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ORIGINAL RESEARCH

# Prevalence of Gastrointestinal Nematodes, Cestodes, and Protozoans of Goats in Nyagatare District, Rwanda

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**Introduction:** Goat farming significantly contributes to the efficient use of land and socioeconomic development in developed and developing countries. During the fiscal year 2017–2018, goats made up 13.5% of the total live livestock exported by Rwanda. Gastrointestinal parasites (GIPs) can negatively impact goat production, especially in developing countries like Rwanda. This study aimed to determine the impact of the goat' age and location (administrative cell) on the prevalence of gastrointestinal nematodes, cestodes, and protozoans (GiNCPs) of goats in Nyagatare district, Rwanda.

**Methods:** In this cross-sectional study, 149 faecal samples were collected from apparently unwell goats and analyzed using the simple flotation technique. Strongyle-type nematodes (STNs) infections were graded using the McMaster method. Pearson chi-square tests of independence were calculated to assess the impact of the goat' age and location on the prevalence of GiNCPs in the study area.

**Results:** All the goats (100%) were infected with GiNCPs. The identified types of parasites were STNs (96.0%), Coccidia (83.2%), *Moniezia* spp (14.8%), *Strongyloides papillosus* (12.8%), *Nematodirus* spp (0.7%) and *Trichuris ovis* (0.7%). Nearly 85.9% (128/149) of the goats were coinfected with 2 to 4 types of parasites and the coinfection of STNs and coccidia preponderated at 58.4%. The location (administrative cell) of the goats correlated with the prevalence of monieziasis ($p<0.05$). The goat's age category was also associated with the prevalence of strongyloidiasis ($p<0.05$).

**Conclusion:** All the goats (100%) were infected with GiNCPs. The location (administrative cell) of the goat also correlated with the prevalence of monieziasis. In addition, the goat's age category was associated with the prevalence of strongyloidiasis. These findings show that any control program for caprine gastrointestinal parasitoses in the study area should focus on STNs and Coccidia.

**Keywords:** caprine endoparasites, strongyle-type nematodes, *Moniezia* spp, *Strongyloides papillosus*, coccidia, Eastern province, Rwanda

## Introduction

Goat farming significantly contributes to the efficient use of land and socioeconomic development both in developed and developing countries.[3] Most households in Rwanda keep domestic goats because they are affordable for both small and big landholders and also for their economic, social, and cultural potential role.[4] Goats require little funds for investment, attain maturity quickly, grow rapidly, and adapt to some environmental conditions more than cattle.[5–7] Because of the significance of agriculture, and mainly livestock in improving the well-being of the underprivileged in rural areas, the government of Rwanda dedicated a development approach in which agriculture occupies a crucial function. During the fiscal year 2018–2019, livestock contributed to 4% of Rwanda's GDP.[8] Goats contribute to the self-reliance of farmers by providing them with food (animal protein and milk), skin, fertilizers from the droppings, urine, and direct cash income.[2,7,9,10] Goats can also adapt to the harsh tropical environment and conveniently be reared on unproductive land where cattle farming is not economical.[11,12]

During the fiscal year 2016/2017, caprine population in Rwanda was estimated at 2.94 million and goats produced 13% of dressed meat in Rwanda. They were the fourth largest livestock that produced dressed meat after cattle, swine, and chicken.[13]



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During the fiscal year 2017–2018, the goats represented 13.5% of total live livestock (n=941,046) exported by Rwanda and they were the third largest exported livestock after cattle and pigs.[14]

Despite the remarkable step made in increasing animal productivity in Rwanda, a lot of constraints and challenges exist in this sector. The economic benefit remains insignificant because of widespread diseases, lack of proper diets, poor husbandry practices, inappropriate reproductive skills, and lack of sufficient veterinary services. Even though farmers are faced with these challenges, the economic contribution of goats in Rwandan society is still very significant in alleviating poverty and in maintaining soil fertility.[4,7,15]

