Beni-Suef University Journal of Basic and Applied Sciences

RESEARCH

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Prevalence and associated risk factors of gastrointestinal helminths and coccidian infections in domestic goats, *Capra hircus*, in Minya, Egypt

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Abstract

Background Helminth and coccidian infections are among potential parasitic infections in the livestock production. The present study aimed to determine the prevalence and intensity of gastrointestinal helminths as well as *Eimeia* species in domestic goats.

Results The overall prevalence of parasitic infections was 50.24% (206/410). Twenty two species of helminth eggs/*Eimeria* spp. oocysts were revealed. The prevalence of helminths was 21.95% (90/410) and that of *Eimeria* spp. was 39.27% (161/410). Mixed infection was reported in 10.98% (45/410). The highest prevalence was found in young animals (75.0%; 60/80) followed by yearlings (58.46%; 76/130) and the lowest one was in adults (35.0%; 70/200). The infection rate was higher in females (59.02%; 180/305) than males (24.76%; 26/105). The prevalence was mostly highest in summer (63.85%; 83/130) followed by winter (57.78%; 52/90), autumn (40.0%; 28/70) and the lowest one was in spring (35.83%; 43/120). Age, sex and seasonal variations revealed significant ($P \leq 0.05$) differences among examined goats. The infection with both nematodes and *Eimeria* spp. were detected in 7.32% (30/410). The co-infection with *Eimeria* spp. and tapeworms were found in 2.93% (12/410). Both trematodes and *Eimeria* spp. were seen in 0.73% (3/410) of examined specimens. Nine *Eimeria* species were recorded; *Eimeria ninakohlyakim-ovae*, *E. hirci*, *E. caprinova*, *E. caprina*, *E. christenseni*, *E. jolchijevi*, *E. arloingi, E. apsheronica* and *E. alijevi*. The most predominant *Eimeria* species was *E. arloingi* (23.17%; 95/410) and the least abundant one was *E. apsheronica* (0.73%; 3/410). The revealed trematodes were *Fasciola* spp. (0.49%) and *Paramphistomum* spp. (0.24%). Among cestodes, tapeworms belonged to Anoplocephalids included *Moniezia* spp. (7.31%) and *Avitellina* sp. (0.49%) were detected. Meanwhile, coproculture revealed that the prevalence of nematodes infection was 13.41% (55/410) including nine species; *Chabertia ovina*, *Ostertagia ostertagi*, *Haemonchus contortus*, *Trichostrongylus axei*, *T. colubriformis*, *Bunostomum* sp., *Cooperia oncophora*, *Cooperia curticei* and *Strongyloides* spp.

Conclusion In the present study, the prevalence of helminths was 21.95% and that of *Eimeria* spp. was 39.27%, which is considered a high infection rate. Accordingly Strict hygienic measures as well as regular deworming are highly recommended to avoid wide spread of both helminth and coccidial infections.

Keywords Helminths, Fecal culture, Prevalence, Goats, *Eimeria*

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1 Background

Small ruminant production is considered one of the principle sectors in the food supply chain. The great increase in the population and its demands for livestock products were the main propel of the development of small ruminant intensive production system in Egypt [1]. In developing countries, small ruminants engage an important niche for sustainable agriculture and support a variety of socioeconomic functions worldwide [2].

Goats, *Capra hircus*, are one of the most beneficial livestock. In Egypt, the development of rural areas could be realize depending on sheep and goats which is deemed as one of the most hopeful animals to fulfill the aims of meat production supplies for the humans [3, 4]. They are one of the important sources of animal protein mainly in the Arabian Countries.

Goats deem very beneficial in many industrial productions. They are used in ceremonial festivities as well as the production of cashmere and mohair fibers [5]. Such animals have very important medical purposes as they are used a source of preparation of human and animal vaccines, manufacturing of medical surgical threads from the small intestine and the formation of manure fertilizers for soil from their fecal pellets [4].

Parasitism is a challenge to the animal health worldwide resulting in economic losses [6]. High prevalences of nematodes, trematodes, cestodes, and protozoan infection have occurred among ruminants in most countries [7, 8] Helminthiasis, particularly parasites, causes gastroenteritis, is a serious health threat that affect the productivity of small ruminants due to the associated morbidity, mortality, cost of treatment and control measures [9]. Nematode parasites affect the animal productivity showing stunted growth, decrease weight gain and poor feed utilization [10]. Gastrointestinal parasites cause mortalities, production loss, and weight loss in small ruminants, thereby impeding their production system. Small ruminants constitute a significant portion of livestock in a country [11–13].

Goats reared under intensive production system are at great risk of *Eimeria* spp. infection [2, 14]. Coccidiosis is one of the highly prevalent parasitic diseases of goats all over the world [15, 16]. This disease results in economic losses due to high mortality and morbidity, poor growth and treatment costs [17, 18]. Coccidiosis occurred by intestinal protozoan parasite of the genus *Eimeria* [19–21]. Caprine coccidiosis caused by protozoa of the genus *Eimeria* is one of the foremost parasitic diseases affecting goats [22, 23].

Coccidian parasites of the genus *Eimeria* cause an enteric disease especially in young or stressed goats under poor farm management with a high mortality in goat kids [24, 25]. Clinical signs of coccidiosis comprises diarrhea, weight loss, anorexia and dehydration. Awareness of the inherent aspects of the disease is important in defining the appropriate preventative measures [26, 27].

Helminths and coccidia are mentioned to be the most common and important gastrointestinal parasites in small ruminants. In the tropics, the most important nematode species affecting small ruminants are *Haemonchus contortus*, *Trichostrongylus* species, *Nematodirus* species, *Cooperia* species, *Bunostomum* species and *esophagostomum* species [28, 29]. Parasitism in goats is a principle cause of lowered resistance, loss of production and even mortality. The present study was conducted to evaluate prevalence of *Eimeria* species and helminths in goats relative to various risk factors.

