

Research Article

Prevalence, Associated Risk Factors, and Economic Loss of Ovine Hemonchosis at Jimma Town Municipal Abattoir, Jimma Zone, Southwestern Ethiopia

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Hemonchosis is considered one of the most severe gastrointestinal parasitic diseases in small ruminants due to the blood feeding habits of the parasites, which results in production loss and death of the animals. A cross-sectional study was conducted from December 2022 to March 2023 at the Jimma town municipal abattoir with the objectives of estimating the occurrence of ovine hemonchosis, investigating potential associated risk factors, and assessing economic loss due to the disease. A total of 374 animals were chosen by systematic random sampling over the study period, and prevalence was estimated based on coprological and postmortem examination for the presence or absence of the parasite according to standard procedures. Accordingly, among the examined sheep, 32.62% and 53.2% were positive for Haemonchus contortus by fecal and postmortem examination, respectively. When the two tests were compared using the latter as the gold standard, the results showed a moderate degree of agreement (kappa statistic = 0.597). The prevalence of *H. contortus* was found to be statistically significant (p < 0.05) with respect to agroecology and season. The highest prevalence of *H. contortus* was observed during the semidry season (65.62%) and began to decline gradually from the middle of the semidry season. The lowest prevalence was recorded during the dry season (41.52%). The present study did not find a statistically significant difference in prevalence across different age and sex groups (p > 0.05). The annual financial loss due to abomasum rejection and carcass reduction associated with hemonchosis at the abattoir was estimated to be 358,591.58 Ethiopian birr. It was concluded that hemonchosis was prevalent in the study area, resulting in a significant loss and dictating applicable control and prevention approaches for hemonchosis.

1. Introduction

Ethiopia has a very diverse terrain, a wide variety of climatic characteristics, and a multitude of agroecological zones, which make the nation appropriate for various agricultural production systems [1]. A total of 70 million cattle, 42 million sheep, 52 million goats, 8 million camels, 56 million chickens, and enormous bee populations and fisheries make up the countries' livestock populations [2].

In Ethiopia, despite a high population of livestock, there are various factors that contribute to low production. Many developing countries' livestock industries face multiple, interrelated, and co-occurring challenges that range from resource and technological limitations at the farm level to market and institutional failures [3]. Livestock diseases, both infectious and noninfectious, are among the main obstacles that have hampered the sector's development [4]. Due to the presence of a variety of agroecological conditions suited for a wide range of hosts and parasite species, sub-Saharan Africa in general and Ethiopia in particular suffer more from the effects of gastrointestinal parasitic infection, which is one of the most serious infectious diseases [5].

The gastrointestinal nematodes (GIN), including Haemonchus, have been elucidated by parasitological investigations as the most prevalent nematode parasites of small ruminants in Ethiopia [6]. A systematic review and meta-analysis of research conducted on GIN infection in small ruminants in Ethiopia indicated that parasites are the most prevalent infection and cause both direct and indirect economic losses [7]. Several small ruminant nematodiasis prevalence studies have been conducted in various regions and agroclimatic zones of Ethiopia. These reports indicated a prevalence ranging from 50.4% to 84.1% [8]. The agroecological suitability of Ethiopia plays a leading role in the higher prevalence of GINs among small ruminants [7]. Due to its high level of biological and ecological plasticity, Haemonchus, which is one of the most common and highly harmful parasite, has the largest biotic potential. It also has a notable capacity to evolve resistance to the majority of commonly used antihelmintics and a distinctive survival strategy. Therefore, Haemonchus is the most significant parasite of domestic ruminants, particularly sheep and goats, when compared to other GINs [9].

The blood-sucking nematode H. contortus is primarily found in the abomasum of small ruminants, particularly sheep and goats. Because of its red- and white-striped female, this nematode is also known as the barber pole worm. Females can lay more than 5,000 eggs each day, which are excreted into the grassland. In all areas of the tropics and subtropics, it has been listed as the parasite of small ruminants with the greatest pathogenic and economic relevance. The main economic costs are mortality, loss of productivity, stunted growth, low weight gain, and poor feed consumption. It can result in the loss of meat (27% and 40%) and wool (40% among sheep and goats) due to hematological and biochemical changes, loss of appetite, weight loss, decrease in protein, impaired digestion efficiency, and poor reproductive performance [10-12]. The primary effects of H. contortus are linked to the parasites' substantial blood loss caused by their blood-sucking activity [13].

