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RESEARCH ARTICLE

Physiological and epidemiological study of some parasitic and viral enteric infections in dromedary camels in Al-Muthanna province

Al-Yasari, A.M.R.[1], Alsalih, N.J.[2], Alsaadawi, M.A.[3*]

[1]Division of Physiology, Biochemistry, and Pharmacology, College of Veterinary Medicine, Al-Muthanna University, Iraq
[2]Division of Parasitology, College of Veterinary Medicine, Al-Muthanna University, Iraq
[3]Division of Microbiology, College of Veterinary Medicine, Al-Muthanna University, Iraq
*Corresponding author: mohenned.hemza@mu.edu.iq

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ABSTRACT

Understanding the normal physiology of the body is the key to study the changes that occur due to any infection. It is known that enteric infections play a considerable role in affecting normal body status. Thus, this study was designed for investigating the enteric infections in Arabian camels in Al-Muthanna Province. In this investigation, 588 fecal and blood serum samples (for diarrheic camels only) were collected from the camels in different areas of Al-Muthanna Province, Iraq from both sexes of different ages during the period from October 2020 up to the end of August 2021. The samples were examined using routine microscopic examination techniques, hematological techniques, and ELISA for parasitic and viral identification. *Eimeria rajasthani*, *Isospora orlovi* were recorded for the first time in Iraqi camels with clinical signs of diarrhea, dehydration, and emaciation. The study recorded four types of protozoa: *Eimeria* spp., *Isospora, Cryptosporidium* and *Balantidium coli*. The recorded types of *Eimeria* were *E. dromedarii*, *E. cameli,* and *E. rajasthani*. There was a significant effect of age on infection rates with *Eimeria* spp. as the highest *Eimeria* ratio was in ages of less than two years animals. The infection rates were also affected with months which reached the highest ratios of *Eimeria* in October while the lowest ratio of *Eimeria* was recorded in July. BVDV infection rate was found in camels that suffered from diarrhea. There is no significant effect of sex on the onset of the viral disease in camels. For hematological parameters, there were significant differences in RBCs, WBCs, Hb, and PCV values in protozoal and BVDV infections. In conclusion, different kinds of protozoal and viral infections were recorded. Some of the recorded infections were associated with acute clinical signs and have zoonotic importance.

Keywords: *Eimeria*; *Isospora*; *Cryptosporidium*; *Balantidium coli*; BVD.

INTRODUCTION

Estimation of normal physiology is one of the important parameters to evaluate the health status of many animals including camels (Algareb *et al*., 2020; Saeed *et al*., 2022). Camels represent about 14.2% of the animals in the Arabian world, and they constitute two-thirds of the number of camels in the world. The number of camels in the Arabian countries is about 10.6 million. Parasites and viruses play a major role in causing harmful diseases either in humans or livestock in Al-Muthanna Province (Alhayali *et al*., 2022; Al Se´adawy, 2010; Alsaadawi *et al*., 2018; Alsaadawi & Alkhuzaie, 2019; Alsaadawi & Alkhaled, 2015; Thwiny *et al*., 2021) including Iraq, due to economic losses and zoonotic importance (Chattaraj *et al*., 2022; Zayed & El-Ghaysh, 1998).

Camels are infected with many diseases that can affect the normal body physiology, like coccidiosis, which is caused by two types of intestinal protozoa, *Eimeria* and *Isospora*, that live inside the cells with decreased epithelium size of the intestine, and form oocysts, which are characterized by resistance to environmental conditions. Mirza (1969) recorded an infection rate of *Eimeria* of 41.6% in Iraq, while Mirza & AL-Rawas (1976) found an 86% infection rate with *Eimeria*. Mahmoud *et al*. (1998) reported that the infection rate was 13% in Saudi Arabia. The infection was considered accidental in camels. Raisinghani *et al*. (1987) isolated the *Isospora* parasite from the camel's calf suffering from diarrhea and abdominal pain. There is no infection rates with this parasite were recorded in Iraq.

