Gastrointestinal nematodes of goats and their anthelmintic resistance around Hawassa, Ethiopia

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Abstract

Gastrointestinal nematodes are seriously affecting the health of goats and negatively impacting their productivity and welfare. A cross-sectional study was conducted from December 2023 to September 2024 to estimate the prevalence of gastrointestinal (GI) nematode infection in goats. A field experiment was also conducted to assess the anthelmintic drug resistance status of goat GI nematodes in Hawassa. Fecal samples were collected from 750 goats selected using systematic random sampling. The fecal samples were examined using the flotation and McMaster egg counting techniques. The overall prevalence of GI nematode infection in goats was 46.5% (95% CI: 43.0-50.1). The multivariable logistic regression analysis showed that age and flock size affected ($p < 0.05$) infection of goats by GI nematodes. The number of eggs per gram of feces (EPG) ranged from 50 to 2300, and the overall mean EPG was 850 (95% CI: 778.1-991.9). Four hundred and fifty-eight third stage larvae were recovered from the culture of fecal samples, pooled from 349 goats positive for strongyle type eggs, for species identification. The nematode genera identified were *Trichostrongylus* (32.3%), *Haemonchus* (26.9%), *Oesophagostomum* (16.6%), *Teladorsagia* (12.5%), *Strongyloides* (6.8%) and *Bunostomum* (5.0%). The post-treatment fecal egg count reduction of the field anthelmintic resistance test for albendazole, tetramisole, and ivermectin were 69.7% (95% CL: 39.4-84.8), 95.7% (95% CL: 90.2-98.1) and 80.3% (95% CL: 72.8-85.7), respectively revealing the presence of resistance for albendazole and ivermectin. Culture of pooled post-treatment fecal samples from each treatment group resulted in the recovery of *Trichostrongylus* spp. and *Haemonchus* spp. from albendazole-treated goats, and *Trichostrongylus* spp. and *Teladorsagia* spp. from ivermectin treated goats, suggesting the respective genera of GI nematodes that developed resistance to these commonly used anthelmintics. The results of the study indicated that it is time to think about developing effective strategies to

slow and manage anthelmintic resistance development in Ethiopia and implement methods such as rotation of anthelmintic classes in large farms and village flocks to delay the development of resistance.

Keywords: Ethiopia; Faecal egg count; Goats; Hawassa; Nematode; Resistance.

Introduction

In Ethiopia, goats are very important sources of income, as well as meat, milk, skins, and manure. Also, they serve as saving, insurance against emergencies, cultural, and ceremonial (Kosgey and Okeyo, 2007; Hirpa and Abebe, 2008; Wodajo *et al*., 2020; CSA, 2022) purposes for smallholder producers. The country has about 83.7 million small ruminants, of which goats account for 54.6% (CSA, 2022). In a smallholder production system, goats are very important due to the fact that they can easily be managed, require small initial investments, and have short generation intervals (Kosgey and Okeyo, 2007; Hirpa and Abebe, 2008). Goats are able to utilize marginal land (Mhlanga *et al*., 2018), and they are often known as poor man's cows. Despite all these advantages, there are various constraints that hinder the full exploitation of goats' production potential. The factors that affect the productivity of goats include feed problems, poor genetic potential, management problems, and various diseases affecting goats (Gobena, 2016). Among the diseases affecting goats, gastrointestinal (GI) nematodes are the most important (Gobena, 2016; Smith and Sherman, 2023). The impacts of GI nematodes include lowering productivity, lowering growth rate, and causing morbidity and mortality. Gastrointestinal nematodes are mainly controlled by anthelmintic treatment (Carta and Scala, 2004; Williams *et al*., 2021). But these days, anthelmintic resistance has become a common and growing problem in GI nematodes of goats (Carta and Scala, 2004; Furgsa *et al*., 2018; Vineer *et al*., 2020). Understanding anthelmintic resistance status in various areas of the country is important to help stakeholders make informed decisions regarding parasite control methods. Therefore, the aim of the current study was to assess the status of anthelmintic resistance in GI nematodes infecting goats in the Hawassa area, besides estimating the prevalence and identification of risk factors for the occurrence of GI nematode infections.

Materials and methods

Study area

The study was conducted from December 2023 to September 2024 in and around Hawassa city, Sidama Regional State, Ethiopia. Geographically, Hawassa is located at 7◦ 3′ N latitude and 38◦ 28′ E longitude, on the escarpment of the Great East African Rift Valley. The altitude range of the town is 1680 to 1790 metre above sea level (m.a.s.l). The annual rainfall and temperature vary from 800-1000 mm and 20.1–25 °C, respectively (HCAFEDD, 2022). The total small ruminant population of Sidama Regional State is estimated at 486,262 goats and 94,829 sheep (CSA, 2022).

The study was conducted in 4 *Kebeles* (the smallest administrative unit in Ethiopia) of Hawassa and its surrounding areas, namely Chafe Kote Jabesa, Gamato, Tulo, and Garariqata.

Study population

The study population included local breeds of goats around Hawassa town that were kept under an extensive management system. All age groups, body conditions, both sex and goats not dewormed in the past three months were included in the study. The age of the study animals was determined based on dentition and wearing of teeth (Abebe and Yami, 2008; Smith and Sherman, 2023). Goats aged less than one year of age were considered as young, whereas those greater than or equal to one year of age as adults. The body condition scoring described by Abebe and Yami (2008) was taken into account, with modification, while scoring the body condition of the study goats into poor (i.e., very thin and thin), medium (i.e., moderate) and good (i.e., fat and very fat) scores.

Study design, sampling, and sample size

A cross-sectional study was employed to estimate the prevalence of GI nematode infection and assess the risk factors for infection in goats kept under an extensive management system. Additionally, a field anthelmintic resistance study was conducted to assess the status of anthelmintic resistance in goat GI nematodes.

