Prevalence and Risk Factors of Gastrointestinal Parasites in Sheep in Kajiado North Sub-County, Kenya.

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ABSTRACT

The gastrointestinal parasite (G.I.P.) species of Public Health, Agricultural and Veterinary concern, which affect the health of sheep and goat, belong to several *Genera* in the Phylum Protozoa (Unicellular Organisms), Phylum Nematohelminthes (Round Worms), and Phylum Platyhelminthes (Flatworms). The species of clinical significance in the Phylum Protozoa belong to the Genera: Eimeria, Isospora, Cryptosporidium, Cyclospora, Toxoplasma, and Giardia. Roundworm species belong to the Class Nematoda, with several Genera. These are Trichostrongylus, Strongylus, Cyanthostomin, Strongyloides, Haemonchus, Cooperia, Nematodirus, Trichuris, Toxocara, Ostertagia, Oesophagostomum, Cherpertia, Bunostomum (Hookworms), and Gongylonema. Flatworm species belong to two classes: Trematoda (Flukes) and Cestoda (Tapeworms). Trematodes of clinical concern belong to the Genera: Fasciola, Dicroelium, and Paramphistomum. The cestode species of clinical concern belong to the Genera: Moniezia, Avitellina and Echinococcus. The Unicellular parasites belong to Phylum: Protozoa, Sub-phylum: Sporozoa, Class Telosporidea and Sub-class Coccidea. The Coccidian parasite species of clinical concern belong to several Genera, namely: Eimeria, Isospora, Cyclospora, Toxoplasma, Cryptosporidium, and Sarcocystis. Gastrointestinal parasites (G.I.P.) of sheep are a threat to sheep industry worldwide. A cross-sectional study was conducted to determine the prevalence and risk factors associated with GIP in sheep under an extensive grazing system from 16 farms in Kajiado North Sub-County.

Faecal samples equal to 640 were collected from randomly selected Red Maasai and Red Maasai x Dorper crossbred sheep in both dry and wet seasons. Faecal samples were subjected to the McMaster technique, sedimentation, larval cultures. Coccidia species identification of eggs and oocysts was based on morphology.

Overall parasites prevalence was 91.3%, with many sheep showing one or more G.I.P (Gastro-Intestinal Parasites). The study revealed Strongylus species nematode eggs (80%), Eimeria species. oocysts at (60.8%) and Cestode eggs (5.2%). The highest prevalence of gastro-intestinal parasites was recorded in the wet season than in the dry season ($p<0.05$). Haemonchus, Trichostrongylus, Cooperia and Oesophagostomum were parasites identified using Baerman's technique. Haemonchus species was the commonest and Oesophagostomum was the least common. Cestodes (Moniezia species) were present, but there were no Trematode species seen. E. parva, E. ovinoidalis, E. crandallis, E. bakuensis, E. faurei, E. ahsata, E. pallida. The following Eimeria species were identified: E. intricata, E. marsica, and E. granulosa, after sporulation using 2.5% potassium dichromate. The majority of sheep were also severely infested with gastrointestinal nematodes (Strongylus species). Multiple correlation analysis revealed elevation, deworming, Body Condition Scores (B.C.S.), and age of the sheep as factors of Gastro-intestinal Parasite (G.I.P.) infection. The study area was highly infested with gastro- intestinal parasites requiring an effective and strategic deworming of all sheep before the rainy season, especially considering the lambs. Further studies should also be taken on Gastrointestinal Nematode (G.I.N.) anthelmintic resistance and their economic losses for effective management practices to minimise the associated mortality and morbidity of sheep.

Keywords: Risk Factors, Sheep, *Eimeria*, *Haemonchus, Strongylus* species.

INTRODUCTION

The Gastrointestinal parasite (G.I.P.) species of Public Health Concern, which afflict sheep and goat, consist of species belonging to several Genera in the Phylum Protozoa (Unicellular Organisms), Nematohelminthes (Round Worms), Platyhelminthes (Flatworms). The species of clinical significance in the Phylum Protozoa belong to the Genera: Eimeria, Isospora, Cryptosporidium, Cyclospora, Toxoplasma, and Giardia. Roundworms belong to the Class Nematoda, with several Genera. These are Trichostrongylus, Strongylus, Cyanthostomin, Strongyloides, Haemonchus, Cooperia, Nematodirus, Trichuris, Toxocara, Ostertagia, Oesophagostomum, Cherpertia, Bunostomum (Hookworms), and Gongylonema. Species of Public Health concern among Flatworms belong to 2 Classes, namely: Trematoda (Flukes) and Cestoda (Tapeworms). Trematodes of clinical concern belong to the Genera: Fasciola, Dicrocoelium and Paramphistomum. The Cestode species of clinical concern belong to the Genera: Moniezia, Avitellina and Echinococcus. The gastrointestinal (Unicecullar or single-celled organisms) parasites in this study belong to Phylum: Protozoa, Sub-phylum: Sporozoa, Class Telosporidea and Sub-class Coccidea. The Coccidian parasite species belong to several Genera, namely: Eimeria, Isospora, Cyclospora, Toxoplasma, Cryptosporidium, and Sarcocystis. The Gastrointestinal parasite species in this study were classified according to the International Zoological Nomenclature (System of Naming parasites) that was used by Jeffrey and Leach [[1]] and Chiodin *et al* [[2]].

