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RESEARCH

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Ovine coccidiosis and associated risk factors in Minya, Egypt

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Abstract

Background: Coccidiosis is a potential protozoal disease of economic importance in sheep worldwide. The current study aimed to detect the prevalence of ovine coccidiosis and identification of the recovered species in Minya, Egypt. Three hundred and fifty sheep from Minia, Egypt, were coprologically examined for the occurrence of *Eimeria* species oocysts by using the standard floatation technique.

Results: Oocysts were detected in 180 (51.43%) animals. Mixed infection was recorded in 37.14% (130/350) and single infection was revealed in 14.29% (50/350) sheep. The prevalence of coccidiosis was significantly higher in young sheep. Fourteen *Eimeria* species were detected; *Eimeria bakuensis*, *E. webybridgensis*, *E. ahusta*, *E. intricata*, *E. granulosa*, *E. faurei*, *E. ninakohlyakim-ovae*, *Eimeria coitae*-like, *E. parva*, *E. pallida*, *E. marsica*, *E. crandallis*, *E. ovinoidalis* and *E. arloingi*. The most predominant *Eimeria* species was *Eimeria parva* (14.57%; 51/350) followed by *E. ovinoidalis* (14.0%; 49/350), *E. granulosa* (8.29%; 29/350), *E. bakuensis* (7.14%; 25/350), *E. intricata* (5.43%; 19/350), *E. faurei* and *E. webybridgensis* (4.86%; 17/350 each), *E. pallida* (4.0%; 14/350), *E. ninakohlyakim-ovae* (3.71%; 13/350), *E. crandallis* and *E. ahsata* (3.43%; 12/350 each), *E. marsica* and *E. arloingi* (1.71%; 6/350 each). The least abundant species was *E. coitae*-like (1.14%; 4/350).

Conclusion: Fourteen *Eimeria* species were recovered from sheep in Minya, Egypt; *Eimeria bakuensis*, *E. webybridgensis*, *E. ahusta*, *E. intricata*, *E. granulosa*, *E. faurei*, *E. ninakohlyakim-ovae*, *Eimeria coitae*-like, *E. parva*, *E. pallida*, *E. marsica*, *E. crandallis*, *E. ovinoidalis* and *E. arloingi*. *Eimeria parva* was the most common while *E. coitae*-like was the least. To the best of our knowledge, this is the first report for the occurrence of *E. coitae*-like in sheep in Egypt. Prevention and effective control programs should be strictly followed to avoid economic losses resulted from the coccidian infection.

Keywords: *Eimeria*, Sheep, Coccidiosis, Morphology, Egypt

1 Background

In the underdeveloped countries, small ruminants, particularly sheep, are of a great economic importance as they capable to survive and produce in poor environments, or even reared on low-cost feeds providing an appropriate target for small families in those countries achieving meat and wool as wells as traditional pastoralism [1, 2]. In Egypt, the estimated sheep population is approximately 5.5 million [3]. Coccidiosis of small ruminants is a protozoan infection caused by coccidia parasites of the genus *Eimeria* which develop in the small and the large intestine of infected animals and affect young animals in particular. Several species of *Eimeria* are involved in different ruminant hosts, but there is no cross infection due to the strict host specificity. Coccidiosis is of great eco-nomic importance because of the losses due to clinical disease (diarrhoea) and subclinical infections as well (poor weight gain in particular).

Parasites of livestock, including sheep, cause diseases of a major global socio-economic importance [4]. Parasites of the genus *Eimeria* (Apicomplexa: Eimeriidae) are considered an important cause of the intestinal infection, coccidiosis [5–7]. *Eimeria* parasites usually affect young

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animals aged up to 4 months, and also they occur in adult animals, acting as reservoirs of the infection [8]. The ingestion of oocysts-infected food and water is the main source of spreading the parasite. Coccidiosis clearly elucidate various clinical signs, such as weight loss, fever, diarrhea (often bloody), dehydration, pale mucous, and even death [9, 10]. The disease might occur in clinical/subclinical form [11]. Clinical coccidiosis often induces potential losses for producers due to costs of medical treatment, adversely affected growth performance and sometimes death of lambs aged less than 3 months [12–14]. A high mortality rate is might be common in animals suffering from heavy bloody diarrhea [15]. Overall, coccidiosis is drastically expected when bloody diarrhea, poor body conditions, remarkable weight loss and abdominal pain [16]. Pushing towards the improvement of body conditions and managemental care is mandatory needed to control the disease. The parasite has two phases of biology; endogenous and exogenous phases. During the first, the parasite undergoes multiple divisions in the enterocytes. Sheep ingest sporulated oocysts via contaminated feed/water. Sporulated oocysts release sporozoites in the intestinal lumen. The exogenous phase occurs in the environment [15]. Once coccidiosis has been diagnosed, the treatment of affected sheep mostly not effective, but the severity might be reduced with the early treatment by anticoccidial drugs like toltrazuril, diclazuril and sulfaquinoxaline [15].