2 Methods

2.1 Study area and animals

Fresh fecal specimens were collected from 410 goats of various ages and genders allocated sporadically in small flocks kept in households in rural areas (average 7–20 animals/flock) owned by farmers in several districts of Minya province (coordinates: 28°07′10″ N 30°44′40″ E), Egypt during the period from October 2020 to September 2021. The age of animals was categorized as less than one year, one year and 2–5 years.

2.2 Specimens collection and laboratory examination

Fecal samples were collected directly from the rectum by using sterile disposable gloves. After labeling, containers were transported via cool box dry ice packs to the laboratory of Parasitology, Faculty of Veterinary Medicine, Beni-Suef University, Egypt. These were kept at 4 °C in a refrigerator until used. Fecal samples were parasitologically examined by the use of standard flotation technique to demonstrate oocysts of *Eimeria* spp and helminth eggs. As follows: Approximately 5 g feces from each animal were well mixed with 10 ml of fully saturated salt solution in a plastic cup. The mixture was strained through a tea strainer to discard the fecal debris. Then, the solution was poured into a 15 ml centrifuge tube then the flotation solution was added to the tip of tubes which were closed with cover slips. Tubes underwent centrifugation at 3000 rpm for 2 min and spinning, then, they allowed settling down. The flotation solution was added to the test tube till a reverse meniscus on the surface layer of this solution was formed, then clean dry cover slips were placed on the rim of tubes for 5 min then removed and examined microscopically using various magnifications. Sediments also were examined for trematode eggs [30, 31].

2.3 Fecal culture and harvesting larvae

The fecal samples were inform of pellets, so they were thoroughly crumbled before being mixed with water to produce more or less pasty mixture, which is slightly compacted, in a depth of about 5 cm in wide glass jars of approximately 1 L capacity. A hole is left in the center of the culture by holding a stamper vertically in the center of the jar, leaving the mixtures lightly compacted around it. The culture was sufficiently moistened to avoid dryness while being incubated, but without being waterlogged. Then, jars were incubated in the dark at 26–28 °C for 5–7 days, during which it was periodically checked and moistened if needed. After the end of the incubation period, the inside of the culture is slightly sprayed with water before being placed in bright light that stimulates third larval stages to migrate up the inner surfaces of the jars' walls. The culture was repeatedly harvested over several days by holding the jar sloped with the mouth pointing downwards and then spraying the inner walls and allowing the larval suspension to drain into suitable containers [32, 33].

2.4 Measurement of oocysts

The calibration of the microscope was done according to [34]. Briefly, using the low power of the compound microscope, the stage micrometer lines were brought into focus and adjusted the zero line of the stage micrometer to coincide with the zero line of the ocular micrometer. Another line on the ocular micrometer which exactly coincides with a second line on the stage scale was found. The number of spaces between the two lines was counted using the ocular scale and divided this number into the number of microns represented between the two lines on the stage (number of small spaces X 10 microns). Morphological characteristics (shape, size, color and existence or lack of micropyle and its cap) of the oocysts and sporocysts have been used to describe the coccidian oocysts species [2, 30, 35].

2.5 Larval identification

Morphological identification of parasitic neamtodes, is mainly dependent on the characterization of larval anterior and posterior ends, the whole larval length and the number of gut cells. The shape of the esophagus and the presence of anterior refractile bodies are needed for some species [33, 36]. Upon the identification of larvae, the tip of the anterior extremity of a larva is referred to as 'head' and the posterior extremity as 'tail' and the free sheath beyond the tail tip as the sheath tail extension (STE). The latter is a unique diagnostic feature for the accurate and appropriate identification of nematodal larvae.

2.6 Larval photographing

Available photographs of larvae were taken using a digital microscope (Leica microsystems, CH-9435 Heebrugg, Ec3, Singapore). Measurements of the recovered larvae were in micrometers [37].

2.7 Statistical analysis

Data were analyzed using a Microsoft Excel worksheet for Windows 2010. Data were summarized by descriptive statistics for the overall prevalence in sheep. The Chi-square test was used to analyze the effect of risk factors; age, sex and seasons, on the overall coccidian and helminth infections. Variables were significant at $P \leq 0.05$.

2.8 Results

The current study revealed that overall prevalence of parasitic infections was 50.24% (206/410). Twenty two species of helminth eggs/*Eimeria* spp. oocysts were revealed. The prevalence of helminths was 21.95% (90/410) and that of *Eimeria* spp. was 39.27% (161/410). Mixed infection was reported in 10.98% (45/410). The highest prevalence reported in young animals (75.0%; 60/80) followed by yearlings (58.46%; 76/130) and the lowest one was in adults (70/200; 35.0%). The infection rate was higher in females (59.02%; 180/305) than males (24.76%; 26/105). The infection rate was the highest in summer (63.85%; 83/130) followed by winter (57.78%; 52/90), autumn (40.0%; 28/70) and the lowest one was in spring (35.83%; 43/120). Age, sex and seasonal variations revealed significant ($P \leq 0.05$) differences among examined goats. The infection with both nematodes and *Eimeria* spp. were detected in 7.32% (30/410). The infection with *Eimeria* spp. and tapeworms were found in 2.93% (12/410). Both trematodes and *Eimeria* spp. were seen in 0.73% (3/410) of examined specimens. Nine *Eimeria* species were recorded; *Eimeria ninakohlyakim-ovae*, *E. hirci*, *E. caprinova*, *E. caprina*, *E. christenseni*, *E. jolchijevi*, *E. arloingi*, *E. apsheronica* and *E. alijevi* (Figs. 1 and 2). The most predominant *Eimeria* species was *Eimeria arloingi* (23.17%; 95/410) followed by *E. ninakohlyakim-ovae* (20.24%; 83/410), *E. alijevi* (9.76%; 40/410), *E. caprina* (3.66%; 15/410), *E. caprinova* (3.17%; 13/410), *E. hirci* (2.93%; 12/410), *E. jolchijevi* (1.95%; 8/410), *E. christenseni* (1.71%; 7/410). The least abundant species was *E. apsheronica* (0.73%; 3/410). The revealed trematodes were *Fasciola* spp. (0.49%) and *Paramphistomum* spp. (0.24%). Among cestodes, tapeworms belonged to Anoplocephalids included *Moniezia* spp. (7.31%) and *Avitellina* sp. (0.49%) were detected. Meanwhile, coproculture revealed that the prevalence of nematodes infection was 13.41% (55/410) including nine species; *Chabertia ovina*, *Ostertagia ostertagi*, *Haemonchus contortus*,