Agriculture remains the backbone of Kenya's economy, accounting for 33% of the Gross Domestic Product (GDP) and employing more than 70% of the rural population [[3,4]]. Although it basically involves growing crops and raising livestock, the two activities are inseparable, with neither being superior to the other. Both play critical roles in a country's food and nutritional security [[5]].

This study focused on the livestock sub-sector, which comprises ruminant and non-ruminant species. The livestock sector is vital to the livelihoods of many rural households and is a significant driver of programs aimed at reducing poverty in Kenya [[6]]. Livestock production supports almost 90% of the livelihoods of rural households. It accounts for nearly 95% of the incomes of families living in the arid and Semi-Arid Areas (ASALs) [[4]]. Given the current urbanization rate, more urban and peri-urban households rely on this sector. The livestock sub-sector has also created direct and indirect jobs selling livestock or its many by-products, including meat, milk, hides, and skins [[7]]. Sheep and goats constitute a significant portion of Kenya's livestock sub-sector [[6]]. They play an essential role in many Kenyans' social and economic lives, particularly farmers and the small-scale majority who live in rural areas [IFAD, 2018]. According to estimates, they provide roughly 30% of the nation's annual consumption of red meat [[9]]. The country has a yearly meat deficit of approximately 300,000 tonnes [[5]].

Despite the urgent need to increase livestock production in Kenya to meet the ever-increasing demand for meat and other animal-based foods, livestock diseases have been and continue to be a significant barrier to any attempt to expand production. The disorders associated with Gastro-intestinal tract (G.I.T) parasites are among the commonest and their epidemiology could worsen due to climate change [[10,11,12]]. Sheep and goats are the most vulnerable ruminants to GIT parasites and the associated diseases, mainly due to their grazing habits [[13]]. High infestation and infection in sheep and goats are associated with their genetically lower immunity against specific helminths. Poor nutrition in the hosts due to poor diets [[14, 15, 16]], coupled with poor sanitation, facilitates the faster spread of the parasites [[17,18]]. Therefore, for effective control of helminths in livestock and specifically in sheep [[19]], it is necessary to identify the risk factors unique to specific ecological or climatic zones.

It is also necessary to identify production or management systems, particularly in the Arid and Semi-arid Lands (A.S.A.Ls.) of Kenya. Therefore, this study aimed to assess the prevalence of Gastro Intestinal Parasites (G.I.P.s) in sheep and the factors that enhance their majority in Kajiado North sub-county.

MATERIALS AND METHODS

Study Area

The study was conducted in 16 farms in Ngong ward, Kajiado North Sub-County, Kenya (Figure 1). Kajiado North Sub-county has a surface area of 148.0 Km^2. Most of Kajiado County falls between ASAL zones V and VI with bimodal rainfall patterns (March-May long rains and October-December short rains) [4]. The weather conditions in Ngong Ward are heavily influenced by the Ngong Hills. The mean annual temperature around Ngong hills is 19.0°C, while the average annual precipitation is about 674 mm according to the meteorological records.