The identification of *Eimeria* species often based on both morphological and molecular features [17]. The molecular approach is disadvantageous as it requires specific tools and high-cost facilities [18]. Therefore, morphological characterization utilizing morphometry of oocysts has been established as a practical and reliable tool for species differentiation [17, 19]. So far, 15 *Eimeria* species parasitizing sheep have been described [20]. Among those, *E. ovinoidalis* and *E. crandallis* are considered as pathogenic species with clear clinical signs of the disease [17]. Other species like *E. ahsata*, *E. marsica*, *E. bakuensis*, *E. granulosa* and *E. parva* have been recorded with a little evidence about the pathogenicity of them [12, 21].

The conventional control strategy is achieved by careful husbandry combined with in-feed anticoccidial drugs or vaccination with live or attenuated parasites. It is very urgent to develop safe and effective multivalent vaccine against mixed infection of all the economically important species of *Eimeria*.

Herein, we aimed to determine the prevalence of different *Eimeria* spp. in sheep obtained from Minya province, Egypt and morphological identification of the recovered *Eimeria* species as well as their associated risk factors.

2 Methods

2.1 Study area and animals

Fresh fecal specimens were collected from 350 sheep of various ages and genders allocated sporadically in small flocks kept in households in rural areas (average 4–15 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 0–6 months, 6–12 months and 2–3 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. 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 [3, 22, 23].

2.3 Measurement of oocysts

The calibration of the microscope was done according to Conway and Mckenzie [24]. 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

Table 1 The overall prevalence of the coccidian infections among the examined sheep

	Examined fecal samples ($n = 350$)	
	Number	**Percentage**
Infected	180	51.43
Single infections	50	14.29
Mixed infections	130	37.14
Total	180	51.43

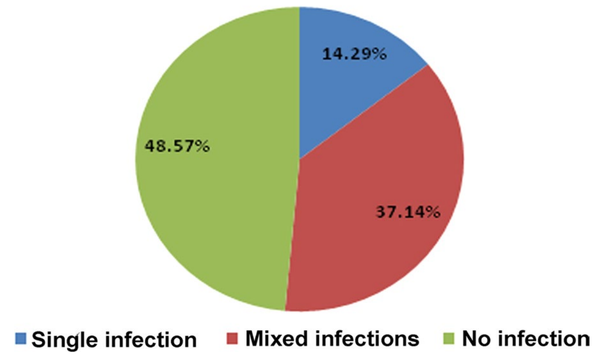

Fig. 1 The overall prevalence of the coccidian infection among the examined sheep

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 $\times$ 10 microns).

2.4 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 coccidial infections. Variables were significant at $P \leq 0.05$ [3, 15, 25].

3 Results

The current study revealed that *Eimeria* spp. oocysts were recorded in 180 (51.43%) out of 350 fecal samples obtained from sheep of different ages and sexes. Mixed infection was found in 37.14% (130/350) and single infection was revealed in 14.29% (50/350) (Table 1; Fig. 1). The prevalence of coccidiosis significantly varied according to the age; the highest infection rate was in young sheep aged less than one year (92/125; 73.6%) followed by yearlings (35/58; 60.34%) and the lowest one was in adults (53/167; 31.74%) (Table 2). The prevalence was higher in female sheep (113/200; 56.50%) rather than males (67/150; 44.67%). The highest prevalence was revealed in cold season (98/132; 74.24%) rather than that in the hot season (82/218; 37.61%).

Table 2 The overall prevalence of coccidian infections relative to the age of sheep

Age	Young sheep (less than 1 year)	Yearlings (1 year)	Adults (2–3 years)	X^2	*P*
Examined	125	58	167		
Infected	92	35	53	52.36	> 0.00001
Prevalence %	73.60	60.34	31.74		

P value is considered significant at > 0.05

X^2 = Chi^2

Table 3 The recovered *Eimeria* species in feces of the examined sheep

Eimeria species	Single infection (%)	Mixed infection (%)	Positive animals (%)
E. ovinoidalis	8 (2.29)	41 (11.71)	49 (14.0)
E. intricata	2 (.57)	17 (4.86)	19 (5.43)
E. crandallis	0.0	12 (3.43)	12 (3.43)
E. pallida	1 (.29)	13 (3.71)	14(4.0)
E. webybridgensis	2 (.57)	15(4.29)	17 (4.86)
E. bakuensis	3 (.86)	22 (6.29)	25 (7.14)
E. granulosa	9 (2.57)	20 (5.71)	29 (8.29)
E. ahsata	3 (.86)	9 (2.57)	12 (3.43)
E. parva	11 (3.14)	40 (11.43)	51 (14.57)
E. ninakohlyakim-ovae	1 (.29)	12 (3.43)	13 (3.71)
E. arloingi	0.0	6 (1.71)	6 (1.71)
E. marsica	1 (.29)	5 (1.42)	6 (1.71)
E. coitae-like	0.0	4 (1.14)	4 (1.14)
E. faurei	3 (.86)	14(4.0)	17 (4.86)

