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Endoparasitic diversity in goats: An analysis of single and co-infections associated with diarrhoea

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Abstract
This study investigated the diversity of gastrointestinal parasites associated with diarrhoea in goats presented at a veterinary facility. Goats, vital to our rural economy, faces health and productivity challenges due to gastrointestinal parasite infections, resulting in the economic losses. Various gastrointestinal parasites affect goats, causing productivity decline. Parasitism involves host, parasite, and environmental factors. The study aims to describe gastrointestinal parasite diversity in goats with diarrhoea through faecal examination and identification. A total of 112 faecal samples with a history of diarrhoea were examined, and 76.78% showed evidence of endoparasitic infections. The most prevalent parasites were *Strongyle* (51.6%), *Eimeria* spp. (47.3%), *Strongyloids* spp. (24.08%), *Trichuris* spp. (15.48%), *Balantidium* spp (1.72%), and *Moniezia* spp. (5.16%), respectively. Young goats (73%) and females (60%) exhibited higher infection rates. Mixed infections were predominant, accounting for 60.47% of the cases. The study highlights the critical role of *strongyles*, as well as significant prevalence of *Eimeria* spp. and *Strongyloides* spp. Regular screening and targeted treatment for gastrointestinal parasites in goats are essential to mitigate productivity losses. However, further research using more precise diagnostic tools and larger sample sizes is needed to improve species-specific identification.

Keywords: Gastrointestinal parasites, diarrhoea, prevalence, *Eimeria*, *Strongyle*, *Trichuris*, *Balantidium*, *Strongyloids*, *Moniezia*

1. Introduction
Goats play a crucial role in rural economy due to their high reproductive rate, affordable purchase cost, adaptability to harsh environments and low-quality diets (Mellado, 2008; Edosomwan and Shoyemi, 2012) [41]. However, their health and productivity are often compromised by infections with gastrointestinal (GI) nematodes, leading to significant economic losses in small ruminant production (Baker, 2001; Suarez *et al.*, 2009; Coop and Kyriazakis, 2001) [5, 65, 15]. A wide range of GI parasites, including protozoa, trematodes, cestodes, and nematodes, affect goats (Paul *et al.*, 2016) [49]. The primary GI parasites causing productivity loss in goats include *Haemonchus*, *Trichostrongylus*, *Oesophagostomum*, *Strongyloides*, *Trichuris*, hookworm, *Moniezia*, *Paramphistomum*, *Fasciola*, and *Schistosoma* (Dey *et al.*, 2020; Hossain *et al.*, 2021; Yasin *et al.*, 2021) [19, 30, 73]. *Eimeria* spp., which cause either a clinical or subclinical form of coccidiosis, are prevalent worldwide and particularly affect young animals under stress, leading to enteric disease and, in severe cases, death (Chandra *et al.*, 2022; Kim *et al.*, 2018) [11, 36]. The acute illness in sheep and goats is characterized by symptoms such as diarrhoea, anemia, reduced weight gain, weakness, edema in the lower parts, decreased productivity, and occasional mortality (Soulsby *et al.*, 1982) [64]. Changes in parasite levels can lead to alterations in animal health products, thereby impacting the global livestock system (Rushton and Bruce, 2017) [53]. Parasitism is the result of the interplay between host factors, parasite factors, and environmental factors. Numerous studies have highlighted the critical role of host age, sex, body condition, housing facilities, medication, and grazing provisions in this interaction (Dey *et al.*, 2020; Nath *et al.*, 2011; Rabbi *et al.*, 2013; Chakrabortty *et al.*, 2023) [19, 45, 51, 10]. This study aimed to describe the diversity of GI parasites in goats associated with diarrhoea that visited a veterinary facility.

Materials and Methods

Study design and sample collection

The investigation was conducted at the Referral Veterinary Polyclinic and Teaching Veterinary Clinical Complex (RVP-TVCC) of the Indian Veterinary Research Institute (IVRI) in Izatnagar, Uttar Pradesh. The study focused on caprine patients which were brought to the outpatient department (OPD) of Medicine at RVP & TVCC. Faecal samples were collected from goats with a history of enteritis using a sterile swab (Sterile, Hiculture collecting equipment, Himedia, Mumbai, India) and placed in separate tubes. To maintain the cold chain, each sample was transported to the laboratory in an icebox. A total of 112 faecal samples were collected between July and December 2023. This rigorous process ensured the integrity and reliability of the samples for the study.