A flock's epidemiology of *H. contortus* infections gives a solid idea of the parasite loads present and the size of the production losses. To identify the significance of parasite infection and suggest the most effective and financially feasible control measures, it is critical to evaluate the kind and degree of parasitism in ruminant cattle. An efficient control strategy can be created by identifying the risk variables connected to the presence of parasites [13, 14].

Even though epidemiological studies have been conducted in and around the study area by different researchers on ovine hemonchosis [7, 14], there is no adequate and updated information regarding the disease prevalence in the study area, and the conducted studies were only based on the results of postmortem examinations. On the other hand, Haemonchus causes a severe loss of body condition in highly infected sheep, resulting in a reduction in carcass weight, which indirectly has an economic impact aside from its direct effect on the health of animals. Although the parasite has a significant impact, the economic significance of this impact in the study area has not been adequately documented. Therefore, the aim of our study was to estimate the prevalence, identify associated risk factors for the disease, and evaluate its economic importance within the study area.

2. Materials and Methods

2.1. Description of the Study Area. The study was carried out at Jimma town municipal abattoir from December 2022 to March 2023, for a total of four months, in the Jimma zone, southwestern Ethiopia. Jimma zone has a total population of 2,495,795, of which 94.3% live in rural areas [15]. The production system in the zone is mixed crop-livestock. Jimma is a highland and a moisture-reliable zone. The zone is one of the major coffee-growing areas, well endowed with natural resources that contribute significantly to the national economy of the country. Apart from coffee, the principal crops cultivated include barley, teff, sorghum, maize, pulses, root crops, and fruits. Teff production and honey production are another source of cash after coffee. Enset is a strategic crop substantially contributing to the food security of the zone [16]. Livestock commodities include cattle, small ruminants (sheep and goats), apiculture, poultry, and equines [2].

Jimma town is one of the oldest and most historic towns in Ethiopia, located 352 kilometers southwest of the Ethiopian capital, Addis Ababa [17]. The town is located at a latitude of approximately 7° 13'-8° 56' N and a longitude of approximately $35^{\circ} 52' - 37^{\circ} 37'$ E, with an elevation ranging from 880 to 3,360 meters above mean sea level. The study area receives a mean annual rainfall of approximately 1530 mm, which comes from the long and short rainy seasons. The annual mean minimum and maximum temperatures are 14.4 and 26.7°C, respectively. The zone has a long yearly wet season that lasts from March to October and consistently receives good precipitation [18]. Most of the sheep slaughtered in this abattoir originate from the districts of Dedo, Kersa, and Seka. The Dedo district, which is 880-2400 meters above sea level, is located near the southernmost point of the zone [17]. The area experiences minimum and maximum daily temperatures of 20 and 280°C, respectively, with an average annual rainfall of 1600 to 2600 mm.

Seka is a district in the Jimma zone located at a distance of 355 km from Addis Ababa at an altitude ranging between 1,580 and 2,560 meters above sea level. The district receives rainfall ranging from 1,200 to 2,800 mm per year. The minimum and maximum daily temperatures of the area are 12.6°C and 29.1°C, respectively [19]. Kersa district is the other origin of sheep in the Jimma zone, which is located 345 km southwest of Addis Ababa with latitudes 7° 35'-8°00' N and between longitudes 36° 46'-37° 14' E, at altitudes between 1,740 and 2,660 m above mean sea level [15].