Table 4 Morphological criteria of recovered ovine *Eimeria* species

Eimeria bakuensis (Fig. 2 a, b)	*Eimeria weybridgensis* (Fig. 2 c, d)	*Eimeria ahsata* (Fig. 2 e, f)	*Eimeria intricata* (Fig. 3a)	*Eimeria granulosa* (Fig. 3b)	*Eimeria faurei* (Fig. 3c)	*Eimeria ninakohlyakimovae* (Fig. 3d)	*Eimeria coitae*-like (Fig. 3 e, f)	*Eimeria parva* (Fig. 4a)	*Eimeria pallida* (Fig. 4b)	*Eimeria marsica* (Fig. 4c)	*Eimeria crandallis* (Fig. 4d)	*Eimeria ovinoidalis* (Fig. 4e)	*Eimeria arloingi* (Fig. 4f)
It was ellipsoidal-shaped, measured 26.1 × 15.6 µm, with a smooth thick yellowish-brown outer layer, with a micropyle and a distinct cap. The shape index was 1.6	It was broad ellipsoidal to spherical in shape, measured 26.1 × 17.4 µm, with a smooth wall, colorless. It had both micropyle and polar cap present. The shape index is 1.5	It was ellipsoidal in shape, measured 35.7 × 26.8 µm, with a smooth wall, yellowish brown color. It had both micropyle and a distinct polar cap	It was ellipsoidal-shaped, measured 43.4 × 29.6 µm, with a thick and striated wall, bi-layered; the internal layer was more intensely colored and striated than the outer one. The outer layer had an irregularly corrugated outer surface giving a mottled appearance to the wall when dorsally seen. It was yellowish-brown in color, with a micropyle and a distinct polar cap. It had a spherical-shaped sporonot measuring 19–26 µm in diameter. The shape index is 1.46	The unsporulated oocyst was urn/pyriform in shape, measured 29.5 × 20.9 µm, with broad shoulders, a bi-layered smooth wall, yellowish-brown in color. The micropyle is located at the broad end of the oocyst with a distinct polar cap. It had a spherical sporont with densely granular protoplasm. The shape index was 1.5	The unsporulated oocyst was egg-shaped, measured 33 × 22.6 µm, with a single smooth membranous outer layer, pale yellowish-brown, with a distinct micropyle, no polar cap. It contained a spherical-shaped sporont measuring 13–20 µm in diameter. The shape index is 1.4	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	It was ovoid/spherical in shape and measured 38.3 × 29.9 µm. The shape index was 1.2 (1.1–1.4). It had two distinct inner layers, both of which was striated and of a yellow brown color. There was neither micropyle nor polar ca	The unsporulated oocyst was spherical/subspherical in shape, measured 20.9 × 15.5 µm, with a smooth wall, colorless. Neither micropyle nor polar cap was present. It had a spherical-shaped sporont measuring 7–14 µm in diameter. The shape index is 1.2. The sporulated oocyst has ovoid sporocyst, each sporozoite has central vacuole	The unsporulated oocyst was ellipsoidal-shaped, measured 13.9 × 11.3 µm, with a very smooth wall, colorless, imperceptible micropyle, no polar cap. It had a spherical-shaped sporont measuring 6–10 µm in diameter. The shape index was 1.2	It was ellipsoidal-shaped, measured 26.1 × 15.6 µm, with a smooth wall, colorless, inconspicuous micropyle, and no polar cap. The shape index was 1.6	It was broad ellipsoidal to spherical in shape, measured 22.6 × 17.4 µm, with a smooth wall, pale-yellowish color, with a polar cap and micropyle. The shape index was 1.3. The sporulated oocyst has rounded or ovoid sporocyst and each has two vacuoles	It was ellipsoidal-shaped, measured 26 × 21.4 µm, with smooth wall, colorless to pale yellow, with micropyle and without a polar cap	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

Fourteen *Eimeria* spp. were identified; *E. ovinoidalis*, *E. crandallis*, *E. pallida*, *E. faurei*, *E. webybridgensis*, *E. bakuensis*, *E. granulosa*, *E. ahsata*, *E. parva*, *E. intricata*, *E. ninakohlyakim-ovae*, *E. arloingi*, *E. coitae*-like and *E. marsica*. *Eimeria parva* was the most predominant species (51/350; 14.57%) followed by *E. ovinoidalis* (49/350; 14.0%), *E. granulosa* (29/350; 8.29%), *E. bakuensis* (25/350; 7.14%), *E. intricata* (19/350; 5.43%), *E. faurei* and *E. webybridgensis* (17/350; 4.86% each), *E. pallida* (14/350; 4.0%) *E. ninakohlyakim-ovae* (13/350; 3.71%), *E. crandallis* and *E. ahsata* (12/350; 3.43% each), *E. marsica* and *E. arloingi* (6/350; 1.71% each). The least abundant *Eimeria* species was *E. coitae*-like (4/350; 1.14%) (Table 3). Morphological features of the revealed *Eimeria* spp. oocysts were included in Table 4 (Figs. 2, 3, 4).