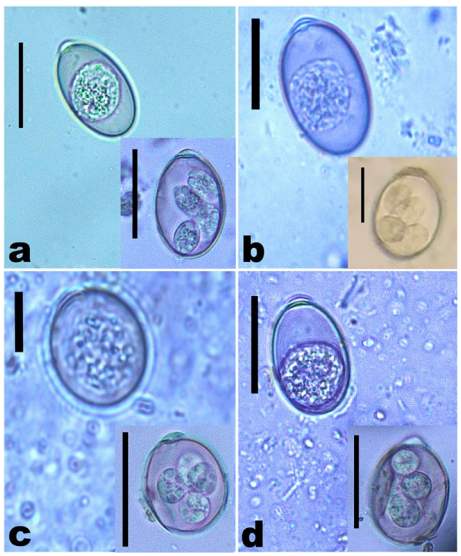

Fig. 1 Morphology of 4 *Eimeria* species recovered from examined goats. **a** *Eimeria arloingi* unsporulated oocyst. Note a distinct micropyle and the polar cap is lid-like and easily dislodged. Scale bar = 25 µm. Inset: The sporulated oocyst has elongated sporocysts with broad ended sporozoites. Scale bar = 25 µm. **b** *Eimeria christenseni* unsporulated oocyst. Note a distinct micropyle and polar cap. Scale bar = 20 µm. Inset: The sporulated oocyst has ovoid sporocysts with broad ended sporozoites Scale bar = 20 µm. **c** *Eimeria hirci* unsporulated oocyst Note a spherical oocyst with a distinct micropyle and polar cap. Scale bar = 10 µm. Inset: The sporulated oocyst has rounded sporocysts and each has two vacuoles. Scale bar = 25 µm. **d** *Eimeria jolchijevi* unsporulated oocyst. Note a distinct micropyle and polar cap. Scale bar = 25 µm. Inset: The sporulated oocyst has rounded/ovoid sporocysts. Scale bar = 25 µm

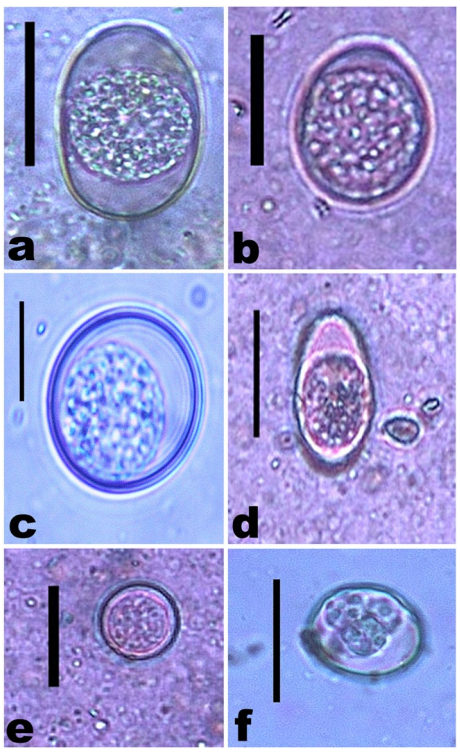

Fig. 2 Morphology of 5 *Eimeria* species recovered from examined goats. **a** *Eimeria caprina* unsporulated oocyst. Note an ellipsoidal-shaped, without a micropylar cap but has a distinct micropyle. Scale bar = 25 µm. **b** *Eimeria caprovina* unsporulated oocyst: The unsporulated oocyst was broad oval with amicropyle; without a micropylar cap. Scale bar = 25 µm. **c** *Eimeria ninakohlyakim-ovae* unsporulated oocyst. Note the lack of micropyle and polar cap (arrowhead). Scale bar = 10 µm. **d** *Eimeria apsheronica* unsporulated oocyst. Note ovoid-shaped oocyst, adistinct micropyle but no micropyle cap. Scale bar = 25 µm. **e** *Eimeria aljevi* unsporulated oocyst. Note the lack of micropyle and polar cap. The beginning of sporont division (arrow). Scale bar = 25 µm. **f** *Eimeria aljevi* sporulated oocyst. Note the lack of micropyle and polar cap. Scale bar = 25 µm

Trichostrongylus axei, *T. Colubriformis*,*Bunostomum* sp., *Cooperia oncophora*, *Cooperia curticei* and *Strongyloides* spp. (Figs. 3 and 4) The most predominant nematode was *Haemonchus contortus* (5.36%; 22/410) followed by *Trichostrongylus axei* (1.95%; 8/410), *Ostertagia ostertagi* (1.71%; 7/410), *Bunostomum* sp. and *Chabertia ovina* (0.98%; 4/410) for each, *T. Colubriformis* and *Cooperia curticei* (0.73%; 3/410 each). The least abundant nematodes were *Strongyloides* spp. and *Cooperia oncophora* (0.49%; 2/410 each).

Concerning the age, it has been recorded that goats aged less than one had the highest infection rate. Among those, a mixed infection was detected in 8.75% (7/80). Nematode helminths were identified in 3.75% (3/80). *Eimeria* spp. were detected in 75.0% (60/80), trematode parasites were reported in 1.25% (one/80) and tapeworms were recorded in 3.75% (3/80) of examined goats. Among animals aged one year, 10.77% (14/130) had tapeworms. A mixed infection was observed in 7.69% (10/130). Meanwhile, *Eimeria* spp. oocysts were revealed in 50.0% (65/130), nematodes were recorded in 5.38% (7/130). However, no trematodes were recorded. Goats aged 2–5 years had the lowest infection rate. Among those, nematodes were observed in 22.5% (45/200), mixed infection was found in 14.0% (28/200), *Eimeria* spp. oocysts were detected in 36/200 (18.0%), tapeworms were recovered in 7.5% (15/200) and trematodes were recorded in 1.0% (2/200) of examined goats. There was a significant difference of the total parasitic infections (Chi-square value was 13.5306 at *P* value 0.001153) (Table 1).