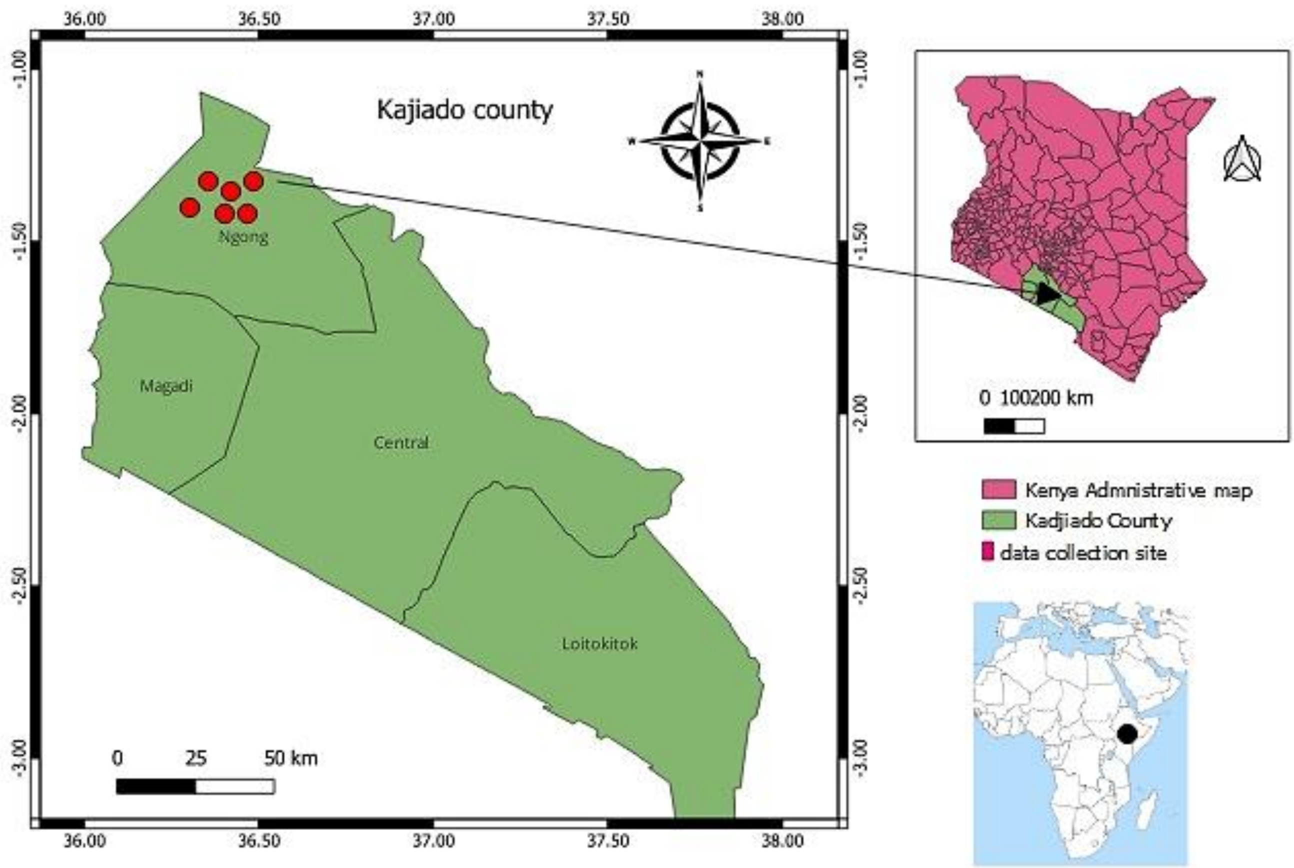

Figure 1 The Map showing the geographical location of the study area

The maroon-coloured map on the right shows the geographic location of the greater Kajiado County, Kenya. The green map on the right shows the four administrative sub-counties with the study area depicted by the red circles. Author (study area, 2024).

Study Design and Selection of Farms

A cross-sectional study was conducted in farms that were purposefully selected with large enough flocks since the study coincided with a severe drought in the country and the region at large. The study was conducted during dry [February 2023] and wet seasons [May 2023]. The study area was purposively selected due to the high number of targeted sheep breeds of Red Maasai and Red Maasai x Dorper crosses under the traditional grazing system. Factors considered were sex (male and female), age (young (<1 year) and adult sheep(> 1 year)), and deworming (< 3 months or > 3 months before the sampling date). Information on age and deworming was obtained from sheep owners before faecal collection. Sixteen farms (from high and low elevations) were therefore selected.

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Selection of Animals

The Red Maasai and Red Maasai X Dorper crosses reared under an extensive management system in Ngong ward were the targeted population for the study. The total population of sheep in Kajiado North Sub-County was 21 728 [20]. The farmers randomly identified and selected the sheep according to their breed, age, and sex.

Once the sheep were selected, the deworming history was sought from the farmer and categorised into two-those dewormed < 3 months and those dewormed > 3 months before the faecal sample collection date. Body Condition Score (B.C.S.) from a well-restrained individual sheep was determined according to Semakula *et al* [21]. In total, 345 and 295 sheep were selected for the dry and wet seasons, respectively.

Faecal Sample Collection

Approximately 30 grams of fresh faeces were obtained from the rectum of each sheep. Individual faecal samples were appropriately labelled in faecal pots and stored in a cool box with ice packs and delivered to the Parasitology Laboratory, Department of Veterinary Pathology, Microbiology, and Parasitology, University of Nairobi, for parasitological analyses.