2.2. Study Animals. The study animals were local breed sheep of both sexes slaughtered at the Jimma town municipal abattoir. The age of animals was estimated using tooth eruptions and classified as adult and young. Animals were classified as young (1–3 years old) if they had four or fewer permanent teeth and adults (4-5 years old) if they had more than four permanent teeth [20]. The body condition score was determined and grouped as poor, medium, and good [21]. According to the Ethiopia report of the 2021 Central Statistical Agency, the total livestock population of Jimma zone is as follows: cattle (2,560,207), sheep (859,914), goats

(570,387), equines (281,113), poultry (2,235,702), and beehives (532,728) [2].

2.3. Study Design. A cross-sectional study was conducted at the Jimma town municipal abattoir to estimate the prevalence of ovine hemonchosis, associated risk factors, and economic loss due to abomasum rejection and carcass reduction.

2.4. Sampling Method and Sample Size Determination. A systematic random sampling technique was used to select the study animals. Average daily slaughtered animals at abattoir were 18 sheep. The sample size was determined using the formula described by Thrusfield [22] by considering an expected prevalence of 33.1% at Jimma municipal abattoir [14] and an absolute precision of 5% with a 95% confidence level since there had been a study conducted in the area before.

$$n = \frac{(1.96)^2 p \exp (1 - p \exp)}{d^2}$$

= $\frac{(1.96)^2 (0.331)(1 - 0.331)}{0.05^2}$ (1)
= 340,

where *n* is the needed sample size, *p* exp is the expected prevalence (p = 33.1%), *d* is the desired absolute precision (5%), and Z = 1.96 for a 95% confidence interval. Accordingly, the sample size was calculated to be 340. However, it was maximized to 374 sheep to increase precision.

2.5. Study Methodology. An active abattoir survey was carried out during the study period. The frequency of abattoir visits was four days per week. The study was conducted based on coprological and postmortem examinations.

2.5.1. Antemortem Examination. Before the sheep were slaughtered, antemortem examinations were performed on the chosen sheep. An identification number was given to the selected animals. Accordingly, each chosen animal's age, sex, origin, body condition, and overall health condition were assessed and scored. The origins of the animals were recorded in the histories of the animal owners.

2.5.2. Coprological Examination. Using sterile disposable plastic gloves, fecal samples (approximately 5g) were collected from the animals' rectums during the initial recording of the animal data and put in a standard bottle. Each sample was given a unique number and labeled with the date, gender, age, and physical condition. Next, the samples were placed in an icebox and transported to the Jimma University Veterinary Parasitology laboratory for coprological examination. Then, the sample was immediately examined. As a result, the floating technique was employed to identify the presence of Haemonchus eggs by combining feces with saturated salt solutions to cause the eggs to float, as they are lighter than the salt solutions. The two most widely utilized salt solutions were those containing ZnSO₄ and NaCl₂. Positive samples were allowed to be cultured, and Haemonchus identification from other genera was made based on larval characteristics [23].

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2.5.3. Postmortem Examination. The abomasum of the sheep was chosen, and it was divided from the omasum and duodenum during the postmortem inspection. The compartment was then carefully inspected for the presence of an adult Haemonchus parasite after being opened throughout its greater curvature. The abomasum wall and its contents were carefully observed for any gross pathological changes. The adult *H. contortus* worms were identified visually by the standard method. The adult parasites are easily identified because of their specific location in the abomasa, their large size (2–3 centimeters), and their color (reddish). In a fresh specimen, the white ovaries winding spirally around the blood-filled intestine produce a "barbed pole" appearance [24].

2.5.4. Economic Loss Assessment. The annual slaughter rate was estimated from the average daily slaughtering capacity of the abattoir, while the average retail market price of abomasum was determined by the butchers in Jimma town [25]. It is not familiar to sell the abomasum separately from the other compartments. However, it was purposefully separated from other segments and weighed individually. Its price was estimated by the butchers. Accordingly, six butcher houses were interviewed, and the average weight of one abomasum was considered to be 92 grams. The information was subjected to mathematical computation using the formula set by A. Ogunrinade and B. Ogunrinade [26].

$$ALC = MSS * MAP * RR$$
 (2)

where ALC is the annual loss from abomasum condemnation, MSS is the mean annual sheep slaughtered at Jimma town municipal abattoir, MAP is the mean price of one abomasum in Jimma town, and RR is the rejection rate of the compartment.