Regarding the sex, infection rates in male goats with helminths and/or *Eimeria* spp oocysts were 7.62% (8/105), 18.1% (19/105), 20.95% (22/105), 13.3% (14/105) and 0.95% (1/105) for nematodes, mixed infections, *Eimeria* spp. oocysts, tapeworms and trematodes, respectively. Moreover, prevalences in female goats were 15.4% (47/305), 8.52% (26/305), 45.57% (139/305), 5.9% (18/305) and 0.66% (2/305) for nematodes, mixed infections, *Eimeria* spp. oocysts, tapeworms and trematodes,

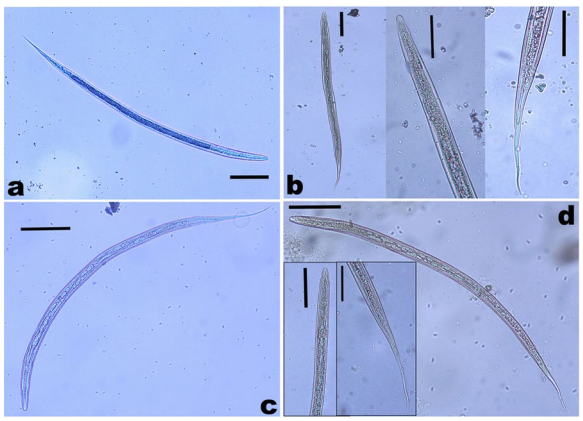

Fig. 3 Morphology of 4 harvested L3 recovered from examined goats. **a** *Trichostrongylus axei* larva. Note a straight larva with rounded head, simple tail and blunt terminal end. No filament and the gut had 16 intestinal cells. Scale bar = 100 µm. **b** *Trichostrongylus Colubriformis* larva. Left: The whole straight larva. Scale bar = 100 µm. Middle: Anterior end showing a rounded head and the gut had 16 intestinal cells. Right: Posterior end revealing no filament tail with 2–3 tubercles (bifid structure). Scale bar = 50 µm. **c** *Cooperia curticei* larva. Note a medium-sized larva with a square-shaped head. Head bearing two refractile oval bodies at anterior end of the esophagus. The caudal tip of the sheath finer tip and vanish into nothingness. Scale bar = 100 µm. **d** *Cooperia oncophora*. Note a medium-sized larva with a square-shaped head. Scale bar = 100 µm. Inset left: Note a head bearing two refractile oval bodies at anterior end of the esophagus. Inset right: Note the caudal tip of the sheath of *C. oncophora* is clearly perceptible. Scale bar = 50 µm

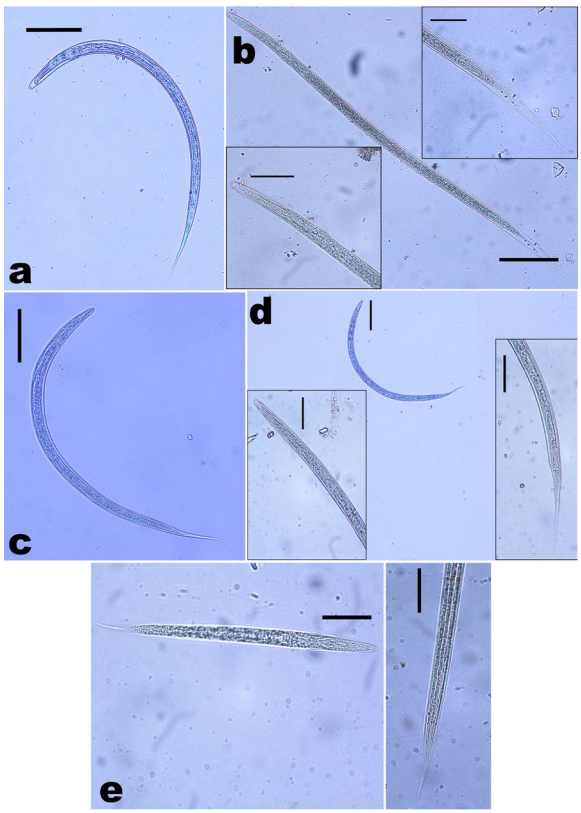

Fig. 4 Morphology of 5 harvested L3 recovered from examined goats. **a** *Bunostomum* sp. Note the head was bullet. The esophagus has a prominent bulb caudally and it had 16 intestinal cells. Scale bar = 100 µm. **b** *Chabertia ovina*. Note a long larva. Scale bar = 100. Inset lower: Note a square-shaped head with 28–32 rectangular-shaped intestinal cells. Scale bar = 50. Inset higher: Note a long thin tail sheath. The filament was medium-sized measuring 33 µm long (approximately 30% of the tail sheath long). Scale bar = 50. **c** *Haemonchus* sp. Note a medium-sized larva, bullet-shaped head with 16 alternating zigzag-shaped intestinal cells. The tail of the sheath tapers to end in a whip-like, medium-sized filament and usually kinked. **d** *Ostertagia ostertagi*. Note a medium-sized larva. Scale bar = 100. Inset left: Note a slight shoulder close to the anterior end (squarish appearance) with 16 intestinal cells. Inset right: The tail is rounded at its end with a short tail sheath (57.14 µm) and blunt tail tip without a filament. Scale bar = 50. **e** *Strongyloides* sp. Note a small slender short larva, measured 507.93 µm in length with uniquely very long esophagus extending nearly for 40% of the body length. Scale bar = 100 µm. Inset right: Note the absence of tail sheath and high magnification shows that the tail is bifid. Scale bar = 50 µm

respectively. Based on the sex, there was a significant difference of the total parasitic infections (Chi-square value was 14.35 at *P* value 0.000152) (Table 2).