Faecal Examination

In this study, both the sedimentation method and the floating concentration method were employed for stool investigation. Saturated zinc sulphate ($ZnSO_4$), with a specific gravity of 1.34 g/cm^2, was used as the flotation solution. This approach facilitated the investigation of helminth eggs and/or protozoa present in the faecal samples.

Identification of Parasites

All the samples in this study were meticulously examined under a light microscope at magnifications of 40x, 100x, and 400x. This allowed for a detailed investigation of parasitic stages such as cysts, oocysts, trophozoites, eggs, and larvae. The identification of these stages was carried out following established literature (Taylor *et al.*, 2016; Chartier and Paraud, 2012) [68, 12] (Figure 1).

Data Analysis

A descriptive analysis was conducted on the collected study data. By dividing the total number of infected by the total number of collected faeces and multiplying the result by 100, the prevalence was computed.

Results

The study on the diversity of endoparasites associated with diarrhoea in goats revealed a variety of single and co-infections. Out of the collected diarrhoeal faecal samples 112 samples were screened in which 86 tested positive for various endoparasitic infections. Single infections accounted for approximately 39.53% of the positive cases. However, co-infections were more prevalent, accounting for about 60.47% of the cases. The co-infections included combinations of various parasites such as *Eimeria* spp.+*Strongyle*+ *Strongyloides* spp. +*Trichuris* spp. (2.32%), *Eimeria* spp.+*Strongyle*+ *Strongyloides* spp. (11.6%), *Eimeria* spp.+*Strongyle*+ *Trichuris* spp. (3.48%), *Eimeria* spp. +*Strongyle*+ *Monezia* spp. (5.81%), *Eimeria* spp+ *Trichuris* spp (4.65%), *Eimeria* spp. +*Strongyle* (18.6%), *Monezia* spp. +*Strongyle* (1.16%), and *Strongyle* +*Strongyloides* spp. (13.95%) (Table 1).

Among all the endoparasitic infections that were observed, the prevalence of *Eimeria* spp., Strongyle, *Trichuris* spp., *Balantidium* spp., *Strongyloid*s spp., and *Monezia* spp., were found to be 47.3%, 51.6%, 15.48%, 1.72%, 24.08%, and 5.16%, respectively (Figure 2). In terms of age, the study found that goats under one year of age had a higher prevalence of endoparasites (73%) compared to those over one year of age (27%) (Figure 3). This suggests that younger goats are more susceptible to these infections. Additionally, the study found a slightly higher prevalence of endoparasites in female goats (60%) compared to male goats (40%)(Figure 4). This could be due to various factors such as differences in exposure, immunity, or other biological factors. These findings underscore the diverse range of endoparasites associated with diarrhoea in goats and highlight the importance of regular screening and treatment to control these infections. It emphasizes the need for comprehensive parasite management strategies to improve the health and productivity of goats.