The sample size required for the study was computed based on the formula described by Thrusfield (2018) for simple random sampling. The study took into account the 92.6% prevalence reported from the Dale district of Sidama Region by Sheferaw *et al*. (2013), a 95% confidence level, and 5% desired absolute precision to calculate the sample size. Accordingly, the total computed sample size for the study was 106 goats, but to increase the accuracy, the computed sample size was increased by about sevenfold. Sixty goats among those found positive for GI nematodes and had greater than 150 EPG during the prevalence study were purposively selected and randomly assigned to the four treatment groups (15 to each group) for field anthelmintic resistance assessment (Cole *et al*., 1992).

The 4 study *Kebeles*/villages (Chafe Kote Jabesa, Gamato, Tulo, and Garariqata) were purposively selected based on their goat population size, while the study goats and flocks were selected by systematic random sampling.

Fecal sample collection

Fecal samples were collected directly from the rectum using arm-length gloves and were placed in a screw-capped universal bottles. The sample bottles were labelled with all the necessary information (owner's name, goat identification mark, sex and age of the goat, fecal consistency, and village name). The samples were transported to the Veterinary Parasitology Laboratory of the Faculty of Veterinary Medicine of Hawassa University and were stored in the refrigerator at +4 ^{o}C until examined within 24 h of collection.

Qualitative and quantitative fecal sample examinations for parasitic ova

The fecal samples were examined within 24 h of the collection by the flotation technique as described by Zajac and Conboy (2021) and Hansen and Perry (1994). A saturated sodium chloride solution (specific gravity = 1.2) was used as the flotation fluid. For both qualitative and quantitative fecal examination, about 3 grams of feces were taken from each of the selected animals and placed in a mortar. Then, 42 ml of flotation fluid was added, and the mixture was mixed very well with a pestle. The mixture was filtered using a tea strainer into a beaker, and then, the test tube was filled with the filtrate until a convex surface at the top of the tube was developed, and a cover slide was carefully placed on it. The test tube was then left in place for twenty minutes, and after twenty minutes, the cover slip was removed and immediately placed on a microscopic slide. The slides were examined under a microscope at 10X and 40X objectives for the presence of strongyle type of eggs (qualitative examination), and the results were recorded as positive or negative.

The filtrates from infected goats (positive for strongyle-type eggs) were then subjected to quantitative examination. The McMaster egg counting method was used to determine the number of eggs per gram of feces (EPG). The filtrate was mixed very well; a portion of it was drawn with a Pasteur pipette and filled into the two chambers of the McMaster slide. All strongyle-type eggs inside the two chambers grid of the McMaster slide were counted (Zajac and Conboy, 2021). Then, using the count, the EPG was computed as described by Cole *et al*. (1992). Based on the EPG, the level of infection was classified as light (up to 800 EGP), moderate (800 to 1200 EPG), or heavy (greater than 1200 EPG) (Hansen and Perry, 1994).

Coproculture and nematode genera identification

Pooled fecal samples from goats positive for GI nematodes were cultured in Petri dishes at room temperature to identify the nematode genera circulating in the study areas. After 13 days, the third-stage larvae were recovered using the modified Baermann technique (Hansen and Perry, 1994; Zajac and Conboy, 2021). All recovered third-stage larvae (458) were then examined under the microscope using 10X and/or 40X objectives after adding a drop of iodine to kill them. The larvae were identified at the genera level based on their morphological characteristics (van Wyk and Mayhew, 2013).

Field experimental study for anthelmintic resistance

Three commonly used anthelmintic drugs in the study area (i.e., albendazole 300 mg; tetramisole 600 mg, and ivermectin 1%) were tested for resistance development by GI nematodes of goats in the area. A total of 60 goats that were 3 to 6 months old and positive for GI nematodes with greater than 150 EPG were selected and randomly assigned to 4 treatment groups, each composed of 15 goats. The study used a completely randomized design (CRD) whereby experimental animals were assigned to each treatment group randomly by a lottery method. There were four treatment groups: non-treated control group (TC), albendazole-treated group (TA), tetramisole-treated group (TT), and ivermectin-treated group (TI). The trade names, manufacturers, doses, and routes of administration of the anthelmintic drugs used in the experiment are presented in Table 1.

On the first day of the experiment, goats in the anthelmintic treated groups (TA, TT, TI) were treated with the respective anthelmintic drugs. On the 14th day of the treatment, fecal samples were collected from all goats in the experiment, including the control group, and were examined for any strongyle type eggs and determination of EPG (post-treatment fecal eggs count). The fecal egg count reduction for each anthelmintic drug was computed using a standard formula (Vizard and Wallace, 1987; Cole *et al.*, 1992). The development of resistance against each anthelmintic drug was judged based on the methods described by Cole *et al.* (1992).

Finally, pooled fecal samples were collected separately from each treatment group on day 14 of the experiment and were cultured separately for 14 days for third-stage larvae recovery and genera identification (Hansen and Perry, 1994; van Wyk *et al.*, 2013).

The study was conducted on-farm. All the study animals were managed in a naturally infected open environment and were maintained in an extensive farming system.

Table 1. Anthelmintics used for the field experiment.