Faecal Sample Analysis

Parasitological analysis identified Gastro Intestinal Tract (G.I.T.) parasites based on their eggs or oocysts morphology using qualitative simple tube flotation [21] and sedimentation techniques [22] to detect available parasites. The McMaster slide technique [23] was used to quantify the intensity of infection, while the simple flotation test was used to determine the prevalence of Coccidia, Nematode, and Cestode species [24, 25]. To determine the total number of EPG/OPG, the number of eggs or oocysts within an observation chamber was multiplied by 100 ([24]). For helminths, the counts were represented as eggs/gram (E.P.G.) of faeces or oocysts/gram (O.P.G.) of faeces for Coccidia. Sedimentation test was used to determine the prevalence of trematodes [22]. All positive faecal samples from each farm were combined and cultured, and each of the parasite's larvae was identified in accordance with Sabatini *et al* [25]. Baermann's faecal analysis procedure was also done [26]. Coccidia species were also identified. The intensity of nematode infection was categorised as no infection, light. moderate and severe [27].

Data Management and Statistical Analysis

The sequence of the analysis was based on preliminary analysis, prevalence estimations, and chi-square tests for descriptive analysis and regression models to determine the risk factors (Sex, age, breed, elevation, deworming, BCS, and season). Prevalence of Gastro Intestinal Parasites (G.I.P.) was determined as the proportion of positive faecal samples from the total number of samples collected [Khan *et al*., 2011]. The R Statistical Software (Version 4.5.0) was used for all computations, and factors were considered significantly associated with the occurrence of (G.I.P.) if $P \leq 0.05$.

RESULTS

The study was based on the sheep grazing on native rangelands. Overall prevalence of GIP found in sheep was 91.3% (584/640) and this shows severe transmission among the sheep. The predominant gastrointestinal parasite (G.I.P.) eggs or oocysts identified were for *Strongylus* species 512 (80.0%), *Moniezia* species 33 (5.2%), and *Eimeria* species 389 (60.8%) oocysts (Table 1). Most sheep had 2-3 parasites in their faeces, and of the 91.3% infected sheep, 51.1% had mixed infection, while 40.2% had a single infection. The highest number of Nematode species identified in this study were in Genera: *Haemonchus*, *Trichostrongylu*s, *Oesophagostomum* and *Cooperia* in decreasing order of their prevalence (Table 2). Ten species of *Eimeria* in the samples were recorded: *E. parva*, *E. ovinoidalis*, *E. crandallis, E. bakuensis*, *E. faurei, E. ahsata*, *E. pallida*, *E. intricata*, *E. marsica*, and *E. granulosa* in descending order of farm level, with *E. crandallis* being the most prevalent and *E. granulosa* the least prevalent (Table 2).

The study also revealed the degree of Gastrointestinal Nematodes (G.I.N.) infestation in sheep as severe, light, moderate, and non-infection (32.8%, 26.6% and 20.6% and 20.0% respectively). Several sheep were severely infected with Gastro-intestinal (G.I.N) (Table 3).

Table 1: Average (%) prevalence of GIT parasites by season

Risk Factors	No. of sheep examined	Positive *Strongylus* species (%)	Positive *Moniezia* Species (%)	Positive *Eimeria* species (%)	Overall positive (%)
Overall	640	512(80.0%)	33(5.2%)	389(60.8%)	584(91.3%)
Season Dry	345	262(75.9%)	12(3.5%)	260(65.3%)	308(89.3%)
Wet	295	250(84.7%)	21(7.1%)	129(53.3%)	276(93.6%)
p-value		0.0056	0.0381	<0.0001	0.0548

Table 2: Average percent of Eimeria and Helminth species in dry and wet seasons

	The dry Season		**The wet season**					
Helminths / Protozoa species	No. of farms with a particular parasite	% of farms with the parasite	No. of farms with a particular parasite	% of farms with the parasite	Total number of farms	(%)	Difference in prevalence between seasons	p-value
Nematode spp.								
Haemonchus spp.	16	100.0%	16	100.0%	32	100.0%	0.0%	-
Oesophagostomum spp.	7	43.8%	2	12.5%	9	28.1%	31.3%	0.0559
Cooperia spp.	3	18.8%	7	43.8%	10	31.3%	-25.0%	0.1341
Trichostrongylus spp.	11	68.8%	14	87.5%	25	78.1%	-18.8%	0.1979
Cestode spp.								
Moniezia spp.	7	43.8%	11	68.8%	18	56.3%	-25.0%	0.1604
Trematode spp.								
Fasciola spp.	0	0.0%	0	0.0%	0	0.0%	0.0%	none
Paramphistomum spp.	0	0.0%	0	0.0%	0	0.0%	0.0%	none
Protozoa spp.								
Coccidia spp.								
E. ovinoidalis	13	81.3%	16	100.0%	29	90.6%	-18.8%	0.0712
E. crandallis	16	100.0%	13	81.3%	29	90.6%	18.8%	0.0712
E. parva	15	93.8%	16	100.0%	31	96.9%	-6.3%	0.3275
E. marsica	1	6.3%	3	18.8%	4	12.5%	-12.5%	0.2738
E. pallida	1	6.3%	7	43.8%	8	25.0%	-37.5%	0.0146
E. intricata	2	12.5%	4	25.0%	6	18.8%	-12.5%	0.3726
E. ahsata	2	12.5%	11	68.8%	13	40.6%	-56.3%	0.0014
E. granulosa	0	0.0%	1	6.3%	1	3.1%	-6.3%	0.3153
E. faurei	6	37.5%	10	62.5%	17	53.1%	-25.0%	0.1639
E. bakuensis	7	43.8%	13	81.3%	20	62.5%	-37.5%	0.031