Discussion

Gastrointestinal parasite (GI) infestations pose significant challenges in the production of small ruminants, particularly in tropical and subtropical regions. These infestations can lead to substantial economic losses due to reduced food consumption, decreased weight gain, lower fertility rates, increased treatment costs, and higher mortality rates in heavily infested animals (Waller, 2006) [47]. In this study, the observed prevalence of GI infestations was 76.78%, which is comparatively lower than figures reported in other regions such as southern Rajasthan (82.97%) (Choubisa and Jaroli, 2013) [14], Durg (85.22%) (Pathak and Pal, 2008) [48], Poland (80.6%) (Gorski *et al.*, 2004) [26], Kathmandu, Nepal (87.25%) (Ghimire and Bhattarai, 2019) [25], West region of Cameroon (90.4%) (Ntonifor *et al.*, 2013) [46], Slovakia (95.9%) (Babja´k *et al.*, 2017) [4], West Indies (98%) (Chikweto *et al.*, 2018) [13], and Iraq (91.5%) (Hassan and Barzinji, 2018) [27]. However, it was higher than the prevalence recorded in Kashmir Valley (54.3%) (Tariq *et al.*, 2010) [67] and the Udgir area of Marathwada (51.89%) (Dappawar *et al.*, 2018) [17]. The discrepancies in these findings could be attributed to variations in deworming and management practices, seasonal fluctuations, host age and sex, as well as differences in altitude and climatic conditions (Daniel *et al.*, 2014; Gul and Tak, 2016) [16, 74]. The study found that compared to adult goats (26.74%), young goats (73.25%) had a higher prevalence of parasites. This is consistent with findings from Assam, Nagpur, and Hyderabad, which also reported a higher frequency of parasite infection in kids (Talukdar, 1996; Pundlikrao, 2009 and Shashank *et al.*, 2019) [66, 50, 57]. This higher prevalence in young goats could be due to factors such as a weaker immune system, overcrowding, susceptibility to infection, and inadequate hygiene standards on farms (Singh *et al.*, 2015; Shashank *et al.*, 2019) [59, 57]. Likewise, it was shown that female goats (60.5%) had a greater infection rate than male goats (39.53%). Comparable results were found by Khajuria *et al.*, (2013) [34], who found that females had a greater prevalence of GI nematode infection (73.33%) than males (61.14%). Notwithstanding, Tariq *et al.*, (2010) [67] discovered no statistically significant variation in the prevalence of GI nematodes concerning the sex of the goats. The impact of sexual orientation on an animal's vulnerability to diseases may be explained by a combination of genetic predisposition and varying susceptibility due to hormonal regulation. In addition to other factors, the physiological characteristics of female animals, which typically act as stressors and lower their immunity to infections, also make them more vulnerable to infections because, as nursing mothers, they are often weak and malnourished (Blood and Radostitis, 2000; Mir *et al.*, 2013) [8].

The study also observed a high rate 84.8% of mixed GI parasite infection, with single infections accounting for

15.2%. Similar findings in India reported a 92% occurrence in mixed infestations and 8% in single infestations (Chikweto *et al.*, 2018) [13]. This may be attributed to the fact that having any one parasite species infestation increases the likelihood of multiple infections (Win *et al.*, 2020) [70]. Higher prevalence of *Strongyle* infestation was observed in goats, followed by Coccidiosis, Strongyloidiasis, Trichuriasis, and Monieziasis, with the least prevalence attributed to *Balantidium* infestation. Similar findings were reported by Anumol *et al.*, (2012) [3], Lata *et al.*, (2017) [37], and Sivajothi and Sudhakar Reddy (2018) [61]. Nematode infestation in goats can lead to stunted growth, clinical anemia, parasitic gastro-enteritis, weakness, weight loss, and a rough hair coat (Anugrah *et al.*, 2018) [75]. Factors contributing to the higher prevalence of GI parasitic infestation in goats include poor hygiene practices, contaminated feed and water, overcrowding, grazing in contaminated grasslands, prolonged use of the same deworming agent, and extensive rearing systems with the mixing of various age groups and sexes (Lata *et al.*, 2017) [37]. This study identified strongyle nematode eggs as the most prevalent type. We didn't conduct larval cultures for a complete diagnosis, grouping them under '*Strongyle*,' including *Haemonchus*, *Ostertagia*, *Trichostrongylus*, *Teladorsagia*, *Cooperia*, *Bunostomum*, and *Oesophagostomum*. Their prevalence was 52.46%, varying from 26.9% to 85.1% in different Indian states (Dixit *et al.*, 2017; Singh *et al.*, 2015; Verma *et al.*, 2018; Dappawar *et al.*, 2018) [21, 59, 71, 17]. These parasites exhibit a dilution effect across livestock species, with prevalence negatively linked to goat densities (Sun *et al.*, 2018) [76]. *Strongyle* infestation caused 7.4% of goat deaths, highlighting their critical role (Khakural, 2003) [35]. Among sheep (66%) and goats (89%), *Haemonchus contortus*, a *Strongyle*, led to a 29% mortality rate, emphasizing their importance for livestock health (Chikweto *et al.*, 2018) [13]. This study identified *Eimeria* as the second most prevalent species affecting the GI tract, leading to goat coccidiosis—a common enteric disease in goats (Hassan and Barzinji 2018; Kaur *et al.*, 2019) [27, 23]. This coccidian parasite can result in high mortality rates and a reduction in the production of milk, hair, or meat (Donkin and Boyazoglu, 2004) [22]. However, the disease may also exhibit subclinical features (Mohamaden *et al.*, 2018) [44]. The current prevalence rate (47.3%) was lower than that reported in previous studies from western Ukraine (100% as per Balicka-Ramisz *et al.*, 2012) [6], Southern Portugal (98.6% according to Silva *et al.*, 2014) [58], Punjab state in India (96.7% reported by Kaur *et al.*, 2019) [23], Kuala Terengganu, Setiu, and Besut (89.2% as per Mat Yusof and Md Isa 2016) [40], and higher than rates observed in the semi-arid region of India (81.07% according to Verma *et al.*, 2018) [71], Mathura (92.31% reported by Sharma *et al.*, 2009) [56], northern Jordan (54% as per Abo-Shehada and Abo-Farieha 2003) [1], Poland (76% as per Balicka-Ramisz *et al.*, 2012) [6], Iraq (42.2% in adults and 19.2% in kids according to Hassan and Barzinji 2018) [27], and Egypt (60% according to Mohamaden *et al.*, 2018) [44].