4 Discussion

Eimeria species are the major cause of coccidiosis in livestock inducing massive economic losses in farm animals largely, reduction in milk and meat, weakness, as well as potential mortality rates [26]. In the present study, out of 350 fecal samples from sheep of various sexes and ages, 180 (51.43%) were infected with *Eimeria* spp. In Egypt, such result more or less coincided with those revealed by El-Akabawy [27] and Boshra [28] in Kaloubia, Nasr et al. [29] in Sharkia, Bkheet et al. [30] in Beharia, Ramadan et al. [14] in Kaloubia, Mahmoud et al. [31] in Assuit, Mohamaden et al. [7] in Suez and El-Alfy et al. [3] in Dakahlia who recorded infection rates 80.4, 80.76, 76.51, 70, 72.5, 65, 57.7 and 68.4%, respectively. Similarly, in Iraq, Sulaiman et al. [32] detected that the prevalence of coccidiosis was 60.5%. However, in Egypt, the current findings were higher than those previously reported by Mahran [33] in Red Sea, Abouzeid et al. [34] in Sinai and Sultan et al. [35] in Kafr-Elsheikh (6.61, 6.7 and 16.52%, respectively). Furthermore, Toulah [36] in Saudi Arabia, Abakar [37] in Sudan and Majeed et al. [38] in Kuwait recorded infection rates 41, 41.2 and 17.5%, respectively). On the other hand, it was lower than those noted by Bastauerous et al. [39] in Assuit, Egypt and Ali [40] in Sudan who revealed prevalences of 94.9% and 86% among examined sheep. Such difference may be due to changes in environmental condition.

Currently, single infection was recorded in 14.29% (50/350) of infected sheep, while mixed infection rate was found in 37.14% (130/350). Such finding was concomitant with that recorded by El-Akabawy [27] in Kaloubia, who found that mixed infection with more than two *Eimeria* species was 78.8%, Mohamaden et al. [7] who detected that the mixed infection was 68.3% of the examined sheep in Suez, Ramadan et al. [14] who demonstrated that the mixed infection was 43.7% in Kalubia and El-Alfy et al. [3] who found that the mixed infection was 73.0% in Dakahlia. Moreover, Toulah [36] in Saudi Arabia noticed that the mixed infection with three *Eimeria* species was 51.22%. On the other hand, the present finding disagreed with that observed by El-Akabawy [27] in Kaloubia, who revealed that the single infection rate was 1.7% among examined sheep. Boshra [28] detected that sheep infected with single *Eimeria* species was 3.03%, double mixed species was 17.63% while mixed infection with more than two species was 79.33% among examined sheep in different localities in Egypt. Meanwhile, in Sudan, Ali [40] elucidated that mixed infection was in 83%. In Saudi Arabia, Toulah [36] noticed that mixed infection with two *Eimeria* species was 36.59%.

Concerning the age, the highest infection rate was revealed among sheep aged less than one year (73.6%), followed by those aged one year (60.3%). While the lowest infection rate was found in animals aged 2–3 years (31.7%). This results agreed with that noted by Nasr et al. [29] in Sharkia, Egypt, who detected that the prevalence was higher in young-aged animals (38.09%), followed by immature (24.38%), while the lowest prevalence was found in adult animals (18.30%). Similarly, Muhammed et al. [41] reported that a higher infection rate was observed in young animals (51.56%) than adult ones (15.53%), Ramadan et al. [14] revealed a higher infection rate in young animals (73.6%) than adults (55.6%) and El-Alfy et al. [3] who noted that the highest prevalence was detected in lambs, followed by sheep aged one year and the lowest rate was seen in adults. In the south eastern Ethiopia, Dabasa et al. [42] found that young-aged sheep was more susceptible (21.4%) to the infection than adults (10.8%). On the other hand, the prevalence of the current eimeriosis disagreed with that reported by El-Akabawy [27] in Kaloubia, who found that adult sheep aged 6–12 months were highly susceptible to the infection (89.2%), followed by those aged less than 6 months (79.2%), Abouzeid et al. [34] in Sinai (9.2% in adults and 8.6% in lambs) and Mahmoud et al. [31] in Assuit, Egypt, who observed a high prevalence of *Eimeria* spp. (65.26%

(See figure on next page.)

Fig. 2 Morphology of 3 *Eimeria* species recovered from examined sheep. **a** *Eimeria bakuensis* unsporulated oocyst. Note the distinct polar cap (arrow). **b** *Eimeria bakuensis* sporulated oocyst. **c** *Eimeria weybridgensis* unsporulated oocyst. Note an ellipsoidal to a spherical shape with a smooth wall (arrow). **d** *Eimeria weybridgensis* sporulated oocyst. **e** *Eimeria ahsata* unsporulated oocyst. Note the smooth wall with yellowish brown coloration (arrow). **f** *Eimeria ahsata* sporulated oocyst. (Scale bar = 10 μm)

