EPG)	1,420 ± 385	0	—

Correlation analysis indicated a significant negative relationship between fecal egg count (EPG) and body condition score (**$r = -0.69$; $P < 0.001$**) as well as between EPG and hemoglobin concentration (**$r = -0.72$; $P < 0.001$**). These findings suggest that increasing parasite burden is associated with deteriorating nutritional status and worsening anemia. The stronger negative correlation observed with hemoglobin suggests that increasing parasite burden may be particularly relevant to anemia-related health deterioration, which is biologically plausible for blood-feeding parasites such as Haemonchus contortus. Nevertheless, correlation does not establish a direct causal relationship, and other nutritional or management factors may contribute to the observed variation. Similar relationships have been documented in previous studies, where heavy parasite loads resulted in reduced feed conversion efficiency and impaired physiological function.

The findings also demonstrated that younger animals (<12 months) had a significantly higher prevalence of infection than adult animals. This observation is likely associated with the immature immune system of young animals, making them more susceptible to parasite establishment and development. In contrast, older animals may acquire partial immunity

following repeated exposure, thereby reducing parasite establishment and egg production. Nevertheless, adult animals can still serve as reservoirs that continuously contaminate grazing areas with parasite eggs. The higher infection rate among younger animals is consistent with their greater susceptibility to gastrointestinal parasites, but age should not be considered in isolation because nutritional status, exposure intensity, and management practices may also differ between age groups.

Management practices were found to play an important role in determining parasite prevalence. Farms implementing rotational grazing, regular fecal monitoring, and strategic deworming programs exhibited considerably lower infection rates than farms relying solely on continuous grazing and routine mass deworming. Proper pasture management reduces the density of infective larvae, while targeted selective treatment decreases unnecessary anthelmintic use and delays the development of drug resistance. These findings support current recommendations advocating integrated parasite management rather than exclusive reliance on chemical treatments.

Overall, the present study confirms that gastrointestinal parasites remain a major health constraint affecting sheep and goats in tropical farming systems. The high prevalence of infection, together with significant reductions in body weight, body condition score, hemoglobin concentration, and packed cell volume, demonstrates the considerable impact of parasitic diseases on animal welfare and productivity. Implementation of integrated parasite control strategies—including regular fecal examinations, targeted selective treatment, improved nutrition, pasture rotation, and farmer education—is therefore essential to reduce parasite transmission, improve livestock health, and enhance the sustainability of small-ruminant production in tropical regions.

CONCLUSION

This study demonstrated that gastrointestinal parasites remain highly prevalent among small ruminants raised under tropical farming systems, with an overall infection rate of **61.3%**. The most frequently identified parasite was *Haemonchus contortus*, followed by *Trichostrongylus* spp., *Eimeria* spp., *Strongyloides* spp., *Moniezia* spp., and *Fasciola* spp. The favorable climatic conditions of tropical regions, combined with extensive grazing practices and insufficient parasite control measures, contribute substantially to the persistence and transmission of these parasites.

The findings revealed that gastrointestinal parasitic infections have a significant negative impact on the health status of sheep and goats. Infected animals exhibited lower body weight, poorer body condition scores, reduced hemoglobin concentration, and decreased packed cell volume compared with non-infected animals. Clinical signs such as anemia, diarrhea, rough hair coats, and poor physical condition further confirmed the detrimental effects of parasitic infections on animal health and productivity.

The study also identified important risk factors associated with parasite prevalence. Younger animals were more susceptible to infection than adults, while farms practicing continuous grazing and irregular deworming programs experienced higher infection rates. Conversely, farms implementing improved grazing management, regular fecal monitoring, and strategic parasite control demonstrated lower parasite burdens, emphasizing the importance of appropriate management practices in reducing disease transmission.

The relationship between fecal egg count and health indicators indicated that increasing parasite burdens were associated with worsening physiological and nutritional conditions. These results highlight the value of combining parasitological examinations with clinical and hematological assessments to accurately evaluate the health status of small ruminants. Such integrated diagnostic approaches can support early detection of infections and facilitate timely intervention before severe production losses occur.

In conclusion, effective control of gastrointestinal parasites in tropical farming systems requires an integrated parasite management strategy that combines routine surveillance, targeted selective anthelmintic treatment, rotational grazing, improved nutrition, and farmer education. Implementing these measures may help reduce parasite transmission, improve animal health and welfare, minimize production losses, and support the long-term sustainability of small-ruminant production systems in tropical regions. Future studies should incorporate molecular diagnostic techniques, seasonal epidemiological monitoring, and assessments of anthelmintic resistance to strengthen parasite control programs and improve livestock health management.

This study has several limitations that should be considered when interpreting the findings. The cross-sectional design provides information on parasite prevalence and health status at a specific period but cannot establish temporal or causal relationships. In addition, conventional microscopic identification may provide limited resolution for distinguishing closely

related parasite species, and the findings may not be directly generalizable to small-ruminant farms with different climatic, nutritional, or management conditions.