* SPP.= species

Table 3: Abundance and prevalence of GIN parasites (*Strongylus* species) by season, deworming, breed, age, sex, BCS and elevation

Risk factor	Levels	Number examined	Mean count	Degree of Infection of GIN (*Strongylus* species)				Pearson ChiSquare
				No Infection	Light	Moderate	Severe	
Season	Dry	345	1059	83 (24.1)*	88 (25.5)	61 (17.7)	113 (32.8)	**.022**
	Wet	295	918	45 (15.3)	82 (27.8)	71 (24.1)	97 (32.9)	
Elevation	High	398	1268	60 (15.1)	95 (23.9)	79 (19.8)	184 (41.2)	**.000**
	Low	242	543	68 (28.1)	75 (31.0)	53 (21.9)	46 (19.0)	
Deworming	<3months	296	899	54 (18.2)	78 (26.4)	68 (23.0)	96 (32.4)	.502
	>3months	344	1075	74 (21.5)	92 (26.7)	64 (18.6)	114 (33.1)	
Breed	RM x D crosses	353	1091	62 (17.6)	94 (26.6)	74 (21.0)	123 (34.8)	.338
	Red Maasai	287	874	66 (23.0)	76 (26.5)	58 (20.2)	87 (30.3)	
Age	<1year	105	1279	28 (26.7)	18 (17.1)	15 (14.3)	44 (41.9)	**.006**
	>1year	535	938	100 (18.7)	152(28.4)	117(21.9)	166 (31.0)	
Sex	Female	410	889	79 (19.3)	119(29.0)	86 (21.0)	126 (30.7)	.214
	Male	230	1181	49 (21.3)	51 (22.2)	46 (20.0)	84 (36.5)	
	Good	58	948	7 (12.1)	12 (20.7)	12 (20.7)	27 (46.6)	.113
BCS	Moderate	326	884	72 (22.1)	94 (28.8)	68 (20.9)	92 (28.2)	
	Poor	256	1144	49 (19.1)	64 (25.0)	52 (20.3)	91 (35.5)	
Total		640		128 (20.0)	170 (26.6)	132 (20.6)	210 (32.8)	

RM= Red Maasai, D=Dorper, Asterisk = Infection in percentages

Risk Factors

The following tables 4, 5, and 6 below present the outputs of the Zero-Inflated Negative Binomial Mixed Effects Model (ZINBMEM) with interaction obtained using the Generalized Linear Mixed Model (GLMM) adaptive package for *Strongylus, Eimeria,* and *Moniezia* species, respectively. This best-fit model gave the incidence rate ratios of various predictor variables, at 95% CI and p-values for comparing the given variable level with the reference level. The model showed that the infection incidence rate was 0.20 times lower in low elevation (95% CI, 0.08-0.45) than in high elevation for *Strongylus species* infection at p=0.001. The sheep with poor body condition had 3.17 times higher (95% CI, 1.14-8.82) incidence rate ratio than sheep with good BCS, p=0.027. All other factors were insignificant (p>0.05) (Table 4).

Table 4: Average incidence rate ratios for *Strongylus* species derived from ZINBMEM

	Strongylus species_EPG_ (with Random effect) Negative binomial with Interaction.		
Factors	**Incidence Rate Ratios**	**CI**	**p**
(Intercept)	4.38	1.05 – 18.27	0.042
Season [Wet]	1.84	0.91 – 3.73	0.088
Elevation [Low]	0.20	0.08 – 0.45	**<0.001**
Deworming [>3 months]	1.86	0.77 – 4.50	0.168
Breed [Red Maasai]	1.42	0.23 – 8.83	0.707
Age [>1year]	0.90	0.61 – 1.31	0.580
Sex [Male]	1.20	0.99 – 1.46	0.068
BCS [Medium]	1.13	0.63 – 2.04	0.682
BCS [Poor]	3.17	1.14 – 8.82	**0.027**
Season [Wet] × Elevation [Low]	2.98	1.68 – 5.31	**<0.001**