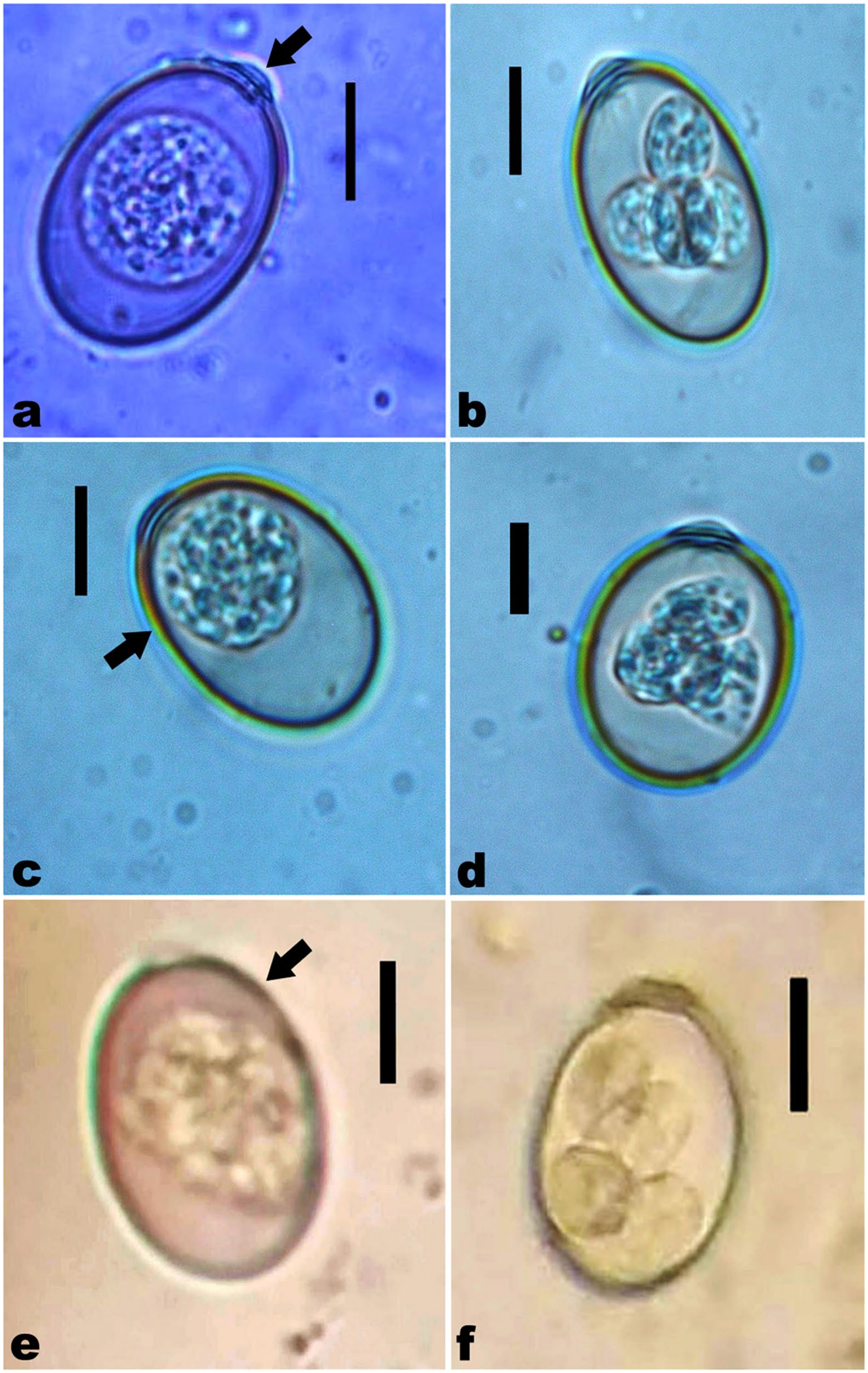

Fig. 2 (See legend on previous page.)

in adults and 63.63% in lambs). Interestingly, Kheirandish et al. [43], Gizachew et al. [44], Rizwan et al. [45] and Yonas and Goa [46] detected that the age of sheep non-significantly affected the infection rate. Such discrepancy might be attributed to the used rearing system of sheep or as result of the development of resistance against *Eimeria* species in relative to the age.

Regarding to the sex, non-significantly, the infection rate was higher in females (56.5%; 113/200) compared to males (44.67%; 67/150). Such finding went parallel to that recovered by El-Akabawy [27] in Kaloubia who recorded that females were more susceptible to the infection (82.3%) than males (78%), and Mohamaden et al. [7] in Suez, who recorded that females showed a higher prevalence (69.1%) than males (48.4%), Ramadan et al. [14] in Kalubia who found that females were more susceptible to coccidiosis (76.3%) than males (68.3%). They attributed the higher infection rate in females to the hormonal imbalance during both pregnancy and lactation. El-Alfy et al. [3] in Dakahlia who recorded that females showed a higher infection rate (71.8%) than males (59.1%). Conversely, Sulaiman et al. [32] observed that the highest infection rate was 58.3% in males and 37.11% in females, Idris et al. [47] elucidated that male lambs were more susceptible (4.66%) to the infection than females (4.15%) and Dabasa et al. [42] recorded a higher infection rate in males (31%) than females (10.4%). While Ali [40], Yakhchali and Rezaei [48], Gizachew et al. [44], Lakew and Seyoum [49], Yonas and Goa [46] recorded that the sex of sheep had no significant effect on the prevalence of *Eimeria* spp. In the authors' opinion, the higher prevalence of coccidiosis in female sheep might be referred to the nature of immune status of females as well as the stress caused by pregnancy and lactation.