In cattle and small ruminants, *Strongyloides papillosus* is a common intestinal nematode that usually infects the small intestine during its female adult stages. In young animals, especially, this can result in malnutrition and diarrhoea (Thamsborg *et al.*, 2017) [70]. The *Strongyloides* egg, containing larvae, demonstrated a prevalence rate of 24.95%, surpassing the rates reported in Madhya Pradesh (9.17% according to Singh *et al.*, 2015) [59], the Udgir area of Marathwada (5.13% as per Dappawar *et al.*, 2018) [17], Jabalpur district of Madhya Pradesh (0.79% reported by Dixit *et al.*, 2017) [21], and Iraq (7.7% in kids and 8.9% in adults as per Hassan and Barzinji, 2018) [27].

Whipworm, scientifically referred to as *Trichuris* spp, is commonly present in the caecum and colon of various ruminants such as sheep, goats, and cattle worldwide. Despite being generally benign, clinical diseases attributable to *T. ovis* can also manifest in both sheep and cattle. *Trichuris* sp. was comprised of about 15. 48% prevalence which was higher than reported from South Gujarat (8.1%) (Sorathiya *et al.*, 2017) [63], from Meghalya (8.36%) (Das *et al.*, 2017) [77], Udgir area of Marathwada (3.24%) (Dappawar *et al.*, 2018) [17], and from Madhya Pradesh (3.85%) (Singh *et al.*, 2015) [59].

In our investigation, *Moniezia* species was the sole tapeworm identified, being an Anoplocephalid cestode affecting ruminants and transmitted by various oribatid mite species in tropical regions (Diop *et al.*, 2015) [20]. The presence of *Moniezia* eggs likely correlates with the abundance of diverse oribatid mite species in India (Mandal *et al.*, 2019) [39]. Our findings revealed a 5.16% prevalence of *Moniezia* in goats, which was lower than reported rates in Meghalaya (10.04% as per Das *et al.*, 2017) [77], Jammu & Kashmir (9.44% according to Bihaqi *et al.*, 2017) [7], and southern Rajasthan (6.98% as reported by Choubisa and Jaroli, 2013) [14]. Transmission occurs through the ingestion of pasture mites infected with larvae. While *Moniezia* is generally considered non-pathogenic, postmortem reports in Nepal linked 13.95% of goat deaths to monieziasis (Khakural, 2003) [35], suggesting potential consequences of coinfection (Maity *et al.*, 2018) [38]. However, the low prevalence of *Moniezia* eggs may be attributed to the fecal floatation examination's limited sensitivity in detecting Cestode ova (Roepstorff and Nansen, 1998) [52].