Alternatively, indirect economic loss was associated with carcass weight reduction due to hemonchosis. A 27% carcass weight loss due to hemonchosis in sheep was reported by Bachaya et al. [12] and Iqbal and Jabbar [11]. The average carcass weight of an Ethiopian sheep was taken as 10 kg [27]. The annual economic loss because of carcass weight reduction due to ovine hemonchosis was assessed using the formula set by A. Ogunrinade and B. Ogunrinade [26].

$$ACW = SSR * CR * MP * P * 10 \text{ kg}$$
(3)

where ACW is the annual loss from carcass weight reduction, SSR is the average number of sheep slaughtered per annum at the study abattoir, CR is the percentage of carcass reduction, MP is the average price of 1 kg of mutton in Jimma town, P is the prevalence rate of hemonchosis at the Jimma town municipal abattoir, and 10 kg is the average carcass weight of eight Ethiopian sheep.

2.6. Data Management and Analysis. During the collection of fecal samples from research animals, all data were recorded in field notebooks using predesigned formats and subsequently input into a computer using a Microsoft Excel spreadsheet from 2010. Before statistical analysis, the data

set was extensively inspected for errors and mistakes and appropriately coded. The Stata version 14 statistical software was used to analyze the data. Logistic regression analyses were conducted using Haemonchus infection as an outcome or dependent variable against each of the independent variables of the hypothesized risk factors (season, age, sex, agroecology, and body condition). Percentage and kappa were used to determine prevalence and agreement tests (floatation technique with postmortem examination, which was considered the gold standard test) (Cohen's kappa is a measure of agreement between the two individuals when two binary variables are attempted by two individuals to measure the same thing). The odds ratio (OR) and its 95% confidence interval (CI) of the variables associated with the outcome variables were calculated. At a 95% confidence level, a p value of 5% indicated the presence of a significant association.

3. Results

3.1. Coprological Examination. The present study showed that of a total of 374 sheep examined, 122 were found to be positive, with an overall prevalence of 32.62% (95% CI: 28.03–37.56%). In this study, the recorded prevalence of hemonchosis between the age groups was 33.76% and 30.76% in young and adults, respectively. Similarly, the prevalence of Haemonchus infection in animals from the midlands was found to be 35.46%, while animals from the lowlands had a prevalence rate of 23.9% (Table 1).

3.2. Postmortem Examination. A total of 374 sheep were inspected for the presence or absence of adult *H. contortus*. Out of the sheep examined at the Jimma town municipal abattoir, 199 were found to be positive for *H. contortus* during postmortem examination. The overall prevalence of hemonchosis in sheep was found to be 53.2% (95% CI: 48.11–58.23%) in the study area. The distribution of the parasite was considered on the basis of risk factors such as sex, age, agroecological origin, season, and body condition during the study period (Table 2).

3.3. Comparative Results of Coprological and Postmortem Examinations. The summary results of the different diagnostic tests employed on 374 sheep and the statistical analysis results are presented in Table 3. By using postmortem examination as a gold standard, the result of fecal examination using the floatation technique was compared with the postmortem results of the same animals (374). Accordingly, there was moderate agreement between the coprological and postmortem results (kappa statistic = 0.5972) (Table 3).

3.4. Univariable Logistic Regression Analysis (Postmortem Finding). The results of a univariable logistic regression analysis of the association between *H. contortus* infections and various risk factors were analyzed. In the current study, the univariable analysis showed that origin and season were statistically significant (p < 0.05). However, age and sex were statistically insignificant (p > 0.05) (Table 4).

3.5. Multivariable Logistic Regression Analysis. Those risk factors with a p value less than 0.25 were subjected to multi-

variable logistic regression, and using the backward elimination technique, the potential risk factors were identified. Thus, agroecological origin and season were the most important risk factors associated with the disease, and hence, they were statistically significant (p < 0.05) (Table 4).