Trade Name	Generic Name	Manufacturer	Dose	Route
Alben-LH 300	Albendazole 300 mg	Hebei Lihua Pharmaceutical Co. Ltd, China	7.5 mg/Kg	PO
Duxam-QK 600mg	Tetramisole 600 mg	Hebei Yuanzheng, China	15 mg/Kg	PO
H-Iver 1%	Ivermectin injection 1%	Hebei Lihua Pharmaceutical Co. Ltd., China	200 µg/kg	SC

Data storage and statistical analysis

Data were organized, edited and coded in Microsoft Excel Spread sheet, and were then imported to STATA Version 14 for analysis. The prevalence of GI nematodes was computed by dividing the number of positive goats to the total number of examined goats, and then multiplying by 100. The associations of risk factors considered for the study (BSC, sex, age, faecal consistency and flock size) with the occurrence of GI nematode infection were first analysed with univariable logistic regression analysis. Risk factors with $p < 0.25$ in the univariable analysis were checked for collinearity using the Kruskal gamma statistic, and the non-collinear factors (factors with gamma values between -0.6 and +0.6) were further subjected to multivariable logistic regression analysis. The study considered 95% confidence level and 5% desired absolute precision.

For the anthelmintic resistance test, EPG was subjected to logarithmic transformation [log (x+1)] to stabilize the variance. The arithmetic means were calculated for the field experimental study for both pre- and post-treatment EPGs, and the percentage of fecal egg count reduction was computed as follows: % FECR = $100 \times (1 - T_2/C_2)$, where T_2 was the mean egg count of the treated group at day 14, and C_2 the mean egg count of the untreated control group on day 14 after treatment (Cole *et al.*, 1992). The upper and lower confidence limits and percentage of egg count reduction were computed using the formula, LCL or UCL = 00(1-T2/C2exp (±2.048√Y2) where Y2 is the log scale variance after treatment. If the fecal egg count reduction was found to be less than 95% and the lower level of confidence below 90%, the development of anthelmintic resistance was suspected.

Results

Prevalence of gastrointestinal nematodes and associated risk factors

The overall GI nematode infection of goats was 46.5% (95% CI = 43.0-50.1). The prevalence of GI nematode infection in goats and the associated risk factors are shown in Table 2.

Table 2. Prevalence of gastrointestinal nematodes with associated risk factors.

Variables	Category	No examined	No Positive	Prevalence (%)	95% CI
Sex	Male	388	169	43.6	38.7-48.6
	Female	362	180	49.7	44.6-54.9
Age	Adult	387	131	33.9	29.3-38.7
	Young	363	218	60.1	54.9-64.1
BCD	Good	232	111	47.8	41.5-54.3
	Medium	280	120	42.9	37.2 -48.7
	Poor	238	118	49.6	43.3-55.9
Flock size	Small	267	89	33.3	27.9-39.2
	Medium	255	106	41.6	35.7-47.7
	Large	228	154	67.5	61.2-73.3
Faecal consistency	Normal	354	156	44.1	38.9-49.3
	Soft	396	193	48.7	43.8-53.7
Overall		750	349	46.5	43.0-50.1

Univariable and multivariable logistic regression analyses

All risk factors with $p < 0.25$ in the univariable analysis were checked for collinearity, and flock size and fecal consistency were found to be collinear ($\gamma = -0.6506$). Fecal consistency was dropped from the multivariable analysis in favor of flock size, as it could be affected by various conditions. As a result, only age, sex, and flock size were subjected to multivariable logistic regression analysis. The multivariable logistic regression analysis revealed that age and flock size were significantly ($p < 0.05$) associated with GI nematode infection in goats (Table 3).

Table 3. Univariable and multivariable logistic regression output of risk factors and their odds of exposure of goats to GI nematodes.

Variables	Category	No examined	No positive (%)	95% CI	Univariable logistic regression			Multivariable logistic regression		
					OR	X^2	*p*-value	OR	X^2	*p*-value
Sex	Male	388	169 (43.6)	38.7-48.6	Ref.	-	-	Ref	-	-
	Female	362	180 (49.7)	44.6-54.9	1.28	2.86	0.091	1.10	0.56	0.576
Age	Adult	387	131 (33.9)	22.9-38.7	Ref.	-	-	Ref.	-	-
	Young	363	218 (60.1)	54.9-65.0	2.94	52.28	0.000	2.97	6.69	0.000
BCS	Good	232	111 (47.8)	41.4-54.3	1.22	1.13	0.259	-	-	-
	Medium	280	120 (42.9)	37.2-48.7	Ref.	-	-	Ref.	-	-
	Poor	238	118 (49.6)	43.2-55.9	1.31	1.53	0.126	-	-	-
Flock size	Small	267	89 (33.3)	27.9-39.2	Ref.	-	-	Ref	-	-
	Medium	255	106 (41.6)	35.7-47.7	1.42	1.94	0.052	4.09	5.02	0.000
	Large	228	154 (67.5)	61.2-73.2	4.16	7.43	0.000	8.44	7.01	0.000
Faecal consistency	Normal	354	156 (44.1)	39.0-49.3	Ref.	-	-	-	-	-
	Soft	396	193 (48.7)	43.8-53.7	1.21	1.28	0.201	-	-	-
Overall		750	349 (46.5)	43.0-50.1						

Level of infection

The fecal egg counts of infected goats ranged from 50 to 2300 EPG, and the overall mean fecal egg count was 850 (95% CI = 778.1-921.9). The mean EPG of the light, medium and heavy levels of infection were 382.9 (95% CI=345.8-420.1), 1068 (95% CI=932.9-1204.9), and 1660.3 (95% CI=1577.9-1742.7), respectively. The proportions of light, medium, and heavy levels of infection were 48.7%, 31.8%, and 19.5%, respectively.

Young goats and female goats (does) recorded relatively higher mean EPGs. Table 4 summarizes the mean EPG by category of the risk factors considered in the study.

Table 4. Mean EPG score versus the risk factors considered in the study.