In tropical and subtropical climates, *Balantidium coli(B.coli)* is common and causes infectious illnesses in ruminants (Ho-Seong, 2006) [29]. Even though it usually lives in the large intestine of animals that appear to be in a healthy condition, clinical illnesses can sometimes appear when immunity is weak (Samad, 1996) [54]. Hyaluronidase is an enzyme that *B. coli* may release, which increases the parasite's capacity to assault intestinal mucosa and cause enteritis (Temples and Lipenko, 1957) [69]. The prevalence rate of *Balantidium* in our study was 1.72%, higher than the rates found in studies conducted in Nepal (7.75%), Egypt (7.1%), Tanzania (4.8%) (Mhoma *et al.*, 2011) [42], Pakistan (3.46%) (Jamil *et al.*, 2015) [31], and Kenya (3%) (Kanyari *et al.*, 2009) [42]. This ciliate may cause inflammatory responses in the large intestine even though goats are not its native hosts (Hassell *et al.*, 2013) [28]. (Elmadawy and Diab, 2017) [24]. Additionally, these protozoa have zoonotic significance for humans (Slifko *et al.*, 2000) [62].

Table 1: The prevalence of endoparasites parasites in the screened diarrheic goats

Endoparasites		Number of positive	Prevalence (%)
Single infection			
	Eimeria spp.	15	17.44
	Strongyle	12	13.95
	Strongyloides spp.	5	5.81
	Balantidium spp.	2	2.32
Co infection			
Quadruple	*Eimeria* spp.+Strongyle+ *Strongyloides* spp. +*Trichuris* spp.	2	2.32
Tripal infection			
	Eimeria spp.+Strongyle+ *Strongyloides* spp.	10	1.62
	Eimeria spp.+Strongyle+ *Trichuris* spp.	3	3.48
	Eimeria spp.+Strongyle +*Monezia* spp.	5	5.81
Dual infection			
	Eimeria spp.+*Trichuris* spp.	4	4.65
	Eimeria spp.+Strongyle	16	18.60
	Strongyle +*Monezia* spp	1	1.16
	Strongyle+ *Strongyloides* spp.	11	13.95
Total		86	101.16