REFERENCES

Besier, R. B., Kahn, L. P., Sargison, N. D., & Van Wyk, J. A. (2016). Diagnosis, treatment and management of *Haemonchus contortus* in small ruminants. *Advances in Parasitology, 93*, 181–238.

Charlier, J., Van der Voort, M., Kenyon, F., Skuce, P., & Vercruysse, J. (2014). Chasing helminths and their economic impact on farmed ruminants. *Trends in Parasitology, 30*(7), 361–367.

Coles, G. C., Jackson, F., Pomroy, W. E., Prichard, R. K., Von Samson-Himmelstjerna, G., Silvestre, A., Taylor, M. A., & Vercruysse, J. (2006). The detection of anthelmintic resistance in nematodes of veterinary importance. *Veterinary Parasitology, 136*(3–4), 167–185.

Devendra, C. (2013). *Small Ruminant Production Systems in South and Southeast Asia*. Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization. (2023). *The State of Food and Agriculture 2023: Revealing the true cost of food to transform agrifood systems*. FAO.

Gilleard, J. S. (2013). *Haemonchus contortus* as a paradigm and model to study anthelmintic drug resistance. *Parasitology, 140*(12), 1506–1522.

Gilleard, J. S., et al. (2021). Haemonchosis in small ruminants: Advances in understanding parasite biology and control. *Annual Review of Animal Biosciences, 9*, 177–204.

Hoste, H., Sotiraki, S., Landau, S. Y., Jackson, F., & Beveridge, I. (2010). Goat–nematode interactions: Think differently. *Trends in Parasitology, 26*(8), 376–381.

Kaplan, R. M. (2020). Biology, epidemiology, diagnosis, and management of anthelmintic resistance in gastrointestinal nematodes of livestock. *Veterinary Clinics of North America: Food Animal Practice, 36*(1), 17–30.

Kaplan, R. M., & Vidyashankar, A. N. (2012). An inconvenient truth: Global warming and anthelmintic resistance. *Veterinary Parasitology, 186*(1–2), 70–78.

Knox, M. R., Torres-Acosta, J. F. J., & Aguilar-Caballero, A. J. (2006). Exploiting the effect of dietary supplementation of small ruminants on resilience and resistance against gastrointestinal nematodes. *Veterinary Parasitology, 139*(4), 385–393.

Mavrot, F., Hertzberg, H., & Torgerson, P. R. (2015). Effect of gastrointestinal nematode infection on sheep performance: A systematic review and meta-analysis. *Parasites & Vectors, 8*, 557.

Miller, J. E., & Horohov, D. W. (2006). Immunological aspects of nematode parasite control in sheep. *Journal of Animal Science, 84*(13 Suppl.), E124–E132.

Perry, B. D., & Randolph, T. F. (1999). *Improving the Assessment of the Economic Impact of Parasitic Diseases and Their Control in Production Animals*. FAO.

Perry, B. D., Randolph, T. F., McDermott, J. J., Sones, K. R., & Thornton, P. K. (2002). *Investing in Animal Health Research to Alleviate Poverty*. ILRI.

Roeber, F., Jex, A. R., & Gasser, R. B. (2013). Next-generation molecular-diagnostic tools for gastrointestinal nematodes of livestock. *Biotechnology Advances, 31*(8), 1130–1142.

Sargison, N. D. (2020). Practical parasite control in sheep and goats. *Veterinary Clinics of North America: Food Animal Practice, 36*(1), 1–16.

Soulsby, E. J. L. (1982). *Helminths, Arthropods and Protozoa of Domesticated Animals* (7th ed.). Baillière Tindall.

Taylor, M. A. (2012). Parasite control in sheep: A changing world. *Veterinary Parasitology, 189*(2–4), 148–154.

Taylor, M. A., Coop, R. L., & Wall, R. L. (2016). *Veterinary Parasitology* (4th ed.). Wiley-Blackwell.

Urquhart, G. M., Armour, J., Duncan, J. L., Dunn, A. M., & Jennings, F. W. (1996). *Veterinary Parasitology* (2nd ed.). Blackwell Science.

Van Wyk, J. A., & Bath, G. F. (2002). The FAMACHA© system for managing haemonchosis in sheep and goats. *Veterinary Research, 33*(5), 509–529.

Vercruysse, J., Charlier, J., Van Dijk, J., Morgan, E., Geary, T., Von Samson-Himmelstjerna, G., & Claerebout, E. (2018). Control of helminth ruminant infections by 2030. *Parasitology, 145*(13), 1655–1664.

Waller, P. J. (2006). Sustainable nematode parasite control strategies for ruminant livestock by grazing management and biological control. *Animal Feed Science and Technology, 126*(3–4), 277–289.

Whittier, W. D., & Currin, J. F. (2009). Internal parasites in sheep and goats. *Virginia Cooperative Extension Publication*, 410–027.

Zajac, A. M., & Conboy, G. A. (2022). *Veterinary Clinical Parasitology* (9th ed.). Wiley-Blackwell.

Zajac, A. M., & Gipson, T. A. (2000). Multiple and anthelmintic-resistant nematode populations in goats. *Veterinary Parasitology, 87*(2–3), 163–172.