The prevalence of the disease and body condition of the animals were considered and found to be significant. However, it was not taken as the potential risk factor for the occurrence of hemonchosis due to reverse causation.

3.6. Economic Loss Analysis. The direct economic loss results from abomasum rejection as the result of hemonchosis. The average annual sheep slaughtered was estimated to be 2496, while the mean retail price of ovine abomasum in Jimma town was 5 ETB, and the rejection rate of abomasum in Jimma municipal abattoir was estimated to be 0.53%. Therefore, the estimated annual loss from organ condemnation is 2496* 5* 0.53% = 66.14 ETB. Indirect economic loss, which is the most important loss, results from carcass weight reduction as a result of Haemonchus infestation. It was calculated as 2496*27% * 100*53.2% * 10 = 358,525.44 ETB. Therefore, the total annual economic loss due to ovine hemonchosis in the study abattoir is the sum of the losses from organ rejection (direct loss) and carcass weight reduction (indirect loss), for a total of 358,591.58 ETB.

4. Discussion

Haemonchus contortus is the species of Haemonchus with the greatest pathogenic and economic importance in small ruminants. It is important to assess the nature and level of parasitism in ruminant livestock to determine the significance of parasite infection and to recommend the most beneficial and economically acceptable control measures. The determination of the risk factors associated with parasite occurrence can be used to design an effective control strategy [28]. The parasite finds highly favorable warm and wet conditions in tropical and subtropical countries [29]; however, over the years, prevalence has also been reported frequently from temperate regions due to climatic changes [30].

During the study period, a coprological examination was conducted on a total of 374 sheep, and an overall prevalence of 32.62% was recorded. This finding is lower than a similar study performed by Bekuma and Dufera [31], who reported a 63.6% prevalence in sheep from Ejere town, West Shoa, Oromia, Ethiopia. It was also much lower than the report of Wossene and Gelaye [32], who reported 96.5% in sheep; Argaw et al. [33], who reported 90.4%; 41% from Debre Birhan [34]; and 62% prevalence from Jimma town [35]. Additionally, 46.1% prevalence was observed in Mitto district, Silte zone, which was lower than the findings of the present study [36] and a prevalence of 47.85% in India [37].

A lower prevalence of coprological results was recorded in the current study. This might be due to seasonal fluctuation on the prevalence of the disease. The study period in the current study was from December to March, which includes the dry and semidry seasons, but the wet season of the zone from March to October, in which a high prevalence was expected, was not covered under this study. In

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Variables	Categories	Number of examined	Number of positive	Prevalence (%)	95% CI
Corr	Male	303	104	34.32	29.16-39.87
Sex	Female	71	18	25.35	16.51-36.82
A	Adult	143	44	30.76	23.71-38.85
Age	Young	231	78	33.76	27.93-40.14
Body condition score	Good	84	11	13.09	7.36-22.22
	Medium	108	20	18.5	12.22-27.04
	Poor	182	91	50	42.74-57.25
. 1	Midland	282	100	35.46	30-41.2
Agroecology	Lowland 92 22	23.9	16.23-33.75		
2	Semidry	256	96	37.5	31.75-43.62
Season	Dry	118	26	22.03	15.41-30.46

TABLE 1: Prevalence of *H. contortus* with risk factors in sheep slaughtered in Jimma town municipal abattoir based on coproscopy (*n* = 374).

TABLE 2: Postmortem prevalence of *H. contortus* based on the hypothesized risk factors (n = 374).

Variables	Categories	Number of examined	Number of positive	Prevalence (%)	95% CI
Corr	Male	303	160	52.8	47.14-58.39
Sex	Female	71	39	54.92	43.17-66.15
A	Adult	143	77	53.84	45.59-61.89
Age	Young	231	122	52.81	46.33-59.2
	Good	84	21	25	16.83-35.43
Body condition score	Medium	108	27	25	17.68-34.08
	Male303Female71Adult143Young231Good84Medium108Poor182Midland282Lowland92Semi Dry256Dry118	151	82.96	76.75-87.78	
A	Midland	282	159	56.38	50.5-62.08
Agroecology	Lowland	92	40	43.47	33.66-53.82
0	Semi Dry	256	150	58.59	52.42-64.5
Season	Dry	118	49	41.52	32.93-50.6

TABLE 3: Test agreement between coprological and postmortem examination.