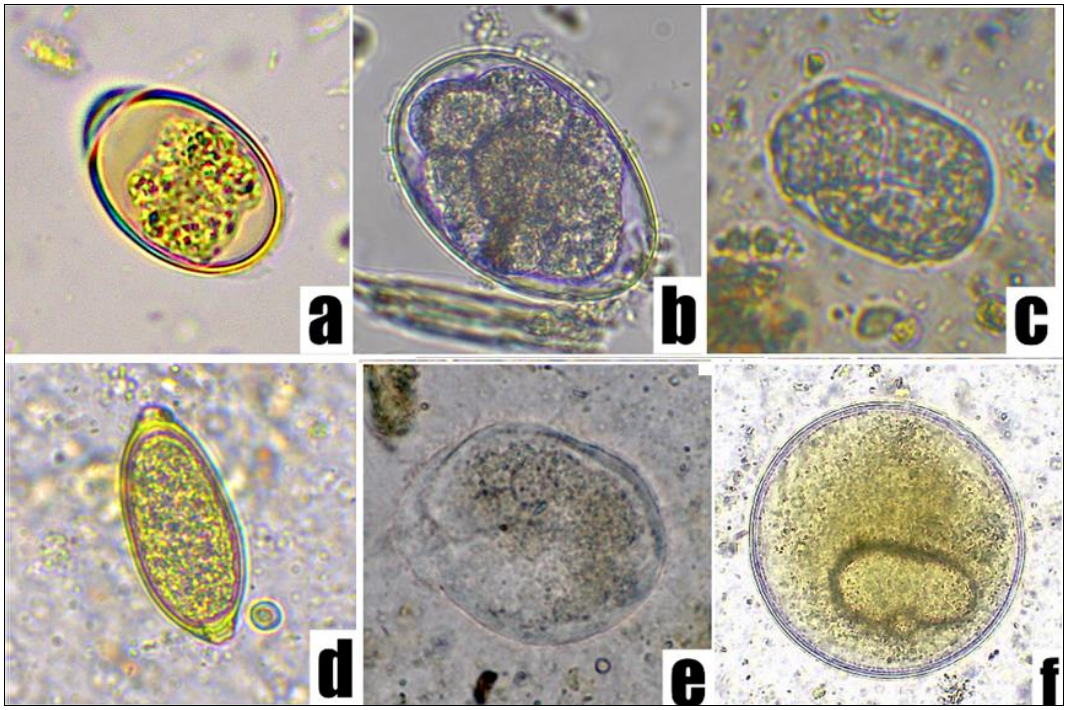

Fig 1: a) *Eimeria* spp. oocyst b) Strongyle egg c) *Strongyloides* spp. egg d) *Trichuris* spp. egg e) *Balantidium* spp. trophozoite f) *Balantidium* spp. oocyst.

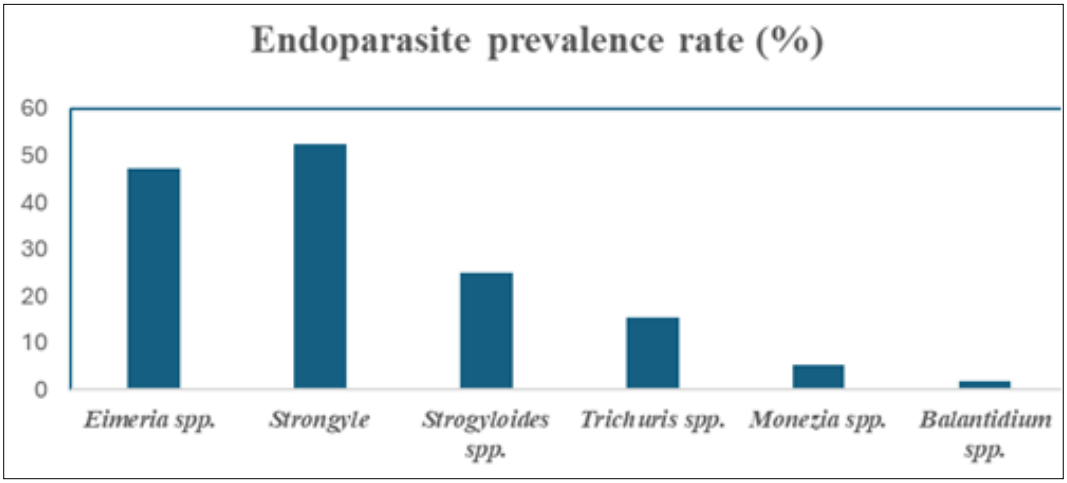

Fig 2: Overall prevalence of different endoparasites.