Seasonal variation affect significantly on the parasitic infection that the highest prevalence was found in summer followed by winter, spring and lowest one was reported in autumn. In summer, *Eimeria* spp. oocysts were the highest (48.46%; 63/130), mixed infection was reported in 8.46% (11/1130), nematodes were seen in 13.85% (18/130), tapeworms were recorded in 9.23% (12/130) and trematodes were found in 0.77% (1/130). In winter, infection rates were 18.89% (17/90), 14.44% (12/90), 46.67% (42/90) and 6.67% (6/90), for nematodes, mixed infections, *Eimeria* spp. oocysts, tapeworms, respectively, no trematodes were recorded. In spring, infection rates were 10.83% (13/120), 10.83% (13/90), 28.33% (34/120), 6.67% (8/120), and 0.83% (1/120), for nematodes, mixed infections, *Eimeria* spp. oocysts, tapeworms and trematodes, respectively. In autumn, percentages of nematodes were 10.0% (7/70), *Eimeria* spp. oocysts 31.43% (22/70), tapeworms 8.57% (6/70), trematodes in 1.43% (one/70) and mixed infections 11.43% (8/70) (Table 3). Statistically, significant differences were detected in the total parasitic infection (Chi-square was 8.2618 at *P* value 0.0409). Morphological characteristics of recovered *Eimeria* spp. oocysts are illustrated in Table 4. As well, morphological features of the harvested L3 are mentioned in Table 5.

Table 1 The prevalence of helminths and/or coccidian oocysts in examined goats relative to the age

	Young goats (less than one year) ($n=80$)		Yearlings (1 year) ($n=130$)		Adults 2–5 years) ($n=200$)		X^2 P
	No	%	No	%	No	%	
Trematodes	One	1.25	–	–	2	1.0	13.5306 > 0.001153
Tapeworms	3	3.75	14	10.77	15	7.5	
Nematodes	3	3.75	7	5.38	45	22.5	
Protozoa	60	75.0	65	50.0	36	18.0	
Mixed infection	7	8.75	10	7.69	28	14.0	
Total	60	75.0	76	58.46	70	35.0	

P value is considered significant at > 0.05

$X^2 = Chi^2$

Table 2 The prevalence of helminth and/or coccidian oocysts in examined goats relative to the sex

	Males ($n=105$)		Females ($n=305$)		X^2 P
	No	%	No	%	
Trematodes	one	0.95	2	0.66	14.35 > 0.000152
Tapeworms	14	13.3	18	5.9	
Nematodes	8	7.62	47	15.4	
Protozoa	22	20.95	139	45.57	
Mixed infection	19	18.1	26	8.52	
Total	26	24.76	180	59.02	

P value is considered significant at > 0.05

$X^2 = Chi^2$

Table 3 The prevalence of helminths and/or coccidian oocysts in examined goats relative to the seasonal variation

	Autumn ($n=70$)		Winter ($n=90$)		Spring ($n=120$)		Summer ($n=130$)		X^2 P
	No	%	No	%	No	%	No	%	
Trematodes	One	1.43	–	–	One	0.83	One	0.77	8.2618 > 0.0409
Tapeworms	6	8.57	6	6.67	8	6.67	12	9.23	
Nematodes	7	15.0	17	18.89	13	10.83	18	13.85	
Protozoa	22	31.43	42	46.67	34	28.33	63	48.46	
Mixed infection	8	11.43	13	14.44	13	10.83	11	8.46	
Total	28	40.0	52	57.78	43	35.83	83	63.85	

P value is considered significant at > 0.05

$X^2 = Chi^2$

3 Discussion

The current study revealed that the overall prevalence of parasitism referred to coprological examination of domestic goats was 50.24% (206/410). Such result was lower than that given by [38].who revealed a prevalence of 96.38% in Giza, Egypt. Similarly, [Esayas [39], Tesfalem [40], Bayou [41], Yoseph [42], Genene [43], Getachew [44], Tefera et al. [45], Bikila et al. [46], Nuraddis et al. [47] from Jimma and from Illubabor, reported prevalences of 82.13%, 84.32%, 94.85%, 94.1%, 92.24%, 88.33%, 93.29%, 77.8% and 87.2%, respectively. Moreover, Asif et al. [48] found that the infection rate was 63.69%. Gadahi et al. [49] reported that 66.45% of examined goats had gastrointestinal parasites. Dabasa et al. [50] detected a prevalence of 79.6%. Kedir et al. [51] from south eastern Ethiopia, recorded an infection rate of 52.78% [13] found that the infection rate was 82.43% in goats in Pakistan. However, it was higher than that reported by Dagnachew

Table 4 Morphological characteristics of recovered *Eimeria* spp. Oocysts

Eimeria caprovina **(Fig. 2 b)**	***Eimeria Christensenis*** **(Fig. 1b)**	***Eimeria hirci*** **(Fig. 1c)**	***Eimeria ninakohlyakimovae*** **(Fig. 2c)**	***Eimeria jolchijevi*** **(Fig. 1 d)**	***Eimeria caprina*** **(Fig. 2a)**	***Eimeria aljevi*** **(Fig. 2f)**	***Eimeria aspheronica*** **(Fig. 2d)**	***Eimeria arloingi*** **(Fig. 1a)**
The unsporulated oocyst was broad oval-shaped, measured 28.57 × 22.22 µm, with a smooth two-layered wall, the outer is thick and colorless while the inner is thick and dark brown, with a micropyle; without a polar cap, no residual body, with 1–4 polar granules	The unsporulated oocyst was ellipsoidal- oval shaped, measured 33.7 × 22.22 µm, with a distinct polar cap, its wall is brownish in color, no residual body but has polar granule 26 µm in diameter. The shape index is 1.46	The unsporulated oocyst was spherical or ovoid-shaped, measured 25.3 × 19 µm, has a small pointed micropyle, polar cap, the wall is smooth & yellow in color, has a clear residual body. The sporulated oocyst has ovoid-shaped sporocysts and their sporozoite has a round vacuole in the middle	The unsporulated oocyst was ellipsoidal/ovoid in shape, measured 22.6 × 17.8 µm, with a smooth wall, colorless. Neither micropyle nor polar cap was present. It had a spherical sporont measuring 12–18 µm in diameter. The shape index was 1.3	The unsporulated oocyst was ovoidal -shaped, measured 30.15 × 20.63 µm with a distinct flat polar cap, yellow to reddish in color oocyst wall, no residual body. The sporulated oocyst has ovoidal shaped sporocysts, each sporocyst has two vacuolated sporozoites	The unsporulated oocyst was ellipsoidal-shaped, measured 33.3 × 20.7 µm, without a polar cap but has a distinct micropyle, the wall is greenish-yellow in color, has no residual body	The unsporulated oocyst is a small spherical oocyst, measured 17.5 × 15.9 µm no polar cap, has a smooth and colorless wall and no residual body. The sporulated oocyst has small ovoid-shaped sporocysts and each sporozoite has a central vacuole	The unsporulated oocyst is ovoid-shaped, measured 31.74 × 17.94 µm. has a distinct micropyle but no polar cap, a yellowish-brown wall and has a large residual body	The unsporulated oocyst was ellipsoidal-shaped, elongated, measured 29.5 × 17.4 µm, pale-yellowish in color, with a distinct micropyle, and the polar cap was a lid-like and easily dislodged. It had a spherical-shaped sporont measuring 11–18 µm in diameter. The shape index was 1.7. The sporulated oocyst has elongated sporocysts and their sporozoite has large vacuole at the broad end