Furthermore, the present study showed that the prevalence of infection was higher during the cold wet season (74.24%) and lower during the hot dry one (37.61%). Those findings were in agreement with those revealed by Maingi and Munyua [50], Abakar et al. [37] Ramadan et al. [14], Al-Alfy et al. [3] and Ali [40]. The later noted that the highest infection rate occurred in spring (98%), while the lowest rate was in summer (2%). In addition, Nasr et al. [29] in Sharkia, noticed that the highest prevalence was recorded in winter (78.89% and 90.82% for males and females, respectively). Mahran [33] in Red sea, Egypt, found a higher prevalence in winter than that in the summer. On the other hand, El-Akabawy [27] reported that the infection rate was higher in the autumn (89.3%) followed by winter (82.7%), summer (77.4%) and spring (73.9%). Also, Boshra [28] recorded that infection rates were 91.04, 78.57, 74.54 and 74.45% in summer, spring autumn and winter, respectively. Similarly, in Suez, Egypt, Mohamaden et al. [7] detected that the highest infection rate was found in the summer followed by autumn and spring while the lowest rate was seen in winter. However, Maingi and Munyua [50] in Kenya and Kheirandish et al. [43] in Iran reported that there was no significant difference among seasons. The high prevalence of the infection during the cold wet season might be attributed to variations of climatic conditions in such a way that the sporulation and survival of coccidian oocysts are encouraged.

In the present work, fourteen *Eimeria* species were recovered based on the morphometry of the oocysts using the direct microscopy including *E. ovinoidalis*, *E. crandallis*, *E. ahsata*, *E. weybridgensis*, *E. bakuensis*, *E. intricata*, *E. faurei*, *E. pallida*, *E. granulosa*, *E. parva* and *E. marsica*, *E. ninakohlyakim-ovae*, *E. arloingi* and *E. coitae*-like. In Egypt, El-Magdoub et al. [51] recorded 10 ovine *Eimeria* species; *E. ovinoidalis*, *E. crandallis*, *E. ahsata*, *E. bakuensis*, *E. intricata*, *E. faurei*, *E. pallida*, *E. granulosa*, *E. parva* and *E. arloingi*. Similarly, Mohamaden et al. [7] revealed the same species. In the same year, Ramadan et al. [14] recovered 8 species; *E. ovinoidalis*, *E. crandallis*, *E. ahsata*, *E. intricata*, *E. faurei*, *E. pallida*, *E. granulose* and *E. parva*. Recently, El-Alfy et al. [3] revealed 11 *Eimeria* species in sheep; *E. ovinoidalis*, *E. crandallis*, *E. ahsata*, *E. weybridgensis*, *E. bakuensis*, *E. intricata*, *E. faurei*, *E. pallida*, *E. granulosa*, *E. parva* and *E. marsica*. In countries of similar topographical conditions, In Saudi Arabia, Toulah [36] reported 4 *Eimeria* species (*E. parva*, *E. intricata*, *E. arloingi* and *E. ovina*). In Sanandaj, Iran, Yakhchali and Gholami [52] detected 6 *Eimeria* species (*E. ovinoidalis*, *E. faurei*, *E. ahsata*, *E. parva*, *E. ovina*, *E. intricata*). Moreover, Yakhchali and Zarei [53] recognized 6 *Eimeria* species (*E. intricata*, *E. ovina*, *E. faurei*, *E. parva*, *E. ahsata* and *E. pallida*) in Tabriz province. In Kuwait, Majeed et al. [38] revealed similar findings. In Germany, Dittmar et al. [54] identified 12 *Eimeria* species of sheep. To the

(See figure on next page.)

Fig. 3 Morphology of 5 *Eimeria* species recovered from examined sheep. **a** *Eimeria intricata* unsporulated oocyst. Note a thick and striated oocystic wall (arrow) as well as distinct micropyle and polar cap (arrowhead). Scale bar = 20 µm. **b** *Eimeria granulosa* unsporulated oocyst. Note a spherical-shaped sporont with densely granular cytoplasm (arrow). Scale bar = 20 µm. **c** *Eimeria faurei* unsporulated oocyst. Note a distinct micropyle without polar cap. Scale bar = 20 µm. **d** *Eimeria ninakohlyakimovae* unsporulated oocyst. Note the lack of micropyle and polar cap (arrowhead). Scale bar = 10 µm. **e** *Eimeria cotiae*-like unsporulated oocyst. Note striated and brownish coloration of the cyst wall with no micropyle or polar cap (arrowhead). Scale bar = 10 µm. **f** *Eimeria cotiae*-like unsporulated oocyst. Note the beginning of sporont division (arrow). Scale bar = 10 µm