Variables	Category	No of Positive	Mean EPG ± SE	95% CI
Sex	Male	169	357.5 ± 27.3	303.7- 411.2
	Female	180	415.2 ± 30.1	356.0 - 474.3
Age	Adult	131	286.1 ± 26.4	234.2 - 338.1
	Young	218	491.0 ± 30.1	431.8 - 550.2
BCS	Good	111	385.5 ± 36.5	313.7 - 457.4
	Medium	120	387.6 ± 34.3	320.2 - 455.0
	Poor	118	382.3 ± 34.7	314.2- 450.4
Flock size	Small	89	288.5 ± 31.2	227.2 - 349.8
	Medium	106	336.2 ± 33.5	270.5 - 402.0
	Large	154	553.5 ± 39.3	476.2 - 630.7
Fecal consistency	Normal	156	370.4 ± 29.6	312.3 - 428.6
	Soft	193	398.6 ± 27.9	343.8 - 453.3
Overall		349	850 ± 36.6	778.1-921.9

Fecal culture and larvae identification

From a pooled faecal culture of the prevalence study, 458 third-stage larvae were recovered through a modified Baerman technique. Six nematode genera were generally recovered, and the most commonly identified genera were *Trichostrongylus* (32.3%) and *Haemonchus* (26.9%) (Figure 2).

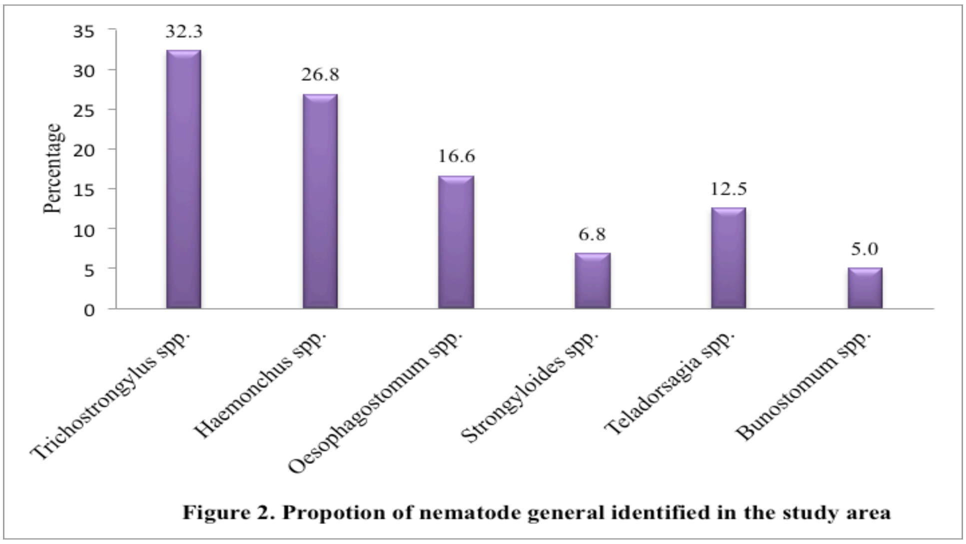

Figure 2. Proportion of nematode genera identified in the study area.

Field anthelmintic resistance test

Table 5 shows the mean pre-treatment and post-treatment percentage of fecal egg count reduction (FECR) and lower and upper 95% confidence limits.

Table 5. Fecal egg count reduction for the tested anthelmintic drugs.

Treatment group	Arithmetic mean of EPG (±SE)		Reduction (%)	95% CL (LCL-UCL)
	Pre-treatment	Post-treatment		
Albendazole	886.6 ± 150.3	256.7 ± 76.8	69.7	39.4 - 84.8
Tetramisole	1053.4 ± 162.9	36. 7 ± 13.4	95.7	90.2 – 98.1
Ivermectin	946.6 ± 162.6	166.6 ± 38.6	80.3	72.8 - 85.7
Control	883.4 ± 137.7	846.6 ± 133.5	-	

From post-treatment, pooled fecal culture, *Trichostrongylus* spp. and *Haemonchus* spp. were recovered from albendazole-treated goats, and *Trichostrongylus* spp. and *Teladorsagia* spp. were recovered from ivermectin-treated goats. From this finding, one can deduce that these two parasites have developed resistance to albendazole and ivermectin.

Discussion

The purposes of the study were to estimate the prevalence of GI nematode infection in goats and to assess the status of anthelmintic resistance in nematodes of goats in and around Hawassa. This study revealed that the overall prevalence of GI nematode infection was 46.5% (95% CI: 43.0--50.1). This observed prevalence (46.5%, 95% CI = 43.0-50.1) is similar and, hence, falls within the 95% CI of reports from various parts of the country (Danachew *et al.*, 2011; Muluneh *et al.*, 2014). Comparatively higher prevalence than the current study have been reported from various parts of the country (Kumsa *et al.*, 2011; Zeryehun, 2012; Shankute *et al.*, 2013; Sheferaw *et al.*, 2013; Terefe *et al.*, 2013; Dilgasa *et al.*, 2015; Mideksa *et al.*, 2016; Yimer and Birhan, 2016; Dabasa *et al.*, 2017; Dugassa *et al.*, 2018; Kabada *et al.*, 2020; Negash *et al.*, 2023). In fact, there are also some relatively lower prevalence reports from the country (Abebe *et al.*, 2010; Yasin *et al.*, 2017). These differences might be due to variations in geographical and environmental conditions, management systems, methods of diagnosis and animal health care activities (Arsenopoulos *et al.*, 2021), and herd size/stocking density (Arneberg *et al.*, 1998).

The multivariate logistic regression analysis revealed that age (OR = 2.85, $p < 0.05$) and flock size (OR = 2.85, $p < 0.05$) were significantly associated with goat's infection with GI nematodes. The prevalence of GI nematodes was greater in younger goats than in adults. This finding is consistent with reports from various parts of the country (Regassa *et al.*, 2006; Tariq *et al.*, 2010; Dilgasa *et al.*, 2015; Ousman and Meribo, 2022; Negash *et al.*, 2023). This could be due to the development of a defense mechanism or immunity against GI nematode infection over time, and so dependent on the age of the animals (Smith *et al.*, 1985; Soulsby, 1985; McRae *et al.*, 2015). Goats' infection by GI nematodes was significantly increased (OR=7.01; $p < 0.05$) with increasing in flock size. The prevalence was higher in larger and medium flock sizes than in smaller flock sizes (Tariq *et al.*, 2010; Zvinorova *et al.*, 2016). Whenever the goat's flock size increases, the probability of pasture contamination could be higher, and this might influence the number of goats to be infected (Le Jambre, 1984; Smith and Sherman, 2023).