		Postmor	Tatal	
Examination type		Positive	Negative	1 otal
Coprological result	Positive	122	0	122
	Negative	77	175	252
Total		199	175	374

Kappa =0.5972.

the cool tropical environment of Ethiopia, [38] recovered a large number of Haemonchus parasites from small ruminants during the wet season. Similarly, peak infection rates of parasites were reported during the rainy season and a lower infection rate during the dry season of the year [39]. Moreover, a survival technique developed by the parasite (hypobiosis) may also result in lower prevalence during dry or semidry seasons. The inhibition of larvae ingested in autumn and winter appears to be an evolutionary adaptation that favors the parasite by delaying the egg-laying phase of the life cycle until after winter, when a higher proportion of eggs will be able to develop and complete their life cycles. Furthermore, fecal samples in the present result were collected from animals brought to the abattoir for slaughter. Animals brought to abattoirs for slaughter are relatively well fed as compared to the rest of the population. Poorly fed animals are more susceptible and carry more worm burdens due to their failure to overcome infection [40].

The current result agreed with the 33.1% prevalence reported by Abera [14] and 31.5% finding by Diba et al. [41]. However, it was higher than the reports of 26.8% [42] and 1.03% [43], the 2.3% prevalence from Somaliland [44], and the finding of Yimer and Birhan [45] and much higher

Variables	Categories	NEA	Prev. (%)	Univariable			Multivariable		
v al lables		INLA		OR	95% CI	p value	OR	95% CI	p value
Corr	Male	303	52.8	ref	ref		_	_	_
Sex	Female	71	54.92	1.08	0.64-1.83	0.7	—	—	
A	Adult	143	53.84	1.04	0.68-1.58	0.84	_	_	_
Age	Young	231	52.81	ref	ref		—	—	—
Agroecology	Midland	282	56.38	1.68	1.04-2.7	0.032	1.68	1.04-2.7	0.032
	Lowland	92	43.47	ref	ref		ref	ref	
Season	Semi Dry	256	58.59	1.99	1.27-3.1	0.002	1.99	1.27-3.1	0.002
	Dry	118	41.52	ref	ref		ref	ref	

TABLE 4: Logistic regression output of risk factors for Haemonchus infection.

NB: NEA = number of examined animals, Prev. = prevalence, OR = odd ratio.

than the result of Tesfaye [46], who recorded a 7.43% prevalence of the parasite from the southern Omo zone of southwestern Ethiopia. Various researchers have reported different prevalence rates of ovine hemonchosis in different geographical areas, which may vary from country to country and even within a country.

The variations in the prevalence of hemonchosis in sheep in different parts of Ethiopia and different countries are attributed to different factors, such as environmental factors (e.g., geoclimatic factors), sample size, host factors (e.g., natural resistance) [47], and the standard of management (e.g., habits of anthelmintic usage and nutrition) [48], which influence the development, distribution, and extended survival of the infective larval stage of the parasite [49].

In the present study, postmortem examination revealed an overall prevalence of 53.2%. This result was in line with a report from the Bahir Dar municipal abattoir with a prevalence of 56.25% [9], a report from Benin with a prevalence of 55.56% [50], and a prevalence of 53.4% outside of Ethiopia [51]. Similarly, it was in agreement with the findings that reported 57.18% prevalence from the Mojo Luna export abattoir [52] and 52.6% prevalence from the Abergelle export abattoir [53].

Conversely, the prevalence was lower than the 96.5% prevalence in an arid and semiarid zone of eastern Ethiopia [32], 91.2% prevalence in the Ogaden region in sheep slaughtered at Debrezeit Elfora abattoir [54], 90.1% from Haramaya municipal abattoir [33], 67.2% in Mitto District, Silte Zone [36], 86.9% from Debre Zeit [55], 80.2% in Gondar town [49], and 77.38% in Debre Zeit, Hemex export abattoir [56].