Table 5 Morphological features of the harvested GIT third stage larvae

***Bunostomum* sp. (Fig. 4 a)**	***Strongyloides* sp. (Fig. 4e)**	***Haemonchus* sp. (Fig. 4c)**	***Chabertia ovina* (Fig. 4b)**	***Ostertagia ostertagi* (Fig. 4 d)**	***Trichostrongylus axei* (Fig. 3a)**	***T. Colubriformis* (Fig. 3b)**	***Cooperia oncophora* (Fig. 3d)**	***Cooperia curticei* (Fig. 3c)**
A medium-sized larva (the total length was 634.92 µm). The head was bullet. The esophagus has a prominent bulb caudally and it had 16 intestinal cells. It had along thin tail sheath measuring 76.9 µm. It had a wide body. The filament was medium, measuring 34.92 µm (approximately 50% of STE)	Slender short sized larva, measured 507.93 µm in length. Uniquely, it has a very long esophagus which extending nearly for 40% of the body length. Absence of tail sheath and high magnification shows that the tail is bifid	A medium-sized larva (the total length ranged from 608 to 693 The head was bullet. It had 16 alternating zigzag-shaped intestinal cells. It had a medium tail sheath (86 µm long). The tail of the sheath tapers to end in a whip-like, medium-sized filament and usually kinked. The filament constituted measured (33 µm long) about 10–15% of the total tail sheath	Long larva (the total length is 800 µm). The head was square-shaped. It had 28–32 intestinal cells which were rectangular- shaped. It had a long thin tail sheath (89 µm long). The filament was medium-sized measuring33 µm long (approximately 30% of the tail sheath long)	The total length was 666.67 µm. The head was head of ovine *Ostertagia* has a slight shoulder close to its anterior end giving it a square appearance. It contained 16 intestinal cells. The tail is rounded at its end, with a short tail sheath (57.14 µm) and blunt tail tip without a filament	The total length was 628.57-685.71 µm. It was a short and straight. The head was rounded and the gut had 16 intestinal cells. The tail had a simple and blunt terminal end. It had a short STE ranged from 33 µm without a filament	Similarly, it was more or less closely related to *T. axei*, but the tail end had 2–3 tubercles (bifid structure, i.e., digitate tail)	Medium-sized larva with squared head, measured 716 µm, tail sheath measured 78 µm, sheath tapering to fine point. Characteristically, The head bears two refractile oval bodies at anterior end of the esophagus, the caudal tip of the sheath of *C. oncophora* is clearly perceptible	Similar to *Cooperia oncophora*, but the head of the L3 is narrower than that of *C. oncophora*. The caudal tip of the sheath Finer tip and vanish into nothingness

et al. [52] who reported a prevalence of 47.67%, Negasi et al. [53] and Das et al. [54] who observed a relatively lower prevalence of gastrointestinal parasites (35.33% and 28.65%, respectively). This variation could be attributed to the difference in agroecology of the study area, climatic changes, management system and deworming activities performed in respective areas.

The prevalence of helminthiasis was 21.95%. Such result was lower than that reported by Dereje [55] who revealed an infection rate of 98.18% in/and around Wolaita Sodo, Hailelul [56] who reported a prevalence of 95.24% in/and around Wollaita Soddo and Tefera et al. [45] who found that 95.0% of goats were affected with one or more helminth species. This variation could be referred to the discrepancy in hygiene systems and management in various districts.

Currently, the prevalence of nematodes infection was 13.41% including nine species; *Chabertia ovina*, *Ostertagia ostertagi*, *Haemonchus contortus*, *Trichostrongylus axei*, *T. Colubriformis*,*Bunostomum* sp., *Cooperia oncophora*, *Cooperia curticei* and *Strongyloides* spp (Figs. 3 and 4). Such result was lower than that obtained by Kuma et al. [57] who recorded a high prevalence of gastrointestinal tract infection (87.9%) in examined goats in Kalhari farm. Lower prevalences were reported in previous literature indicating 34.2%-84.1% (Yimer et al. [58], Ahmed et al. [59]).On the other hand, a higher prevalence was reported by Wondimu et al. [60]. This variation might be due to differences in agroecological conditions and management system. The present study revealed that the prevalence of *Moniezia* spp. was 7.31%. Such finding was lower than that conducted by Sultan et al. [3] and Hassan et al. [38] in Giza, Egypt, Negasi et al. [53], Das et al. [54] and Verma et al. [61] who recorded *Moniezia* spp. with prevalences of 18.22%, 19.04%, 15.09%, 10.0% and 18.74%, respectively. In Egypt, Abdelazeem et al. [4] recorded a lower infection rate of 6.7%. The prevalence of *Avitellina* sp. was 0.49%. Such prevalence was lower than that revealed by Esayas [39] who reported a prevalence of 7.86% in Ogaden, Hailelul [56] who reported 11.90% and Tefera et al. [45] who recorded a prevalence of 40.0%. This variation might be due to existence of the intermediate hosts, oribatid mites, management system and control methods.