The proportion of light-level infections (48.7%) was predominating, which was followed by medium (31.8%) and heavy levels (19.5%) infections. Similar observations from Ethiopia (Emiru *et al.*, 2013; Tibebu *et al.*, 2018; Sheferaw *et al.*, 2021) and other areas (Paul *et al.*, 2020; Wuthijaree *et al.*, 2022) were reported.

This form and order of level of infection is commonly seen in the tropical environment and smallholder production systems. According to Paul *et al*. (2020), a higher proportion of light nematode infection could depict animals shedding a few eggs due to adaptive immunity. The mean eggs per gram per feces of infected goats were higher in females (95% CI: 356.0-474.3), young (95% CI: 431.8-550.2), and large flock size (95% CI: 476.2-630.7).

From eleven GI nematodes genera documented in Ethiopia (Asmare *et al*., 2016) six were observed in the current study,namely *Trichostrongylus* spp. (32.3%), *Haemonchus* spp. (26.8%), *Oesophagostomum* spp. (16.6%), *Teladorsagia* spp. (12.5%), *Strongyloides* spp. (6.8%) and *Bunostomum* spp. (5.0%).

The field anthelmintic resistance test revealed that the FECRT percentage for albendazole, tetramisole, and ivermectin were 69.7% (95% CI: LCL-UCL = 39.4-84.8), 95.7% (95%CI: LCL-UCL = 90.2-98.1) and 80.3% (95% CI: LCL-UCL = 72.8-85.7), respectively. Whenever the FECRT is less than 95% and the lower confidence level is less than 90%, it should be considered as the presence of resistance (Cole *et al*., 1992). The FECRT percentage and lower confidence level of albendazole and ivermectin were less than 95% and 90%, respectively, suggesting the presence of anthelmintic resistance to albendazole and ivermectin among GI nematodes of goats in Hawassa area. Anthelmintic resistance development by small ruminants GI nematodes was reported from many parts of the country (Kumsa and Abebe, 2009; Sheferaw *et al*., 2015) and elsewhere in the world (Byaruhanga and Okwee-Acai 2013; Zanzani *et al*., 2014; Gelot *et al*., 2016; Ratanapob *et al*., 2022). It is very clear that anthelmintic resistance is a growing problem in most parts of the world and is common in goat GI nematodes (Vineer *et al*., 2020). Anthelmintic resistance arises as an outcome of misuse, under-dosing and frequent utilization of the drug (Carta and Scala, 2004; Kumsa and Abebe, 2009; Furgasa *et al*., 2018; Hassan and Ghazy, 2022). Moreover, anthelmintic resistance might occur when consecutive generations of nematodes are exposed to the same class of anthelmintics due to prolonged use of the same anthelmintic drug. Factors like host, parasite genetics, chemical nature of anthelmintic, and epidemiological factors also play key roles in the development of anthelmintic resistance (Furgasa *et al*., 2018; Fissiha and Kinde, 2021). Albendazole and ivermectin are the most common circulating anthelmintics in the study area.

Trichostrongylus spp. and *Haemonchus* spp. were recovered from post-treatment pooled fecal culture of the treated group, whereas *Trichostrongylus* spp.

and *Teladorsagia* spp. were recovered from ivermectin-treated group. The results suggest that *Trichostrongylus* spp. might have developed resistance to the two commonly used anthelmintic drugs (albendazole and ivermectin) in the study area. Almost similar genera of GI nematodes have been reported to show resistance to these anthelmintics by various investigators in Ethiopia (Kumsa and Abebe, 2009; Aga *et al*., 2013; Wondimu and Bayu, 2022; Alaro *et al*., 2023; Negash *et al*., 2023).

Conclusions

The prevalence of gastrointestinal nematode infection in goats was high in and around Hawassa. Flock size and age of goats were significantly associated with the prevalence of gastrointestinal nematode infection in goats. The main nematode genera identified in and around Hawassa include: *Trichostrongylus* spp., *Haemonchus* spp., *Oesophagostomum* spp., *Teladorsagia* spp., *Strongyloides* spp. and *Bunostomum* spp. The study demonstrated that *Trichostrongylus* spp. might have developed resistance to albendazole and ivermectin (i.e., Multiple drugs resistance). In contrast, *Haemonchus* spp. were found to be resistant to albendazole, and *Teladorsagia* spp. to ivermectin. The results of this study demonstrated that important GI nematodes of goats might have developed resistance to the most commonly used anthelmintics in the study area. As a result, anthelmintic resistance of GI nematodes may pose a major threat to sustainable goat production in the area and could result in substantial loss in productivity. Therefore, developing national strategies to manage and delay anthelmintic resistance may be necessary to mitigate its effect on livestock productivity, and anthelmintic resistance control methods such as rotation of anthelmintic classes may be implemented in large farms and village flocks.

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Conflict of interest

There are no known competing interests we declare.

Ethical consideration

Before starting the study the aim of the study was explained to the owners of the animals and verbal consent was obtained from all participants.