Deworming [>3 months] × Breed [Red Maasai]	1.44	0.49 – 4.20	0.505
Season [Wet] × Age[>1year]	0.59	0.35 – 0.99	**0.045**
Breed [Red Maasai] × BCS[Medium]	1.07	0.20 – 5.71	0.934
Breed [Red Maasai] × BCS	0.51	0.09 – 2.74	0.430
Zero-Inflated Model			
(Intercept)	1.33	0.00 – 1081.08	0.934
Season [Wet]	0.00	0.00 – 0.58	0.034
Elevation [Low]	5.90	0.51 – 68.61	0.156
Deworming [>3 months]	3.68	0.31 – 43.39	0.301
Breed [Red Maasai]	3.33	0.23 – 47.49	0.374
Age [>1year]	0.08	0.02 – 0.33	<0.001
Sex [Male]	1.64	0.53 – 5.04	0.387
BCS [Medium]	0.11	0.00 – 43.43	0.465
BCS [Poor]	0.02	0.00 – 14.71	0.255
Random Effects			
σ2	0.00	-	-
τ00	0.49 Farms	-	-
ICC	1.00	-	-
N	16 Farms	-	-
Observations	640	-	-
Marginal R2 / Conditional R2	0.523 / 1.000	-	-
AIC	27 df	3963.996	-
BIC	27 df	3984.856	-

df_degree of freedom

In terms of *Eimeria species* (Table 5), adult sheep as a single predictor had 0.14 times less incidence rate ratio (95% CI, 0.09-0.22) than the younger sheep p= 0.001.

The adult sheep had 2.86 times higher incidence rate ratio (95% CI, 1.52-5.40) of being infected with *Eimeria species* than young sheep in the wet season (p=0.001.

Table 5: Average incidence rate ratios for *Eimeria* species derived from ZINBMEM

	Eimeria_OPG (with random effect) Negative Binomial with Interaction		
Factors	**Incidence Rate Ratios**	**CI**	**p**
(Intercept)	26.10	6.97 – 97.71	<0.001
Season [Wet]	0.54	0.24 – 1.24	0.147
Elevation [Low]	0.68	0.30 – 1.51	0.340
Deworming [>3months]	1.70	0.76 – 3.83	0.197
Breed [Red Maasai]	0.68	0.07 – 6.70	0.741
Age [>1year]	0.14	0.09 – 0.22	**<0.001**
Sex [Male]	0.92	0.68 – 1.23	0.560
BCS [Medium]	0.60	0.32 – 1.15	0.124
BCS [Poor]	0.66	0.22 – 1.99	0.465
Season [Wet] × Elevation [Low]	0.68	0.32 – 1.45	0.316
Deworming [>3months] ×Breed [Red Maasai]	0.24	0.08 – 0.70	**0.009**

Season [Wet] × Age[>1year]	2.86	1.52 – 5.40	**0.001**
Breed [Red Maasai] × BCS[Medium]	2.15	0.26 – 17.85	0.478
Breed [Red Maasai] × BCS[Poor]	2.67	0.29 – 24.72	0.386
Zero-Inflated Model			
(Intercept)	0.00	0.00 – 1.24	0.058
Season [Wet]	0.07	0.01 – 0.61	0.016
Elevation [Low]	1.20	0.44 – 3.29	0.721
Deworming [>3months]	0.98	0.36 – 2.69	0.971
Breed [Red Maasai]	1.48	0.49 – 4.42	0.485
Age [>1year]	48.20	0.42 – 5536.39	0.109
Sex [Male]	0.89	0.32 – 2.45	0.815
BCS [Moderate]	9.47	0.09 – 968.93	0.341
BCS [Poor]	4.06	0.04 – 446.77	0.559
Random Effects			
σ2	0.00	-	-
τ00	0.28 Farm_Number	-	-
ICC	1.00	-	-
N	16 Farm_Number	-	-
Observations	640	-	-
Marginal R2 / Conditional R2	0.680 / 1.000	-	-
AIC	27 df	2957.058	-
BIC	27 df	2977.918	-

df_degree of freedom

Table 6 shows the infection of Moniezia species, where deworming sheep in more than 3 months is 0.03 times lower incidence rate ratio of having Moniezia species compared to the period of less than 3 months in a 95% confidence interval (0.00-0.38), considering p=0.012. A sheep over 1 year old had a 0.06 times lower incidence rate of having Moniezia species than the sheep less than 1 year old in a 95 % confidence interval (0.01-0.29), considering p=0.001. sheep with medium body condition had a 0.06 times lower incidence rate ratio of being infected with Moniezia species than the sheep with good body condition, considering a (0.00-0.86) 95% confidence interval, p=0.038. Finally, for the single predictors, the poor body condition sheep have a 0.00 times incidence rate for having Moniezia species compared to the good body condition, considering the (0.000.23) 95% confidence interval, p=0.015.