GIPs are common constraints on small ruminant farming and they impact the incidence and death rates, cost of treatment, and control measures for helminthiasis resulting in huge losses of livestock products.[16–20] GIPs infections can result in loss of weight and poor growth in young animals, diarrhea, anemia, and protein loss.[21,22] These parasites negatively impact the output and quality of milk and can also result in stunting, death as well as in condemnation of organs at slaughter.[12,23,24] Goats are susceptible to different gastrointestinal helminths (nematodes, trematodes, and cestodes) and protozoa.[25] STNs (*Haemonchus contortus, Cooperia curticei, Trichostrongylus* spp, *Oesophagostomum columbianum, Teladorsagia circumcincta, Bunostomum trigonocephalum, Nematodirus* spp) cause major caprine helminthiases.[26] Other important caprine nematodes include *Strongyloides papillosus* and *Trichuris ovis*. Common cestodes and trematodes of goats include *Moniezia* spp, *Fasciola* spp, *Paramphistomum* spp, and *Dicrocoelium* spp. *Eimeria* spp are the major coccidia of goats. Goats infected with GIPs manifest various clinical signs depending on the causative parasite including anorexia, diarrhea, loss of weight, body weakness, rough hair coat, cough, oedema, and anaemia.[22,27]

These effects can predispose goats to secondary infections which result in overspending on veterinary care and increased risk for anthelmintic resistance due to treatment without proper diagnosis.[24] Some small ruminant parasites are also zoonotic, and they are transmitted to humans. The latter include trematodes (*Fasciola* spp), nematodes (*Trichostrongylus* spp, *H. contortus, Mashallagia marshalli, Nematodirus abnormalis, Ostertagia ostertagi*, and *T. circumcincta*) and protozoa (*Entamoeba* spp, *Balantidium* spp, and *Giardia* spp).[28–32]

In Rwanda, there is little information documented about caprine GIPs. A study that investigated caprine and ovine *H. contortus* infections in Nyagatare District revealed a prevalence of 75.7%.[2] Studies conducted elsewhere reported a prevalence of caprine GIPs infections that vary between 18% and 100%.[33] This study, therefore, ascertained the impact of the goat's age and location (administrative cell) on the prevalence of gastrointestinal nematodes, cestodes, and protozoans of goats in the study area. The findings can guide local animal health service providers to design the control and prevention program for caprine gastrointestinal parasitoses in the study district and Rwanda at large.

# Materials and Methods

## Study Area

This study was carried out in Nyagatare administrative district (01°18′S 30°20′E) between February and March 2022. Administratively, Rwanda has five provinces and Nyagatare District is located in the Eastern province. Nyagatare is one of the 30 administrative districts of Rwanda and it is made up of 14 administrative sectors which are divided into 106 cells.[14] Nyagatare District is bounded northerly by Uganda, easterly by Tanzania, southerly by Gatsibo District, and westerly by Gicumbi District.

Rwanda has a tropical climate and it is mainly divided into four climatic zones including the eastern plains, where Nyagatare District is located.[34] In Rwanda, the mean temperature is around 20°C while the annual average temperature across the eastern plains varies between 20°C and 21°C while the annual rainfall is <900 mm.

Rwanda has two rain and dry seasons: the longest rain season occurs between March and May while the shortest one runs from October to December. The short dry season runs from January to February while the longest one occurs between June and September.[35] The vegetation in Nyagatare District is mostly an afforested savanna and some forestry galleries.

In the first instance, Nyagatare District was selected on purpose: in an agricultural household survey conducted in Rwanda in 2017, the number of households owning livestock nationwide was estimated at 1.7 million. Goats were recorded as the second most kept livestock after cattle with 53.6% and goat-rearing was highest in the Eastern province with 70.2%.[36] In addition, Nyagatare has the highest livestock population in Rwanda. For example, in 2013, Nyagatare District was home to 181,637 goats which was 6% (n= 2,970,780) of the national caprine population at the time.[37] Lastly, Nyagatare sector was chosen because it has