References

Abebe, G. and Yami, A., 2008. Sheep and goats management: In "Sheep and Goat production Handbook for Ethiopia," Edited by Yami, A. and Merkel, R.C., ESGPIP, USAID, and MoA. pp. 33-56

Abebe, R., Gebreyohannes, M., Mekuria, S., Abunna, F., Regassa, A., 2010. Gastrointestinal nematode infections in small ruminants under the traditional husbandry system during the dry season in southern Ethiopia. *Trop. Anim. Health Prod.*, 42, 1111-1117. http://doi.org/ 10.1007/s11250-010-9532-3

Alaro, T., Dulo, F., Wodajo, W. and Mathewos, L., 2023. Anthelmintic resistance of gastrointestinal nematodes of communally-grazing goats in Humbo District, Southern Ethiopia. *Vet. Med. Res. Rep.,* 14, 185-194. https://doi.org/10.2147/ VMRR.S434584

Arneberg, P., Skorping, A., Grenfell, B. and Read, A.F. (1998): Host densities as determinants of abundance in parasite communities. *Proc. R. Soc. Lond. B*, 265, 1283-1289.

Arsenopoulos, K.V., Fthenakis, G.C., Katsarou, E.I. and Papadopoulos, E., 2021. Haemonchosis: a challenging parasitic infection of sheep and goats. *Animals*, 11(2), 363. http://doi.org/ 10.3390/ani11020363

Asmare, A., Sheferaw, D., Aragaw, K., Abera, M., Sibhat, B., Haile, A., Kiara, H., Szonyi, B. and Wieland B., 2016. Gastrointestinal nematode infection in small ruminants in Ethiopia: a systematic review and meta-analysis. *Acta Tropica*, 160, 68-77. http://doi.org/ 10.1016/j.actatopica.2016.04.016

Byaruhanga, C. and Okwee-Acai, J., 2013. Efficacy of albendazole, levamisole, and ivermectin against gastro-intestinal nematodes in naturally infected goats at the National Semi-arid Resources Research Institute, Serere, Uganda. Vet. Parasitol., 195(1-2), 183-186. http:// doi.org/10.1016/j.vetpar.2013.01.007

Carta, A. and Scala, A., 2004. Recent findings on the genetics of gastrointestinal nematode resistance in ruminants. *Parasitologia*, 46(1-2), 251-255. PMID: 15305728

Coles, G.C., Bauer, C., Borgsteede, F.H.M., Geerts, S., Klei, T.R., Taylor, M.A. and Waller, P.J., 1992. World Association for the Advancement of Veterinary Parasitology (W.A.A.V.P) methods for the detection of anthelmintic resistance in nematodes of veterinary importance. *Vet. Parasitol.*, 44(1-2), 35-44. https://doi.org/10.1016.0304-4017(92(90141-U

CSA, 2022. Agricultural sample survey of 2021/22, Volume II, report on livestock and livestock characteristics, Statistical Bulletin 594, Federal Democratic Republic of Ethiopia, Ethiopian Statistics Service, Addis Ababa. pp. 219

Dabasa, G., Shanko, T., Zewdei, W., Jilo, K., Gurmesa, G. and Abdela, N., 2017. Prevalence of small ruminant gastrointestinal parasites infections and associated risk factors in selected districts of Bale zone, south-eastern Ethiopia. *J. Parasitol. Vector Biol.*, 9(6), 81-88. http://doi.org/10.5897/JPVB2017.0286

Dagnachew, S., Amamute, A. and Temesgen, W., 2011. Epidemiology of gastrointestinal helminthiasis of small ruminants in selected sites of North Gondar zone, Northwest Ethiopia. *Ethiop. Vet. J.*, 15 (2), 57-68. http://doi.org/10.4314/evj.v15i2.67694

Dilgasa. L., Asrade, B. and Kassaye, S., 2015. Prevalence of gastrointestinal nematodes of small ruminants in and around Arsi Negele town, Ethiopia. *Am-Euras. J. Sci. Res.*, 10(3), 121-125. http://doi.org/10.5829/idosi.aejsr.2015.10.3.9474

Dugassa, J., Hussein, A., Kebede, A. and Mohammed, C., 2018. Prevalence and associated risk factors of gastrointestinal nematodes of sheep and goats in Ziway-Dugda district, Eastern Arsi Zone of Oromia Regional State, Ethiopia. *ARC J. Anim. Vet. Sci.*, 4(2), 6-14. http://dx.doi.org/10.20431/2455-2518.0402002

Emiru, B., Amede, Y., Tigre, W., Feyera, T. and Deressa B., 2013. Epidemiology of gastrointestinal parasites of small ruminants in Gechi District, Southwest Ethiopia. Adv. Biol. Res., 7(5), 169-174. http://doi.org/10.5829/idosi.abr.2013.7.5. 74176

Fissiha, W. and Kinde, M.Z., 2021. Anthelmintic resistance and its mechanism: a review. *Infec. Drug Resist.*, 14, 5403-5410. ~~http://doi.org/10.2147/ID.S332378~~

Furgasa, W., Abunna, F., Yimer, L. and Haile, G., 2018. Review on anthelmintic resistance against gastrointestinal nematodes of small ruminants: its status and future perspective in Ethiopia. *J. Vet. Sci. Ani. Husb.*, 6(4), 407. www.annexpublishers.com

Gobena, M.M., 2016. Production Performance, Challenges and Opportunity of Goat Production in Ethiopia. Advances in Life Science and Technology, 50: 26-35. www.iiste.org

Gelot, I., Singh, V., Shyma, K. and Parsani, H., 2016. Emergence of multiple resistances against gastrointestinal nematodes of Mehsana-cross goats in a semi-organized farm of semi-arid region of India. J. Appl. Animal Res., 44(1), 146-149. http://doi.org/10.1080/09712119. 2015.1021809

Hansen, J. and Perry, B., 1994. The epidemiology, diagnosis, and control of helminth parasites of ruminant, (Handbook). International Laboratory for Research on Animal Diseases (ILRAD) Press. Nairobi, Kenya. pp. 27. https://hdl.handle.net/10568/49809.