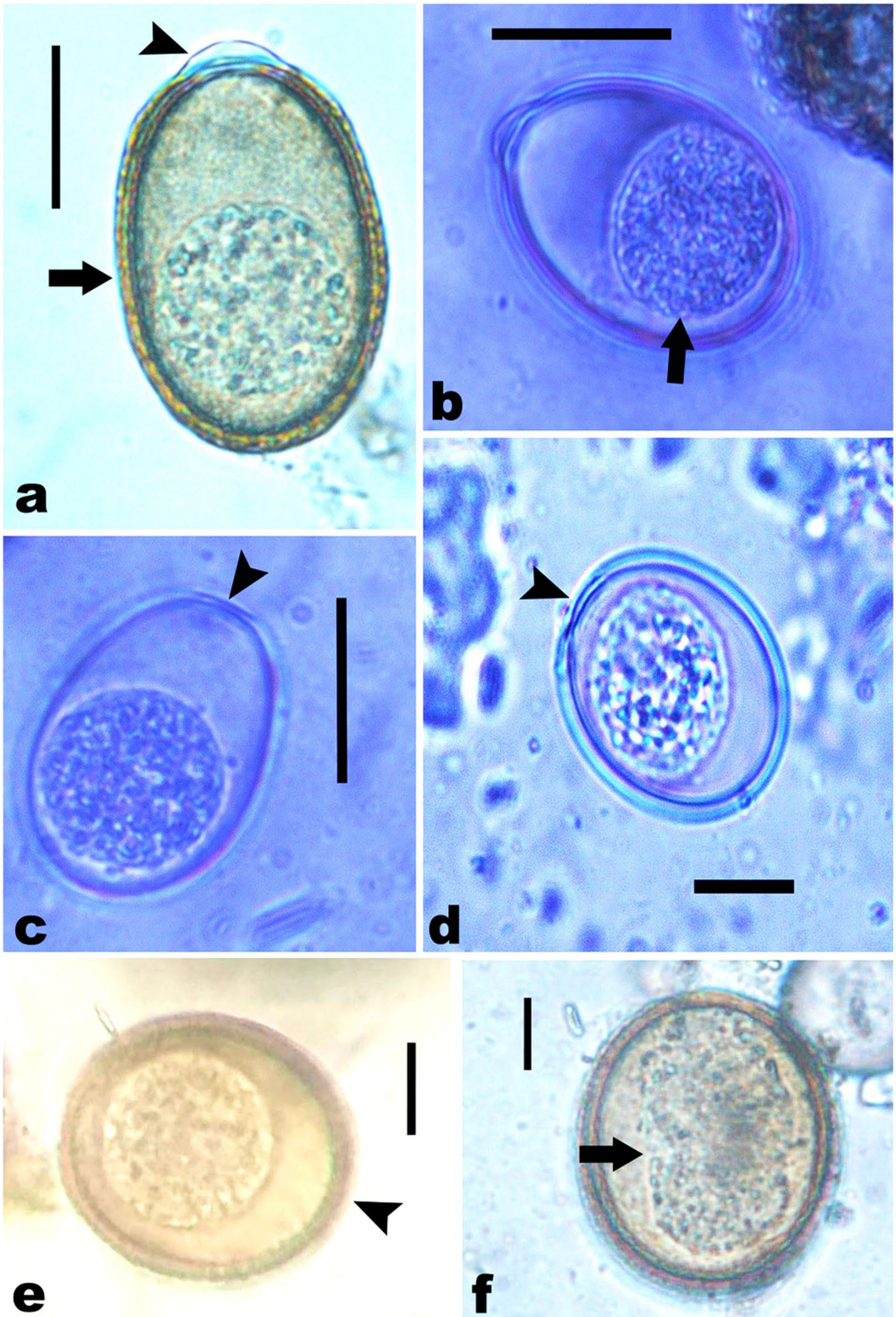

Fig. 3 (See legend on previous page.)