Table 6: Average incidence rate ratios for Moniezia species derived from Zinbmem

	Moniezia species _EPG (with random effect) Negative Binomial with interaction		
Factors	**Incidence Rate Ratios**	**CI**	**p**
(Intercept)	7679.73	24.56 – 2400933.88	0.002
Season [Wet]	1.86	0.07 – 50.66	0.712
Elevation [Low]	5.89	0.78 – 44.32	0.085
Deworming [>3 months]	0.03	0.00 – 0.48	**0.012**
Breed [Red Maasai]	0.01	0.00 – 1.52	0.072
Age [>1year]	0.06	0.01 – 0.29	**0.001**
Sex [Male]	1.09	0.29 – 4.11	0.894
BCS [Medium]	0.06	0.00 – 0.86	**0.038**
BCS [Poor]	0.00	0.00 – 0.23	**0.015**
Season [Wet] × Elevation [Low]	0.08	0.01 – 0.88	**0.039**
Deworming [>3 months] ×Breed [Red Maasai]	1.71	0.07 – 43.52	0.746

Season [Wet] × Age [>1year]	0.38	0.03 – 4.41	0.443
Breed [Red Maasai] × BCS [Medium]	7.44	0.06 – 908.97	0.413
Breed [Red Maasai] × BCS [Poor]	125.50	0.67 – 23546.43	0.070
Zero-Inflated Model			
(Intercept)	484.50	5.34 – 43991.12	0.007
Season [Wet]	0.08	0.01 – 0.92	0.042
Elevation [Low]	2.80	0.68 – 11.63	0.156
Deworming [>3 months]	0.26	0.03 – 2.09	0.205
Breed [Red Maasai]	1.24	0.30 – 5.20	0.766
Age [>1year]	1.35	0.42 – 4.31	0.609
Sex [Male]	0.72	0.26 – 2.01	0.537
BCS [Medium]	0.17	0.02 – 1.78	0.139
BCS [Poor]	0.01	0.00 – 1.11	0.055
Random Effects			
σ2	0.00	-	-
τ00	0.01 Farm_Number	-	-
ICC	1.00	-	-
N	16 Farm_Number	-	-
Observations	640	-	-
Marginal R2 / Conditional R2	0.999 / 1.000	-	-
AIC	27 df	447.3070	-
BIC	27 df	468.1669	-

df_degree of freedom

DISCUSSION

Similar to the current study, the prevalence of GIP was also found in Benin, 96.82% [29], 95.9% in Nigeria [30], and 89.2% in Pakistan [31]. However, the prevalence in this study was higher than findings in Pakistan at 32.8% [32], Egypt at 50.24% [33], Kerio Valley in Kenya at 59.8% [34], Egypt at 71.4% [35], and 74.4% in southern Ethiopia [36] and Uganda (59). The Ugandan study reported prevalence of Nematode species at (61.8%) with Haemonchus species at (36.4%), Trichostrongylus species (43.6%) and Strongyloides species at (14.6%) and Strongylus species were reported at (0.9%). Moreover, Moniezia species were reported at (14.6), Fasciola species (11.8%) and Eimeria species (37.7%) (59). Thus, the prevalence of Strongylus species reported in this study (80%) was higher than that reported in Uganda (12.7%). Moreover, the prevalence of Eimeria species (60.8%) was higher than that reported in Uganda (37.8%) by Nematosi et al (59). However, the prevalence of Moniezia species in this study (5.2%) was much lower than that reported in the Ugandan study (14.6%) according to Nematosi *et al*. (59).

High prevalence in this study could be ascribed to regional and climatic differences, favouring the establishment of parasites and exposure through traditional grazing on land overstocked with many animals from different management practices. The prevalence of gastro intestinal parasites (G.I.P.) was 93.6% (276/345) and 89.3% (308/345) for the wet and dry seasons, respectively, and was statistically significant (p=0.05). The current study was similar to the one conducted in Benin [29], Nigeria [30], Indonesia (37), and Ethiopia [16,38,39]. The highest prevalence in the wet season was associated with hypobiosis in the dry season and a shortage of pasture, which induced animal stress and an inability to defend against infections. It could also be attributed to the vegetation that grew after rains, allowing migration of the infective larvae (L3) [40,41,42], which infected more animals.