In addition, the findings of the present study were lower than the 77% prevalence in Kenya [57], 78% in Heilongjiang [58], and 80.64% in Pakistan [59]. This finding is lower than a similar study that reported an overall prevalence of 78.1% in Bishoftu town [60]. A prevalence of 77.7% was observed in Jehangirabad district, Pakistan, which was higher than the result of the present study [61]. This was still low compared to the occurrence reported in other countries: 82% in Togo, 94% in the Middle East, 58% from Bangladesh, 55.56% from Benin, and 76.92% from India [62]. However, the current finding was higher than a previous study that reported 33.1% in Jimma town [14] and 40.9% in Wukro, Ethiopia [63]. Similarly, this finding was higher than the report from Abergelle export abattoir, with a prevalence of 26.8% [42] and a prevalence of 1.03% from Finote Selam, which was again lower than the result of the present study [43]. Outside Ethiopia, a prevalence of 7.9% was reported in Egypt [64]. The variation in postmortem results might be attributed to the difference in distribution of the parasite and level of inspection during postmortem examination.

According to the present study, agroecology was revealed as a potential risk factor, and the highest prevalence was recorded in sheep originating from the midland, which was 56.38%, followed by the lowlands, with a prevalence of 43.47%, with a statistically significant difference between agroecosystems (p < 0.05). This study disagrees with a previous study that reported a higher prevalence in lowlands than in highlands and midlands [65], and other findings reported a higher prevalence in lowland areas than in highlands [34, 47]. The present study revealed that the prevalence of H. contortus was significantly different among animals originating from different agroecological zones (AEZs) of the study area. The significant association observed between the AEZ and the prevalence of H. contortus might be due to geographical and AEZ climatic variability, the number of animals included in various AEZs, and the management practices adopted locally [66].

Because these regions have higher rainfall, higher humidity, and moderate temperatures that are appropriate for the fecundity and epidemiology of gastrointestinal nematodes, the parasite is more prevalent in dry-humid and humid zones [67]. The low prevalence in the lowlands was illustrated by [66], who stated that the low prevalence of nematodes in arid zones (lowlands) might be attributed to the fact that these areas are extremely hot and receive scarce, erratic rainfall, which is unfavorable for nematode development, survival, and transmission. This contradicting result of the present study on the parasite prevalence on an agroecological basis might be related to the parasite's adaptation to different temperature and humidity ranges. Haemonchus species prefer hot, humid environments [24]. This difference could also be because sheep in the area were managed under an extensive management system with high stocking density, where large numbers of animals graze together throughout the year in communal grazing land, which can lead to more

contamination of the pasture by eggs and then increase the number of worms spread on a pasture [68].

Seasonally, there was a statistically significant difference between the prevalence of *H. contortus* and the season of inspection (p < 0.05). The highest prevalence was observed in the semidry season (58.59%) and started to decline from the mid-semidry season, and the lowest prevalence was recorded in the dry season (autumn), which was 41.52%. This finding agrees with the previous work that reported significant differences (p < 0.05) during two seasons (wet and dry) of the year [65]. This seasonal variation in the results of the present study was similar to studies in other tropical countries with distinct rainy and dry seasons [69]. It was also supported by findings with minimum and maximum infection rates of 24.00% in a very dry month and 72.00% in a very wet month, respectively [37].