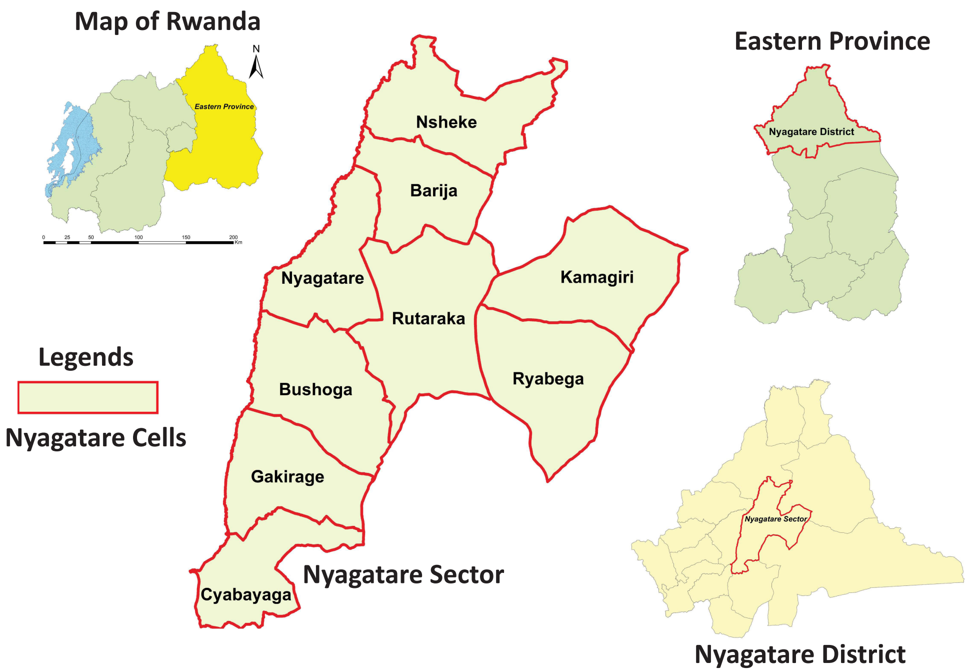


**Figure 1** A map of the study area. Shows the location of Nyagatare administrative sector (bordered by red limits) in Rwanda and its nine cells including Bushoga, Nyagatare, Kamagiri, Nsheke, Cyabayaga, Barija, Rutaraka, Ryabega, and Gakirage.

the highest caprine population in Nyagatare District. Six of nine administrative cells of Nyagatare sector were recruited in this study namely Barija, Bushoga, Nyagatare, Ryabega, Rutaraka, and Nsheke. The rest of the cells were home to a very limited caprine population and were not included in the present study. A map of the Nyagatare sector and the study cells is shown (Figure 1).[38]

## Study Design and Sample Size

This was a cross-sectional study involving the collection of faecal samples from apparently unwell goats (i.e., with poor hair coat or diarrhea or body weakness or poor body condition). The goats were selected from small-scale farmers who reared their goats under a semi-intensive farming system. The goats older than 3 months were considered for this study and those aged 3 to 6 months were categorized as young ones while those aged at least 7 months were categorized as old goats. No formula was used to determine the goats' age rather the researchers relied on the farmer's information and their own judgment. The fact that the small-scale farmers preferred having more female goats than male ones resulted in that, the study did not use the goat's sex as a factor. The animals were reared under an open grazing system on natural pastures and shrubs.

During the night, the goats were kept in a house at a farmer's home while during the daytime, most of the goats were tethered though they sometimes moved freely. The study subjects were selected randomly from different goat farms in the selected administrative cells (locations). For each study farm, 2 goats were selected randomly that is a young one (3–6 months) and an old goat (aged at least 7 months). Registers of the Nyagatare sector level proved caprine population in the sector was approximated to 30,000 in 2021. With a margin error of 10% and a 90% level of confidence, we computed the minimum sample size using Yamane's sample size formula for proportions[39,40] as follows:

$$n = N \,/\, \left[1 + N\,(e)^2\right] = 30000/\left[1 + 30000\,(0.1)^2\right] = 99.6 \approx 100 \text{ goats}$$

Where $N$ is the population and $e$ is the precision level. Given Nyagatare District is an area dedicated to farming and that the study was conducted when the residents were busy with agricultural activities and specifically the harvest, we had trouble meeting farmers at their homes. The computed sample size was increased by 50% to redress the probable non-response.[41,42] This study thus aimed at sampling 150 goats of which 149 were successfully sampled.

## Faecal Sample Collection and Parasitological Examination

Goats were restrained in a standing position and fresh faecal samples were collected directly from the rectum using a gloved index finger into a faecal pot. The collected samples were labeled, stored in a cool box, and transported to the parasitology laboratory of University of Rwanda, School of Veterinary Medicine for analysis. Faecal samples were stored in a refrigerator overnight and examined the next day. The faecal samples were processed using the flotation method and the McMaster method was only used to quantify the degree of infection for STNs. The identification of eggs and oocysts was done using the flotation method as described.[43] Flotation solution was prepared using sodium chloride (specific gravity of 1.2g). Identification of GIPs was based on morphological characteristics of eggs and oocysts. To detect the degree of infection of caprine STNs, McMaster egg counting parasitological technique was used.[43] To count STNs eggs, 4 grams of feces were suspended in 56 mL of the flotation fluid. The mixture was sieved and mixed and both chambers of the McMaster slide were loaded with the flotation fluid and left for 5 minutes before counting STNs eggs under a microscope at 10x magnification. The number of eggs per gram of feces was calculated by multiplying by 50.[43]