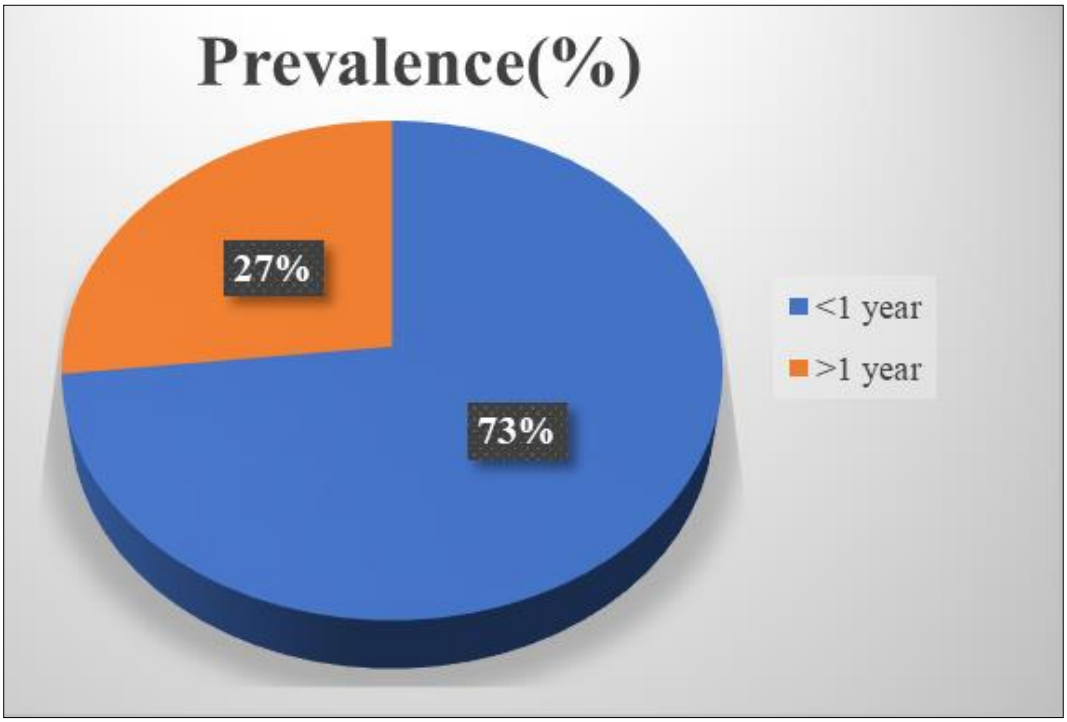

Fig 3: Age wise prevalence of endoparasites.

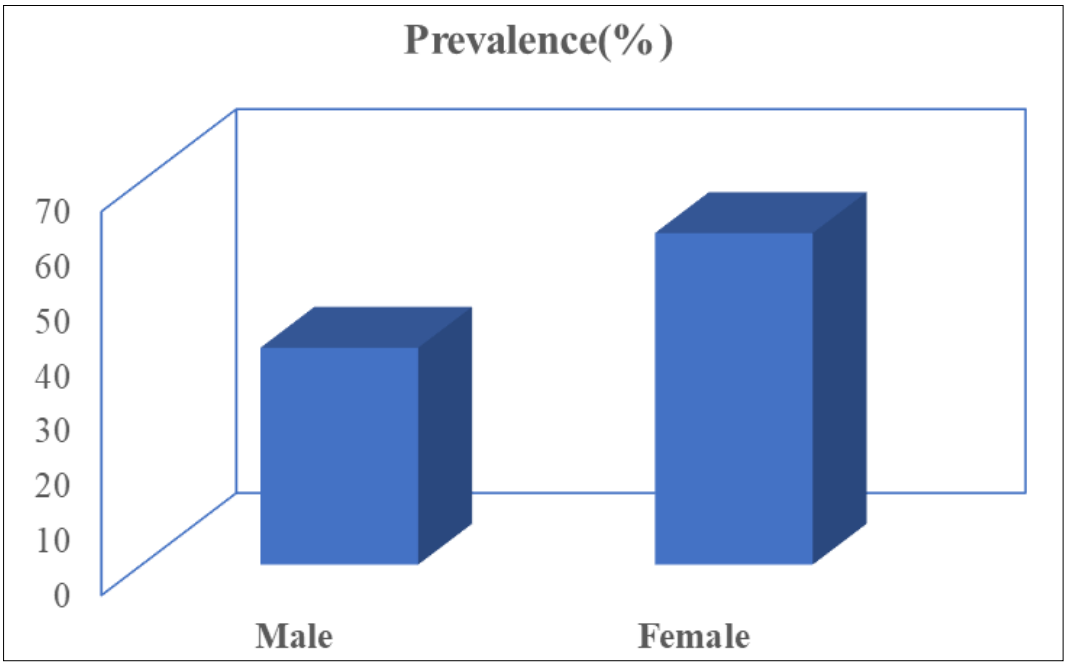

Fig 4: Sex wise prevalence of endoparasites.

Conclusion

In conclusion, the study highlights that goats brought to veterinary facilities from various parts of the country carry a high burden of gastrointestinal parasites. This poses a risk of increased morbidity and mortality. While some of these parasites may not lead to pathological consequences, the study emphasizes the critical role of anthelmintics in managing these parasitic infections. However, it's important to note that this study has its limitations. Copro-microscopy was the only method used for parasite detection, which makes species-specific identification challenging in many cases. Therefore, for a more comprehensive investigation of parasitism, further research involving a larger population and more precise diagnostic tools is recommended. This will help in better understanding the prevalence and impact of these parasites and in developing more effective strategies for their management.

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