The prevalence of *Haemonchus contortus* was 5.36%. Such prevalence was lower than that reported by Arafa [62] in Beni-Suef reported an infection rate of 19.5%, El-Shahawy et al. [63] who detected the nematode in 15.5% of the examined goats in Upper Egypt and Gareh et al. [64] who recovered an infection rate of 16.66%. Meanwhile, Tefera et al. [45], Hailelul [56] who reported 65.0% and 54.76%, respectively. Such result was higher than that reported by Tripathi et al. [65] who reported an infection rate of 3.43% in Shivraj. The differences in prevalences could be attributed to the basis of differential management practices (Mandonnet [66]), natural resistance (Soulsby [67]) and drugs administration (Barnes et al. [68]). Concerning *Trichstrongylus* species, the prevalence of *T. axei* was 1.95% and that of *T. colubriformis* was 0.73%. Such finding was lower than that reported by El-Khtam [69] in Menofia, Egypt (18.42%), Elsedawy et al. [70] in Dakahlia,Egypt (14.7%), [45] (55.0%) and Esayas [39] (16.59%) in Ogaden. The current finding was slightly lower than that obtained by Hamad [71] who recorded 3.7% in Aswan, Egypt. Variations in infection rates might be attributed to management patterns. Herein, the prevalence of *Chabertia ovina* was 0.98%. Such prevalence was lower than that given by Tefera et al. [45] who detected a prevalence of 25% and Arafa et al. [72] who reported an infection rate 2.6% in Assiut, Egypt. The prevalence of *Ostertagia ostertagi* was 1.71%. Such prevalence was lower than that obtained by Tefera et al. [45] (25%), Dabasa et al. [50] (1.7%) and Amenu [73] (15.6%) in goats of three agro ecological zones of southern Ethiopia.

Currently, *Strongyloides* spp. was revealed in 0.49% of examined goats. Such prevalence was lower than that given by Hassan et al. [38] who recorded prevalence of *S. papillosus* with 3.55% in Egypt, Dabasa et al. [50] who reported *Strongyloides* spp. in 25.36%, Singh et al. [74] (9.17%), Yusof [8] (45.6%), Das et al. [54] (8.91%) and Verma et al. [61] (0.7%). Such discrepancy might be due to the existence of various degrees of immunity of examined animals as well as geographical and environmental and managemental system.

The prevalence of *Bunostomum* sp. was 0.98%. Such result was lower than that obtained by Tefera et al. [45] (35.0%) in Ethiopia and Esayas [39] (59.38%) in Ogaden. The prevalence of *Cooperia oncophora* was 0.49%. A lower infection rate was given by Arafa et al. [72] (2.6%).

Concerning the infection with digenean trematodes, the prevalence of *Fasciola* spp. was 0.49%. Such prevalence was lower than that reported by Haridy et al. [75] (3.54%), Sobhy [76] (3.41%), Arafa et al. [72] (3.7%), Negasi et al. [53] (20.75%), El-Shahawy et al. [63] (4.4%) and Hassan et al. [38] (0.89%). Those variations might be due to proper and progressive application of control measures against fascioliasis in Egypt. Furthermore, *Paramphistomum* spp. was detected in 0.24% of examined goats. Such prevalence was lower than that achieved by Hassan et al. [38] who found rumen flukes in 0.9% of animals and El-Shahawy et al. [63] who recorded *Paramphistomum microbothrium* (2.2%) in Upper Egypt.

Concerning the age, prevalence of gastrointestinal helminth parasites was the highest in goats aged 2–5 years. Such finding disagreed with that given by Bedada et al. [77] who conducted that the prevalence of helminth

parasites was higher in adult animals than young ones. However, age wise observation revealed no statistically significant difference. This finding coincided with reports from Gambia and Semi-arid part of Kenya indicated that GIT helminths affect both ages insignificantly (Waruiru et al. [78]). The present finding disagreed with previous literatures Gamble et al. [79]. In the authors' opinion, such conflict might be attributed to variation of immune system.

Regarding to the sex, the present study concluded that females had a higher infection rate than males. Such result went parallel with that reported by Bedada et al. [77], Hassan et al. [38] who reported that female goats appear to be more susceptible to parasitic infections than male goats (Tariq et al. [80], Zvinorova et al. [81]).

Furthermore, the present study showed that the prevalence of infection was the highest in summer followed by winter, spring and lowest one was reported in autumn. Similarly, Biswas et al. [82] reported the highest prevalence in summer season (84.6%), followed by rainy (83.6%) and winter (81.2%) seasons in Bhola district, Bangladesh. However, this disagreed with that detected by Yadav et al. [83] who reported the highest prevalence during rainy season (88.5%) in Jammu Province, Kashmir (summer 83.2% and winter 76.0%) seasons. Singh et al. [74] recorded the maximum prevalence during monsoons (98.0%) while the minimum was recorded in winter (91.7%) in Madhya Pradesh, India. Also, Singh et al. [74] revealed the highest seasonal variation during rainy (90.10%) (winter 83.84% and summer 78.35%) in Punjab, India. Higher GIT helminths during the rainy season might be due to suitable environmental conditions for growth and development of GIT parasites and their larval stages.