## Statistical Analysis

The data generated was entered into Microsoft excel for Windows 2010 and transferred to the statistical package for social sciences (SPSS) version 23 for analysis. In order to calculate the prevalence, the totality of goats infected with GiNCPs was divided by that of study goats and multiplied by one hundred. To get the EPG (Eggs per gram of faeces) for STNs, the sum of counted eggs was multiplied by 50. The intensity of infection (EPG) was classified as mild (50–799), moderate (800–1200), and severe (>1200) as described previously.[44] Pearson chi-square tests of independence[45] were calculated to assess the impact of study goats' age and location (administrative cell) on the prevalence of GiNCPs. Any $p < 0.05$ was considered statistically significant.

# Results

Of all 149 goats sampled, 100% suffered from GiNCPs (Table 1). The Effect of the goat's age category on the prevalence of caprine GI nematode, cestode, and protozoan infections in Nyagatare District is presented in Table 2. The prevalence of gastrointestinal nematode, cestode and protozoan mixed infections in goats in Nyagatare District is presented in Table 3. The intensity of Strongyle-type nematode infections in goats in Nyagatare District is presented in Table 4. The impact of the goat' age on the intensity of STNs infections in Nyagatare District is presented in Table 5. The intensity of strongyle-type nematode infections in the goats vis-à-vis their locations (administrative cells) is presented in Table 6.

**Table 1** Overall Prevalence of Caprine Gastrointestinal Nematode, Cestode, and Protozoan Infections in Nyagatare District (n=149)

| Type of Parasites | Study Cell | Sample | Positive Cases (%) | Prevalence (%) | P value |
|---|---|---|---|---|---|
| STNs[a] | Barija | 24 | 23 (16.1) | 95.8 | 0.351 |
| | Bushoga | 26 | 26 (18.2) | 100.0 | |
| | Nsheke | 25 | 24 (16.8) | 96.0 | |
| | Nyagatare | 24 | 23 (16.1) | 95.8 | |
| | Rutaraka | 27 | 24 (16.8) | 88.9 | |
| | Ryabega | 23 | 23 (16.1) | 100.0 | |
| | Total | 149 | 143 (100) | 96.0 | |

(*Continued*)

**Table 1** (Continued).

| Type of Parasites | Study Cell | Sample | Positive Cases (%) | Prevalence (%) | P value |
|---|---|---|---|---|---|
| *Moniezia* spp | Barija | 24 | 4(18.2) | 16.7 | 0.007 |
| | Bushoga | 26 | 0 | – | |
| | Nsheke | 25 | 3(13.6) | 12 | |
| | Nyagatare | 24 | 9(40.9) | 37.5 | |
| | Rutaraka | 27 | 2(9.1) | 7.4 | |
| | Ryabega | 23 | 4(18.2) | 17.4 | |
| | Total | 149 | 22(100) | 14.8 | |
| Coccidia | Barija | 24 | 21(16.9) | 87.5 | 0.061 |
| | Bushoga | 26 | 24(19.4) | 92.3 | |
| | Nsheke | 25 | 17(13.7) | 68.0 | |
| | Nyagatare | 24 | 17(13.7) | 70.8 | |
| | Rutaraka | 27 | 25(20.2) | 92.6 | |
| | Ryabega | 23 | 20(16.1) | 87.0 | |
| | Total | 149 | 124(100) | 83.2 | |
| *Strongyloides papillosus* | Barija | 24 | 3(15.8) | 12.5 | 0.155 |
| | Bushoga | 26 | 4(21.1) | 15.4 | |
| | Nsheke | 25 | 0 | 0.0 | |
| | Nyagatare | 24 | 2(10.5) | 8.3 | |
| | Rutaraka | 27 | 4(21.1) | 18.1 | |
| | Ryabega | 23 | 6(31.6) | 26.1 | |
| | Total | 149 | 19(100) | 12.8 | |

**Notes**: [a]Strongyle-type nematodes. The overall prevalence was 100% and the identified parasites included STNs (96.0%) (Supplementary Figure S1), Coccidia (83.2%) (Supplementary Figure S2), *Moniezia* spp (14.8%) and *Strongyloides papillosus* (12.8%). Other identified parasites were *Nematodirus* spp (0.7%) ($p$=0.387) and *Trichuris ovis* (0.7%) ($p$=0.446). In addition, the prevalence of *Moniezia* spp infection (Supplementary Figure S3) had a direct correlation with the administrative cells (locations) that were home to the goats ($p < 0.05$).