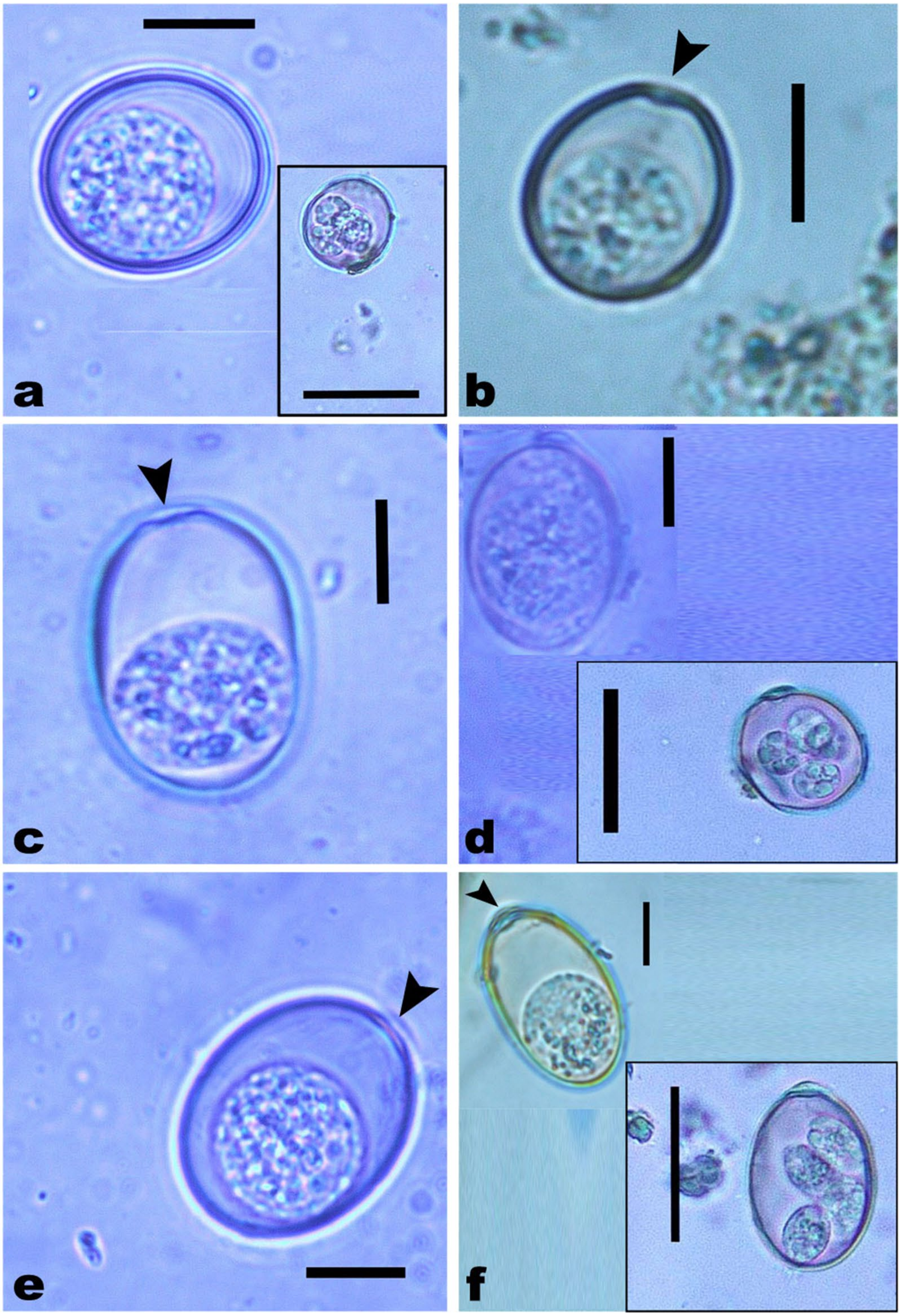

Fig. 4 Morphology of 6 *Eimeria* species recovered from examined sheep. **a** *Eimeria parva* unsporulated oocyst. Note the lack of micropyle and polar cap. Inset: The sporulated oocyst has ovoid sporocyst, each sporozoite has central vacuole Scale bar = 25 µm. **b** *Eimeria pallida* unsporulated oocyst. Note the imperceptible micropyle (arrowhead). **c** *Eimeria marsica* unsporulated oocyst. Note the inconspicuous micropyle (arrowhead). **d** *Eimeria crandallis* unsporulated oocyst and sporulated oocyst. Inset: The sporulated oocyst has rounded or ovoid sporocyst and each has two vacuoles Scale bar = 25 µm. **e** *Eimeria ovinoidalis* unsporulated oocyst. Note the presence of micropyle without a polar cap (arrowhead). **f** *Eimeria arloingi* unsporulated oocyst. Note a distinct micropyle and the polar cap is lid-like and easily dislodged (arrowhead). Scale bar = 10 µm. Inset: The sporulated oocyst has elongated sporocysts and their sporozoite has large vacuole at the broad end. Scale bar = 25 µm

best of our knowledge, *E. coitae*-like was first described in sheep in Egypt.

5 Conclusions

Ovine coccidiosis is a potential disease of veterinary importance. The overall prevalence of ovine coccidiosis was 51.43%. The current study revealed 14 *Eimeria* species; *E. ovinoidalis*, *E. crandallis*, *E. ahsata*, *E. weybridgensis*, *E. bakuensis*, *E. intricata*, *E. faurei*, *E. pallida*, *E. granulosa*, *E. parva* and *E. marsica*, *E. ninakohlyakimovae*, *E. arloingi* and *E. coitae*-like. Among those, *E. coitae*-like is recorded for the first time. Mixed infection was found in 37.14% (130/350) and single infection was revealed in 14.29% (50/350). The prevalence of coccidiosis significantly varied according to the age; the highest infection rate was in young sheep aged less than one year (92/125; 73.6%) followed by yearlings (35/58; 60.34%) and the lowest one was in adults (53/167; 31.74%). The prevalence was higher in female sheep (113/200; 56.50%) rather than males (67/150; 44.67%). The highest prevalence was revealed in cold season (98/132; 74.24%) rather than that in the hot season (82/218; 37.61%). The occurrence of the disease is basically related to the ingestion of oocysts in both foodstuffs and the surrounding utensils. The proper management and hygiene during rearing of lambs and adults are mandatory to avoid ovine coccidiosis. Subsequently, more studies are needed to clarify the transmission dynamics depending on the multilocus genetic analysis of different *Eimeria* species infecting sheep and other ruminant animals.

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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 KME and HIM and all authors commented on previous versions of the manuscript. WMA applied the statistical analysis. All authors read and approved the final manuscript.

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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
Not applicable.

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

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