Hassan, N.M. and Ghazy, A.A., 2022. Advances in diagnosis and control of anthelmintic resistant gastrointestinal helminths infecting ruminants. J. Parasit. Dis., 46, 901-915. https:// doi.org/10.1007/s12639-021-01457-z

HCAFEDD, 2022. Socioeconomic and Geo-spatial data analysis and dissemination core work process. Socioeconomic profile (unpublished)

Hirpa, A. and Abebe, G., 2008. Economic significance of sheep and goats: In “Sheep and goats production handbook for Ethiopia,” Edited by Yami, A. and Merkel, R.C., ESGPIP, USAID and MoARD, Ethiopia. pp. 1-4

Kabada, T., Tolera, D. and Abera, A., 2020. Prevalence and the associated risk factors of gastrointestinal parasites of shoats in Tiyo District, Arsi zone, Oromia, South West Ethiopia. *Int. J. Agric. Sc. Food Technol.*, 6(1), 075-078. http://doi.org/10.17352/2455-815X.000058

Kosgey, I.S. and Okeyo, A.M., 2007. Genetic improvement of small ruminants in low-input, smallholder production systems: technical and infrastructural issues. *Small Rumin. Res.* 70 (1), 76-88. https://doi.org/10.1016/j.smallrumres.2007.01.007

Kumsa, B. and Abebe, G., 2009. Multiple anthelmintic resistances on a goat farm in Hawassa (southern Ethiopia). *Trop. Anim. Health Prod.*, 41, 655-662. http://doi.org/10.1007/s11250-008-9237-z

Kumsa, B., Tadesse, T., Sori, T., Dugum, R. and Hussen, B., 2011. Helminths of sheep and goats in central Oromia (Ethiopia) during the dry season, *J. Anim. Vet. Adv.*, 10(14), 1845-1849. http:// doi.org/10.3923/JAVAA.2011.1845.1849

Le Jambre, L.F., 1984. Stocking rate effects on the worm burdens of Angora goats and Merino sheep. *Aust. Vet. J., 61(9), 280–282.* http://doi.org/10.1111/j.1751-0813.1984.tb06009.x.

McRae, K.M., Stear, M.J., Good, B. and. Keane, O.M., 2015. The host immune response to gastrointestinal nematode infection in sheep. *Parasite Immunol.*, 37, 605–613. http:// doi.org/10.1111/pim.12290

Mhlanga, T.T., Mutibvu, T. and Mbiriri, D.T., 2018. Goat flock productivity under smallholder farmer management in Zimbabwe, hort communication. *Small Rumin. Res.*, 164, 105-109. http://doi.org/10.1016/j/smallrumres.2018.05.010

Mideksa, S., Mekonnen, N. and Muktar, Y., 2016. Prevalence and burden of nematode parasites of small ruminants in and around Haramaya University. *World Appl. Sci. J.*, 34 (5), 644-651. http://doi.org/10.5829/idosi.wasj.2016.34.5.10350

Muluneh, J., Bogale, B. and Chanie, M., 2014. Major gastrointestinal nematodes of small ruminants in Dembia district, northwest Ethiopia. *Europ. J. Appl. Sci.*, 6 (2), 30-36. http:// doi.org/10.5829/idosi.ejas.2014.6.2.8652

Negash, B., Wasihun Seyoum, W. and Sheferaw, D., 2023. Seasonal prevalence and status of anthelmintic resistance of goats' gastrointestinal nematodes, Mirab Abaya, Southern Ethiopia. *J. Parasitol. Res.*, 2023:9945998. https://doi.org/10.1155/2023/9945998

Ousman, A. and Meribo, A., 2022. Study on prevalence of gastrointestinal nematodes of small ruminant in Adami Tulu Jiddo Kombolcha District, East Shoa Zone of Oromia, Ethiopia. *Int. J. Adv. Res. Biol. Sci.*, 9(2), 72-81. http://dx.doi.org/10.22192/ijarbs.2022.09.02.008

Paul, B.T., Jesse, F.F.A., Chung, E.L.T., Che'Amat, A. and Lila, M.A.M., 2020. Risk factors and severity of gastrointestinal parasites in selected small ruminants from Malaysia. *Vet. Sci., 7(4), 208*. http://doi.org/10.3390/vetsci7040208

Ratanapob, N., Thuamsuwan, N. and Thongyuan, S., 2022. Anthelmintic resistance status of goat gastrointestinal nematodes in Sing Buri Province, Thailand. *Vet. World*, 15(1), 83-90. http://doi:10.14202/vetworld.2022.83-90

Regassa, F., Sori, T., Dhuguma, R. and Kiros, Y., 2006. Epidemiology of gastrointestinal parasites of ruminants in western Oromia, Ethiopia. *Int. J. Appl. Res. Vet. Med.*, 4(1), 51-57.

Shankute, G., Bogale, B. and Melaku, A., 2013. An abattoir survey on gastrointestinal nematodes in sheep and goats in Hemex-Export abattoir, Bishoftu, central Ethiopia. *J. Adv. Vet. Res.*, 3 (2), 60-63.

Sheferaw, D., Getachew, D., Bekele, J. and Denbarga, Y., 2013. Assessment of anthelmintic resistance in gastrointestinal nematodes of small ruminants, Dale district, southern Ethiopia. *J. Vet. Med. Anim. Health,* 5(9), 257-261. https://DOI-https://10.5897/JVMAH 13.0215

Sheferaw, D., Mohammed, A. and Degefu, A., 2021. Distribution and prevalence of gastrointestinal tract nematodes of sheep at highland and midland areas, Ethiopia. *J. Parasit. Dis.*, 45(4), 995-1001. http://doi.org/10.1007/s12639-021-01397-8

Smith, M.C. and Sherman, D.M., 2023. Goat Medicine, 3rd edition, John Wiley and Sons Inc., 111 River Street, Hoboken, NJ 07030, USA. pp. 435.