**Table 2** Effect of the Goat's Age Category on the Prevalence of Caprine Gastrointestinal Nematode, Cestode, and Protozoan Infections in Nyagatare District (N= 149)

| Type of Parasites | Age Category | Sample | Positive Cases (%) | Prevalence (%) | P value |
|---|---|---|---|---|---|
| STNs[a] | Old | 76 | 72 (50.3) | 94.7 | 0.433 |
| | Young | 73 | 71(49.7) | 97.3 | |
| | Total | 149 | 143 (100) | 96 | |
| *Moniezia* spp | Old | 76 | 11(50) | 14.5 | 0.919 |
| | Young | 73 | 11(50) | 15.1 | |
| | Total | 149 | 22 (100) | 14.8 | |

(*Continued*)

**Table 2** (Continued).

| Type of Parasites | Age Category | Sample | Positive Cases (%) | Prevalence (%) | P value |
|---|---|---|---|---|---|
| Coccidia | Old | 76 | 67(54) | 88.2 | 0.1 |
| | Young | 73 | 57 (46) | 78.1 | |
| | Total | 149 | 124(100) | 83.2 | |
| *Nematodirus spp* | Old | 76 | 0 (0) | 0 | 0.306 |
| | Young | 73 | 1(100) | 1.4 | |
| | Total | 149 | 1(100) | 0.7 | |
| *Strongyloides papillosus* | Old | 76 | 14(73.7) | 18.4 | 0.034 |
| | Young | 73 | 5(26.3) | 6.8 | |
| | Total | 149 | 19(100) | 12.8 | |
| *Trichuris ovis* | Old | 76 | 1(100) | 1.3 | 0.325 |
| | Young | 73 | 0(0) | 0 | |
| | Total | 149 | 1(100) | 0.7 | |

**Notes**: [a]Strongyle-type nematodes. The results show that the proportions of the older goats infected with STNs (50.3%), Coccidia (54%), and *Strongyloides papillosus* (73.7%) were higher compared to those of the young goats suffered from the same type of parasites. The goat's age category correlated with the prevalence of *S. papillosus* infections ($p<0.05$).

**Table 3** Prevalence of Gastrointestinal Nematode, Cestode and Protozoan Mixed Infections in Goats in Nyagatare District

| Type of Parasites | Frequency | Prevalence (%) |
|---|---|---|
| Coccidia | 5 | 3.4 |
| STNs[a] | 16 | 10.7 |
| STNs + Coccidia | 87 | 58.4 |
| STNs + *Moniezia* spp | 4 | 2.7 |
| STNs + *Strongyloides papillosus* | 3 | 2 |
| STNs + *Moniezia* spp+ Coccidia | 16 | 10.7 |
| STNs + Coccidia + *Strongyloides papillosus* | 14 | 9.4 |
| STNs + Coccidia + *Nematodirus* spp | 1 | 0.7 |
| STNs + Coccidia + *Trichuris* ovis | 1 | 0.7 |
| STNs + *Moniezia* spp + *Strongyloides papillosus* | 1 | 0.7 |
| STNs + *Moniezia* spp + Coccidia + *Strongyloides papillosus* | 1 | 0.7 |
| Total | 149 | 100 |

**Notes**: [a]Strongyle-type nematodes. Nearly 14.1% of the study goats developed GiNCPs infections caused by one type of parasite while 85.9% developed mixed infections of 2–4 different types of parasites. Supplementary Figure S4 illustrates eggs of STNs, *Moniezia* spp, and coccidian oocytes detected from a study goat with such a coinfection. Supplementary Figure S5 shows eggs of STNs, *Moniezia* spp, *Strongyloides papillosus*, and coccidian oocytes detected from a study goat with such a coinfection.