The result was still comparable with the report that described the highest prevalence of hemonchosis during the wet season of the summer months, followed by spring and winter, while it was the lowest during autumn, which is the driest season [70], and a report of a higher infection rate in the wet season followed by late rainy and dry seasons, respectively, by Josiah et al. [71]. The previous finding that reported the highest rates of infection in the wet season (36.36%), followed by the semidry season (32.37%), and the lowest prevalence in the dry season (2.73%) [72], was also in line with the present study. Similarly, the report with a prevalence of H. contortus of 75%, 67%, and 60%, corresponding to wet, humid, and warm dry seasons, respectively, fits the results of the present study [73]. The other study showed a high prevalence of the parasite in the wet season, followed by the semidry and dry seasons, which was still in agreement with the results of the present study [74]. These findings are consistent with those of reports by Vlasoff et al. [75], Nginyi et al. [76], Shahadat et al. [77], Khajuria and Kapoor [78], Lateef et al. [79], Keyyu et al. [80], and Nwosu et al. [81]. They reported that the high biotic potential of H. contortus results in its rapidly assuming dominance at times when environmental conditions on pasture are favorable for the development and survival of the freeliving stages. They reported a high prevalence and seasonal abundance of eggs and adult stages of Haemonchus parasites in sheep and goats during the hot, humid season. From the results, it was shown that environmental conditions during the semidry season were quite favorable for the development and completion of the H. contortus life cycle, which corresponded with the rainfall pattern in the study area during the study time. The management system operated by most small ruminant owners, especially during the rainy season when animals are confined to avoid damage to crops, influences the prevalence. Consequently, such animals are overstocked because the pens are not properly cleaned.

These factors, along with the high humidity during the rainy season, predispose them to parasitic infections [71]. The observed gradual decline in the infection prevalence might be attributed to the lower survival of eggs and preinfective larvae (L1, L2) on pasture due to less moisture and dry conditions. Based on a 53.2% prevalence of ovine hemonchosis in the current study, the annual financial loss from the direct and indirect effects of hemonchosis during the study period was estimated at 358,591.58 ETB. This result is very high when compared with the work that found a loss of 2,868 rupees in India, which became 1,892.88 Ethiopian birr [82], and the result that reported 325.33 rupees (214.71 ETB) [83]. The difference that resulted might be due to variations in the distribution of the parasite. The estimated financial losses become higher when all the direct and indirect losses associated with the disease are included. *H. contortus*, an important, voracious blood-sucking parasite of small ruminants, causing major economic losses worldwide and heavy burden of this blood feeding parasite causes anemia, diarrhoea, loss of weight, edema, recumbence, severe debility, and ultimately death [24, 47, 84].

5. Conclusion and Recommendations

The current study's results revealed that hemonchosis is a serious disease in the study area, putting animal breeders at a high risk of incurring losses as a result of the parasite's impacts, with an estimated prevalence of 53.2%. The parasite-affected animals originated from midland areas more frequently, and the infection rate was high during the semidry season when compared with the dry season due to sufficient rainfall throughout the aforementioned season. These high frequencies of occurrence, along with the parasite's highly significant pathogenic effect, cause a major economic loss to the small ruminant sector of agriculture, which is crucial for the sector of the research area's livelihood. According to this study, the disease results in an estimated enormous annual financial loss. The indirect effect of the parasite due to a decrease in carcass weight caused the most loss. The animals that originated in midland areas need due attention when designing control programs against the parasite. A study that focuses on economically important gastrointestinal nematodes with an emphasis on the most important risk factors should be conducted to design an appropriate control and prevention strategy. Furthermore, regular deworming should be practicable on the basis of scientific findings, especially climatic conditions, with a major emphasis on the start of the dry season and prolonged rain to remove persisting hypobiotic larvae.

Data Availability

The analyzed data during this study will be provided on request from the corresponding author (teshitae2602@gmail.com).

Ethical Approval

The study protocol was approved by Research Ethics and Review Committee of the Wolaita Sodo University, with a reference number WSU 41/22/2241. The best practices for veterinary care were followed, and those who owned the farms were informed of the objective of the research and that the protocol had been approved.

Consent

All the authors have read the final text and agreed to submit the manuscript in its present form. All animals' owners gave their informed consent for inclusion before they participated in the study, and the verbal informed consent process is documented in the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

FZ and TEB were responsible for the conception, study design, execution, acquisition of data, analysis, and interpretation and drafted, revised, or critically reviewed the article. TSM drafted, revised, or reviewed the article; all authors took part in drafting, revising, or critically reviewing the article, gave final approval of the version to be published, have agreed on the journal to which the article has been submitted, and agree to be accountable for all aspects of the work.

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