Most identified Nematode species in this study were in Genera: Haemonchus, Trichostrongylus, Oesophagostomum and Cooperia in decreasing order of their prevalence. In Kenya, similar Helminth species in the Genera: Trichostrongylus, Haemonchus, Cooperia, and Oesophagostomum [6,29] were also found. The highest prevalence of Haemonchus species in the current study matches with the study on Horro sheep in western

Oromiya, Ethiopia [16] and Chhattisgarh [10], but is in contrast with others [43]. The dissimilarity was brought about by different regions and seasons [44] and management practices within the farms, since they trigger infections. High numbers of Haemonchus contortus in this study are also attributed to the hypobiotic state during the arid periods [44]), its high biotic potential [16], the contaminated communal grazing lands, poor sanitation in animal enclosures, as well as the lack of knowledge on anthelmintic use by farmers [11]. The results of the current study on the very low prevalence of Moniezia species (cestodes) agree with those of Cameroon in ruminants [29]. Low prevalence of Cestodes could be the lack of intermediate hosts, as Cestodes have an indirect life cycle, constituting another host between themselves and the definitive host [45]. No Trematodes were found in the study, which agrees with the investigation in Pakistan [46]. The reason for not capturing the trematodes in the current study could be due to the unavailability of the oribatid mites in the area or also due to the vegetation, which did not create a conducive microhabitat for the mites [47].

Ten *Eimeria* species were recorded in this study, namely: E. parva, E. ovinoidalis, E. crandallis, E. bakuensis, E. faurei, E. ahsata, E. pallida, E. intricata, E. marsica, and E. granulosa. The study in Kenya by Kanyari [48] recorded the same species, but without E. bakuensis. The study in Antakya, E. granulosa was also captured [49], in Punjab, Pakistan [28], and in Iraq [50]. The prevalence of *Eimeria* species in this study is ascribed to untidy rangelands, grazing young and old animals in the same area, and contaminated water with infected faeces in the water troughs in the enclosures [19].

The study revealed the degree of gastro-intestinal nematodes (G.I.N.) infestation in sheep was severe, light, moderate, and noninfection (32.8%, 26.6% and 20.6% and 20.0% respectively). The study disagrees with studies where the animals were lightly, moderately, and massively infected with Gastrointestinal Parasite (G.I.P.) in Tiyo District, Southwest Ethiopia [51] and in Oromia state, central Ethiopia [16]. The variations in strongyle infestation could be due to the management systems and climatic variability favouring *Strongylus* species establishment and development [39].

Regarding the risk factors, several models were fitted with several predictor variables to determine which significantly influenced the prevalence of Gastro-intestinal Tract (G.I.T.) parasites, namely: *Strongylus*, *Eimeria,* and *Moniezia* species. High elevation was considered a risk factor in the prevalence of gastrointestinal parasites (G.I.P.) in this current study. This agrees with Salehi *et al* [22] and Khattak *et al* [38]. However, contrasts with Baihaqi *et al*. [52]. The variation could be brought about by the ability of infective larvae and embryonated eggs to survive desiccation in temperatures below freezing in high elevations because of climate warming. It could also be the availability of vegetation cover, which creates a conducive microhabitat that can harbour the establishment, transmission, and development of disease parasites. Age is also one of the risk factors associated with GIP infection in this current study, where lambs are more infected than adults. Therefore, it agrees with studies conducted in Sri Lanka (53), Brazil [54], and West Shoa, Ethiopia [55]. However, some studies contradict the current findings [39]. The difference in the infection could be the susceptibility of the young ones to endo-parasites due to underdeveloped immune systems needed to fight foreign bodies and disease parasites better [47]. It could be the peri-parturient rise (PPR) in egg excretion from the pregnant ewes and after lambing, which infected newborns and grazing lambs. Additionally, the body condition of the sheep significantly contributed to the infection by GIP. Some studies align with the current study [56]. However, some studies contradict [57]. This could be due to the immune-compromised sheep with low immune systems due to some diseases from the regions contaminated with parasites and the lack of feed, which could also confirm the reason for high parasite infection. Deworming was the risk factor that significantly affected the parasite infection in sheep in the current study. Some studies agree [58], even though some noted otherwise [39]. The discrepancy could be brought by farmers' knowledge of using the dewormers. Also, it could be due to the resistance of anthelmintics developed by the parasites in the host animal bodies [11]. In addition, the differences could be brought about by the time deworming was done in the flock and the high burdens of parasites at sampling time.

CONCLUSION

In conclusion, sheep in the rangelands of Kajiado North Sub-County were highly infected with helminths and coccidia. The majority of the sheep were severely infected with nematodes. The risk factors which were associated with the infection were body condition, elevation, deworming, and age. Having found out that the helminths and coccidia were prevalent in the study area, there should be regular and effective, strategic management practices to reduce infestation of GIP. Most importantly, the young ones should be more considered while engaging in the deworming before the onset of rains. Furthermore, there should also be further studies on the GIN anthelmintic resistance in sheep since the majority were also infected with nematodes. This could reduce the economic loss as well as the mortality of sheep in the study area.

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Conflict of Interest:

There is no conflict of interest in this study. Data from this study can be shared with other scientists and institutions.

Ethical Approval:

Ethical approval for this study was obtained from the Ethics Committee of the University of Nairobi, Kenya.

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