**Table 4** Intensity of Strongyle-Type Nematode Infections in Goats in Nyagatare District (N= 143)

| Degree of STNs[a] Infections | EPG[b] | Frequency of Positive Cases | Proportion (%) |
|---|---|---|---|
| Mild | 50–799 | 109 | 76.2 |
| Moderate | 800–1200 | 16 | 11.2 |
| Severe | >1200 | 18 | 12.6 |
| Total | | 143 | 100 |

**Notes**: [a]Strongyle-type nematodes. [b]Eggs per gram of faeces. The degree of STNs infections in goats shows that the majority of the goats (76.2%) suffered from mild STNs infections.

**Table 5** Impact of the Goat's Age on the Intensity of STNs Infections in Nyagatare District (N= 143)

| Age of Goats | Degree of STNs[a] Infection (%) | | | Total (%) | P value |
|---|---|---|---|---|---|
| | Mild (50–799) | Moderate (800–1200) | Severe (>1200) | | |
| Young | 54 (49.5) | 5 (31.2) | 12 (66.7) | 71 (49.7) | 0.119 |
| Old | 55 (50.5) | 11 (68.8) | 6 (33.3) | 72 (50.3) | |
| Total (%) | 10 (76.2) | 16 (11.2) | 18 (12.6) | 143 (100) | |

**Notes**: [a]Strongyle-type nematodes. The results show that severe STNs infections prevailed in the young goats (66.7%) than in the old. There was no statistically significant association between the goat's age and the intensity of STNs infections (p > 0.05).

**Table 6** Intensity of Strongyle-Type Nematode Infections in the Goats Vis-À-Vis Their Locations (Administrative Cells)

| Study cell | Degree of Infection (%) | | | Total (%) | P value |
|---|---|---|---|---|---|
| | Mild (50–799) | Moderate (800–1200) | Severe (> 1200) | | |
| Barija | 13 (11.9) | 4 (25.0) | 6 (33.3) | 23 (16.1) | 0.154 |
| Bushoga | 23 (21.1) | 2 (12.5) | 1 (5.6) | 26 (18.2) | |
| Nsheke | 17 (15.6) | 3 (18.8) | 4 (22.2) | 24 (16.8) | |
| Nyagatare | 18 (16.5) | 1 (6.2) | 4 (22.2) | 23 (16.1) | |
| Rutaraka | 18 (16.5) | 5 (31.2) | 1 (5.6) | 24 (16.8) | |
| Ryabega | 20 (18.3) | 1 (6.2) | 2 (11.1) | 23 (16.1) | |
| Total | 109 (76.2) | 16 (11.2) | 18 (12.6) | 143 (100) | |

**Notes**: The majority (76.2%) of the goats in the different locations (study administrative cells) developed mild STNs infections and the location of the goats did not influence the intensity of STNs infection (p >0.05).

# Discussion

This study found that the overall prevalence of gastrointestinal nematodes, cestodes and protozoa of goats in Nyagatare District, Rwanda was 100%. The goat's age category and location had a direct correlation with the prevalence of strongyloidiasis and *Moniezia* spp infections, respectively. This also shows that all the goats had equal chances of infection given that apart from *Moniezia* spp, there was no correlation between the prevalence of caprine parasites and locations. These findings can guide local animal health service providers to design a prevention and control program for caprine gastrointestinal parasitoses in the study district and Rwanda at large. This study's overall prevalence of 100% agrees with that (100%) reported in Thailand and India[42,46] but it is higher than 78.7%, 89.33%, 90.4%, and 93.2% reported in Ethiopia, Egypt, Cameroon, and Italy respectively.[12,24,47,48] The high frequency of GiNCPs reported in the current study is comparable to previous findings reported in Ethiopia and Egypt.[47,49] In addition, adults GIPs can produce a fair number of eggs that are shed in feces and hatched within 1–2 days, and this increases the parasite load in the environment.[1]