Currently, the prevalence of *Eimeria* spp. infection was 39.27% (161/410). The obtained results were lower than those mentioned by Hassanen et al. [2].who recorded 83.6% infection rate in sharkia, Egypt, Radfar et al. [84] who recorded that the prevalence was 89.27% in Iran. Tefera et al. [45] conducted 100% of examined goats infected with *Eimeria* spp. Kheirandish et al. [85] who found that 89.9% had *Eimeria* spp. oocysts in Iran, Similarly in Egypt, El-Shahawy [86] (65.07%) in Upper Egypt, Mohamaden et al. [87] (60.0%), Hassan et al. [38] (76.89%), Abdelaziz et al. [23] (40.63%) in northern and southern Egypt. Such results were higher than those reported by Das et al. [54] who detected that the infection rate was 23%. In the present investigation, 9 *Eimeria* species were recorded; *Eimeria ninakohlyakim-ovae*, *E. hirci*, *E. caprinova*, *E. caprina*, *E. christenseni*, *E. jolchijevi*, *E. arloingi, E. apsheronica* and *E.* alijevi (Figs. 1 and 2). The most predominant species was *E. arloingi* (23.17%) followed by *E. ninakohlyakim-ovae* (20.24%), *E. alijevi* (9.76%), *E. caprina* (3.66%), *E. caprinova* (3.17%), *E. hirci* (2.93%), *E. jolchijevi* (1.95%), *E. christenseni* (1.71%). In Egypt, El-Shahawy [86] identified seven *Eimeria* species, *E. ninakohlyakim-ovae, E. hirci, E. caprina, E. christenseni, E. jolchijevi, E. apsheronica* and *E.* The least abundant species was *E. apsheronica* (0.73%). Similar species were recorded by Hassanen et al. [2]. Mohamaden et al. [87] recovered *E. arloingi* (37.04%), *E. ninakohlyakim-ovae* (30.86%) and *E. hirci* (24.69%) in goat feces. Abdelaziz et al. [23] recorded 4 species of *Eimeria*; *Eimeria arloingi*, *E. caprina*, *E. caprovina* and *E. hirci*. In Turkey, Deger et al. [88] identified *E. arloingi* (47.43%), *E. christenseni* (45.14%), *E. ninakohlyakim-ovae* (36.00%), *E. alijevi* (26.85%), *E. hirci* (23.42%), *E. caprina* (18.28%) and *E. caprovina* (16.57%). In China, Zhao et al. [89] reported 6 *Eimeria* species: *E. jolchijevi, E. arloingi, E. alijevi, E. caprina, E. hirci* and *E. christenseni.* Concomitantly, de Macedo et al. [27] revealed *E. jolchijevi, E. arloingi, E. alijevi, E. caprina, E. hirci,* and *E. christenseni. arloingi*. Alcala-Canto et al. [90] determined eight species; *E. caprovina, E. christenseni, E. hirci, E. arloingi, E. caprina, E. alijevi, E. ninakohlyakim-ovae,* and *E. Jolchijevi.*

Regarding the coccidiosis relative to the age, the infection rate was higher in females (45.57%) than males (20.95%). This finding was in agreement with that given by Hassanen et al. [2]. Previous literature reported that ewes and does are exposed to physiological stress in relation to pregnancy, giving birth and lactation that make it more susceptible to *Eimeria* spp. infection than males (Rehman et al. [19], Mohamaden et al. [87]). However, Ibrahim [91], Mohamaden et al. [87] and de Macedo et al. [27] reported that both sexes were equally susceptible to coccidiosis in goats.

Concerning season, the highest infection rate was in summer (48.46%) and winter (46.67%) followed by spring (28.33%) and autumn (10.0%). Sharma et al. [92] demonstrated that in winter and spring, the infection rate was the highest. This might be due to the availability of the suitable temperature and humidity, and oxygenation that is needed for oocysts sporulation. However, Abdelaziz et al. [23] reported that the infection rate in the winter was significantly the highest, followed by spring, autumn, and the lowest infection rate was in summer. Smith et al. [5] mentioned that hot and humid weather is particularly conducive to sporocysts development and outbreaks of clinical coccidiosis. Concerning the age, it has been recorded that goats aged less than one year had the highest infection rate of *Eimeria* spp. (75.0%). The prevalence of coccidiosis in animals aged one year was 50.0%. Goats aged 2–5 years had the lowest infection rate (18.0%). This might be attributed to the low immune status in young kids, and the absence of humoral/cellular immune response that can counter attack the sporozoites into

epithelial cells of the small intestine of the infected host. Similar results were observed by Maichomo et al. [93] in Pakistan. Yusof [8] found that the prevalence of *Eimeria* oocysts was significantly higher in young goats compared to adults. On the other hand, in Egypt, Abdelaziz et al. [23] found that adult goats were more susceptible to coccidiosis.

4 Conclusion

It is concluded that in the present study, the prevalence of helminths was 21.95% and that of *Eimeria* spp. was 39.27%, which is considered a high infection rate. The highest prevalence of parasitic infection was found in young animals (75.0%; 60/80) in authors opinion this was due to reduction in resistance of diseases and decreased required immunity. Higher prevalence was in females (59.02%; 180/305) than males, authors attributed the higher infection rate in females to the hormonal imbalance during both pregnancy and lactation (24.76%; 26/105). The parasitic infection was mostly highest in summer (63.85%) this might be due to availability of the suitable temperature and humidity, and oxygenation that is needed for oocysts sporulation and GIT parasites; Accordingly, periodical monitoring as well as effective and well-planned control measures to check the parasitic population in small ruminants have to been implicated by conducting extension programs to educate the farmers regarding the proper use of anthelmintics.

Acknowledgments
Authors gratefully acknowledge the financial support from Beni-suef University, university performance development center, support and finance office, project ID (YR4-BSU2118). Also authors thank all veterinarians and farmers who facilitated collecting fecal specimens.

Author contributions
All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by all authors. The first draft of the manuscript was written by Khaled Mohamed El-Dakhly and Hend Ibrahim Mohamed and all authors commented on previous versions of the manuscript. Waleed M. Arafa applied the statistical analysis. All authors read and approved the final manuscript.

Funding
This work was supported by the financial support from Beni-suef University, university performance development center, support and finance office, project ID (YR4-BSU2118).

Availability of data and materials
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The authors assert that all procedures contributing to this work comply with the ethical standards of the institutional Animal Care and Use Committee Beni-Suef University (BSU-IACUC 022-225).

Consent for publication
All authors give their consent for publication of this article.

Competing interests
The authors declare that they have no competing interests.

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Received: 26 December 2022 Accepted: 28 February 2023
Published online: 08 March 2023

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