Smith, W.D., Jackson, F., Jackson, E. and Williams, J., 1985. Age immunity to *Ostertagia circumcincta*: Comparison of the local immune responses of 4.5 and

10-month-old lambs. *J. Comp. Path.*, 95(2), 235-245. http://doi.org/10.1016/0021-9975(85)90010-6

Soulsby, E.J.L., 1985. Advances in immunoparasitology. *Vet. Parasitol.*, 18, 303-319. http:// doi.org/10.1016/0304-4017(85)90066-4

Tariq, K.A., Chishti, M.Z. and Ahmad, F., 2010. Gastrointestinal nematode infections in goats relative to season, host sex, and age from the Kashmir valley, India. *Indian J. Helminthol.,* 84(1), 93–97. http://doi.org/10.1017/S0022149X09990113

Terefe, G., Faji, U. and Tolossa, Y.H., 2013. Field investigation of anthelmintic efficacy and risk factors for anthelmintic drug resistance in sheep at Bedelle District of Oromia Region, Ethiopia. *Ethiop. Vet. J.*, 17(2), 37-49. http://doi.org/10.4314/evj.v17i2.3

Thrusfield, M., 2018. Veterinary Epidemiology, 4th Edition, John Wiley and Sons, Ltd., 9600 Garsington Road, Oxford, OX4 2DQ, UK. pp. 270-276.

Tibebu, A., Tamiru, Y. and Abdeta, D., 2018. Prevalence of major gastrointestinal nematode and degree of parasite infestation in sheep of Bako Agricultural Research Center community-based breeding program project smallholder farms at Horro District. *Dairy Vet. Sci. J.,* 8(3), 555740. http://doi.org/10.19080/JDVS.2018.08.555740

Van Wyk, J.A. and Mayhew, E., 2013. Morphological identification of parasitic nematode infective larvae of small ruminants and cattle: a practical lab guide. *Onderstepoort J. Vet. Res.,* 80(1), 539. http://dx.doi.org/10.4102/ojvr.v80i1.539

Vineer, H.R., Morgan, E.R., Hertzberg, H., Bartley, D.J., Bosco, A., Charlier, J., Chartier, C. *et al.,* 2020. Increasing importance of anthelmintic resistance in European livestock: creation and meta-analysis of an open database. *Parasite*, 27, 69. http://doi.org/10.1051/ parasite/2020062

Vizard, A.L. and Wallace, R.J., 1987. A simplified faecal egg count reduction test. *Aust. Vet. J.*, 64(4), 109-111. https://doi.org/10.1111/j.1751-0813.1987. tb09641.x

Williams, W.G., Brophy, P.M., Williams, H.W., N.D. and Jones, R.A., 2021. Gastrointestinal nematode control practices in ewes: Identification of factors associated with application of control methods known to influence anthelmintic resistance development. *Vet. Parasitol. Reg. Stud. Reports*, 24, 100562. http://doi.org/10.1016/j.vprsr.2021.100562

Wodajo, H.D., Gemeda, B.A., Kinati, W., Mulem, A.A.; van Eerdewijk, A. and Wieland, B., 2020. Contribution of small ruminants to food security for Ethiopian smallholder farmers. *Small Rum. Res.*, 184, 106064. http://doi.org/10.1016/j,smallrur es.2020.106064

Wondimu, A. and Bayu, Y., 2022. Anthelmintic drug resistance of gastrointestinal nematodes of naturally infected goats in Haramaya, Ethiopia. *J. Parasitol. Res.*, 17, 2022, 4025902. http:// doi.org/10.1155/2022/4025902

Wuthijaree, K., Tatsapong, P. and Lambertz, C., 2022. The prevalence of intestinal parasite infections in goats from smallholder farms in Northern Thailand. *Helminthologia,* 59(1), 64-73. http://doi.org/10.2478/helm-2022-0007

Yasin, U., Wodajnew, B. and Tsehaineh, D., 2017. Study on the prevalence of GIT nematode infection of small ruminants in Kurmuk Woreda, Assosa Zone of Benishangul Gumuz Region, western Ethiopia. *Rep. Opinion*, 9(10), 48-59. http://doi.org/10.7537/marsroj 091017.10

Yimer, A. and Birhan, E., 2016. Prevalence and identification of gastrointestinal nematodes of small ruminants in northern Ethiopia. *Middle-East J. Sci. Res.*, 24(8), 2602-2608. http://doi.orrg/10.5829/idosi.mejsr.2016.24.08.223834

Zajac, A.M. and Conboy, G.A., 2021. Veterinary Clinical Parasitology, 9th Edition, John Wiley and Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA. pp. 408

Zanzani, S.A., Gazzonis, A.L., di Cerbo, A., Varady, M. and Manfredi, M.T., 2014. Gastrointestinal nematodes of dairy goats, anthelmintic resistance and practices of parasite control in Northern Italy. *BMC Vet. Res.,* 10(1), 114. http://doi.org/10.1186/1746-6148-10-114

Zeryehun, T., 2012. Helminthosis of sheep and goats in and around Haramaya, southeastern Ethiopia. *J. Vet. Med. Anim. Health*, 4(3), 48-55. http://doi.org/10.5897/JVMAH12.0014

Zvinorova, P.I., Halimani, T.E., Muchadeyi, F.C., Matika, O., Riggioe, V. and Dzama, K., 2016. Prevalence and risk factors of gastrointestinal parasitic infections in goats in low-input low-output farming systems in Zimbabwe. *Small Rumin. Res.,* 143, 75–83. http://doi.org/ 10.1016/j.smallrumres.2016.09.005