The prevalence of STNs infections (96%) recorded in this study was higher than 92%, 90%, 48.3%, 37.9%, 31%, and 12.88% reported in Slovakia, Kenya, Nigeria, Italy, Zimbabwe, and Egypt respectively.[22,24,26,28,47,50] Coccidia was detected at the rate of 83.2% and this was higher than 78.4%, 76.89%, 43.87%, and 43% recorded in Italy, Egypt, Pakistan, and Zimbabwe respectively.[24,26,27,47] The high frequency of STNs and Coccidia revealed by this study may be due to the confinement of goats in specific places or tethering on pegs to allow them to graze on the available surrounding pastures. This would increase the possibility of picking the infective larva or oocyst stages.[51,52] This type of practice of keeping goats tethered on pegs has contributed significantly to economic losses in ruminant production in sub-Saharan countries.[48,53] Some STNs are also zoonotic and thus transmitted from ruminants to humans.[29–31] This indicates that some of the nematodes identified in this study might be zoonotic namely *Nematodirus* spp and other STNs.[1] The present study prevalence of monieziasis (14.8%) was lower than 16%, 18.22%, and 19.4% reported in Kenya, Egypt, and Ethiopia respectively.[12,28,47] The fact that the occurrence of monieziasis positively correlated with the location of the goats can indicate that some pastures across the study administrative cells (locations) harbored oribatid mites contaminated with *Moniezia* spp larvae.[25,26] This study's prevalence of *Strongyloides papillosus* (12.8%) was higher than 8.33% reported in Ethiopia[54] but it was lower than 14.05% and 25.58% found in Slovakia and Somalia, respectively.[22,55] This study's prevalence of trichuriasis (0.7%) was lower than 35.45%, 7.84%, 5.33%, and 4.65% recorded in Pakistan, Slovakia, Egypt, and Somalia, respectively.[22,27,47,55] The 0.7% prevalence of nematodirosis (*Nematodirus* spp) reported in this study was lower than 13%, 4.65%, and 3.98% reported in Pakistan, Somalia, and Slovakia respectively.[22,27,55] The low prevalence of trichuriasis can be related to difficulty in detecting light infection of this nematode by the fecal flotation technique.[25] Similar to other studies conducted on caprine parasitoses in Nigeria, Cameroon, and Iraq,[19,47,48,56] 85.9% of this study goats developed mixed infections. The latter could be attributed to the exposure of the goats to pastures contaminated by eggs, oocytes, and larvae of different types of parasites.

This study's higher proportion of goats with mild STNs infections agrees with a study conducted on goats and sheep in Malaysia.[25] Similar to a previous study, the prevalence of *Moniezia* spp infection was influenced by the location of the goats.[29] Again, the goat's age correlated with the prevalence of strongyloidiasis.

The present study had some limitations. The parasites were identified using the flotation method, a technique that can miss some infections. For instance, mild trichuriasis is difficult to detect with the fecal flotation technique.[25] Again, with such a technique, we could not speciate the parasites. The sampling was also done once, and it was impossible to assess seasonal effects on the prevalence of GiNCPs in the study goats. In addition, the fact that the study recruited small-scale farmers who preferred keeping female goats than male ones resulted in not collecting the data on study goats' sex. Further studies on caprine gastrointestinal parasites using other techniques, for instance, molecular tools would be most appropriate. Additionally, future studies should consider ascertaining the effect of season and goats' sex on the prevalence of gastrointestinal parasites.

## Conclusions

All the study goats (100%) were infected with nematodes, cestodes, and protozoa. The identified types of parasites were STNs (96.0%), Coccidia (83.2%), *Moniezia* spp (14.8%), *Strongyloides papillosus* (12.8%), *Nematodirus* spp (0.7%) and *Trichuris ovis* (0.7%). The location (administrative cell) of the goat also correlated with the prevalence of monieziasis. In addition, the goat's age category was associated with the prevalence of strongyloidiasis. These findings show that any control program for caprine gastrointestinal parasitoses in the study area should focus on STNs and Coccidia. Although the identified parasites were not speciated due to the limitation of the method used, members of the identified STNs might have public health importance. For example, *Haemonchus contortus* and *Nematodirus abnormalis* are zoonotic.[1] Indeed, a previous study that investigated ovine and caprine haemonchosis in Nyagatare District found that the prevalence of *H. contortus* infections was 75.7%.[2]

## Abbreviations

EPG, Eggs per gram of faeces; GIPs, Gastrointestinal parasitoses; STNs, Strongyle-type nematodes; GiNCPs, Gastrointestinal nematodes, cestodes and protozoans.

## Ethics Approval and Informed Consent

The study involved live goats rather than humans. It was approved by the academic council of the School of Veterinary Medicine at the University of Rwanda. Before collecting the data, the study was explained to the goat farmers, and only those who consented to admit their goats for faecal sampling were recruited. In addition, the animals were treated with the best practice of veterinary care.

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## Author Contributions

All authors significantly contributed to this work, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; participated in drafting, revising, or critically reviewing it. The authors also have approved the final version before submitting it; agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

## Disclosure

The authors declare no conflicts of interest regarding the publication of this paper.

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