Pestivirus is the causative agent of bovine viral diarrhea, commonly named Bovine viral diarrhea virus (BVDV). It causes serious clinical symptoms in calves including respiratory, reproductive, or immunosuppressive signs (Duong *et al*., 2008). Carrier calves can shed the virus that is stuck in the uterus for the whole life and thus can spread the infection throughout the flock (Passler *et al*., 2009). This invasive virus can infect other livestock such as camels (Belknap *et al*., 2000) with severe clinical manifestations like enteric and respiratory signs (Kapil *et al*., 2009). The recent epidemiological records have not clearly shown the global distribution curves, while these studies referred to the disease as an emerging illness (Wernery, 2012). The study aims to investigate the most important intestinal protozoa and the seroprevalence of BVDV by using routine methods and linking that to some physio-hematological estimation in camels for the first time in Iraq.

MATERIALS AND METHODS

This study was carried out to investigate intestinal protozoa and viral infections in diarrheic camels by routine and physiological methods. This work was approved by the Veterinary Medicine College Ethical Approval Committee (Application Number: 202002). The parasitic investigation was done by collecting and examining fecal samples from 588 Arabian camels of both sexes of different ages. The number of males reached 89 and females 499 animals in different locations in Al-Muthanna Province, starting from October 2020 until the end of August 2021. The sex and age of each of 588 Arabian camels were confirmed by the method of teething (Gatenby, 1991). Samples were collected by taking 10-15 g of fecal samples directly from the rectum and placed in clean plastic containers, on which the sample number, sex, and age of the animal were recorded. The ages of animals were divided into groups (less than 2 years, 2-4 years, 4-6 years, 6-8 years, 8-10 years and more than 10 years). Additional information was recorded in special cards for the place and date of sampling, the name of the owner of the animal, and the health status of the animal. Subsequently, the samples were transferred directly to the laboratory for laboratory tests. Blood samples were collected from only camels suffering from diarrhea for viral detection. Different methods were used in the study which include a gross examination to observe the physical characteristics such as; color, texture, and smell, microscopic examination by using the following methods (direct cotton swab method, direct swab method using Lugol's Iodine tincture, treating stool samples for the purpose of investigating different forms of intestinal protozoa using ethyl acetate solution, detection of the oocysts of *Eimeria* and *Isospora* parasites by using flotation with Sheather's sugar solution, sporulation to investigate *Eimeria* and *Isospora* egg oocysts (Alkhuzaie, 2019; Alsaadawi, 2019). In addition, the serological test [the indirect Enzyme-Linked Immunosorbent Assay (ELISA)] was used for the virus diagnosis using BVDV (NS3); a Kit from Bio-X Diagnostics, Belgium. The instructions of the manufacturer were used as a guide for doing the test. The results were read by a microplate reader where the optical density (OD) of the positive and negative sera and those of all the samples were measured at 450 nm wavelength. Moreover, physiological parameters (hematology) were used to determine the impact of protozoal and BVDV on hematological parameters in infected animals, RBCs, WBCs, PCV, and Hb values were detected by using a blood analyzer for CBC count (Alsaadawi *et al*., 2022a; Alsaadawi *et al*., 2022b; Alsalih *et al*., 2021; Thwiny *et al*., 2022).

Statistical analysis

Graph Pad Prism version 9 software was used for statistical analysis of data. Quantitative results are indicated as mean ± SEM. $P < 0.05$ was considered significant.

RESULTS

Epidemiological survey

588 faecal samples were collected from camels of different ages and places from Al-Muthanna Province from October 2020 to August 2021. It is shown that the total number of infected camels with enteric protozoa (*Eimeria*, *Isospora*, *Cryptosporidium*, and *Balantidium coli*) was 372 (63.26%). The infection rate *Eimeria* parasite was 21.93% (129), *Isospora* 0.34% (2), *Cryptosporidium* 26.36% (155), and *Balantadium coli* 43.53% (256) (Figure 1).

Parasites identification

Eimeria

The results of the examination of faecal samples using direct methods, flotation with sugar Sheather's solution, precipitation with ethyl acetate solution, and spores showed that 129 (21.93%) animals were infected (Figure 1, left panel). *Eimeria* oocysts appeared in three different shapes and sizes of the three recorded species: *E. cameli*, *E. dromedarii* and *E. rajassthani*.

Species

The infection with *E. cameli, E. dromedarii,* and *E. rajasthani* appeared in 31, 72, 26 animals (24.03%, 55.81%, and 22.48% respectively of infected animals) (Figure 1, right panel). The length and width of the oocysts, the shape, wall features, colors, and presence of the polar cup were explained in Table 1 and Figure 2.

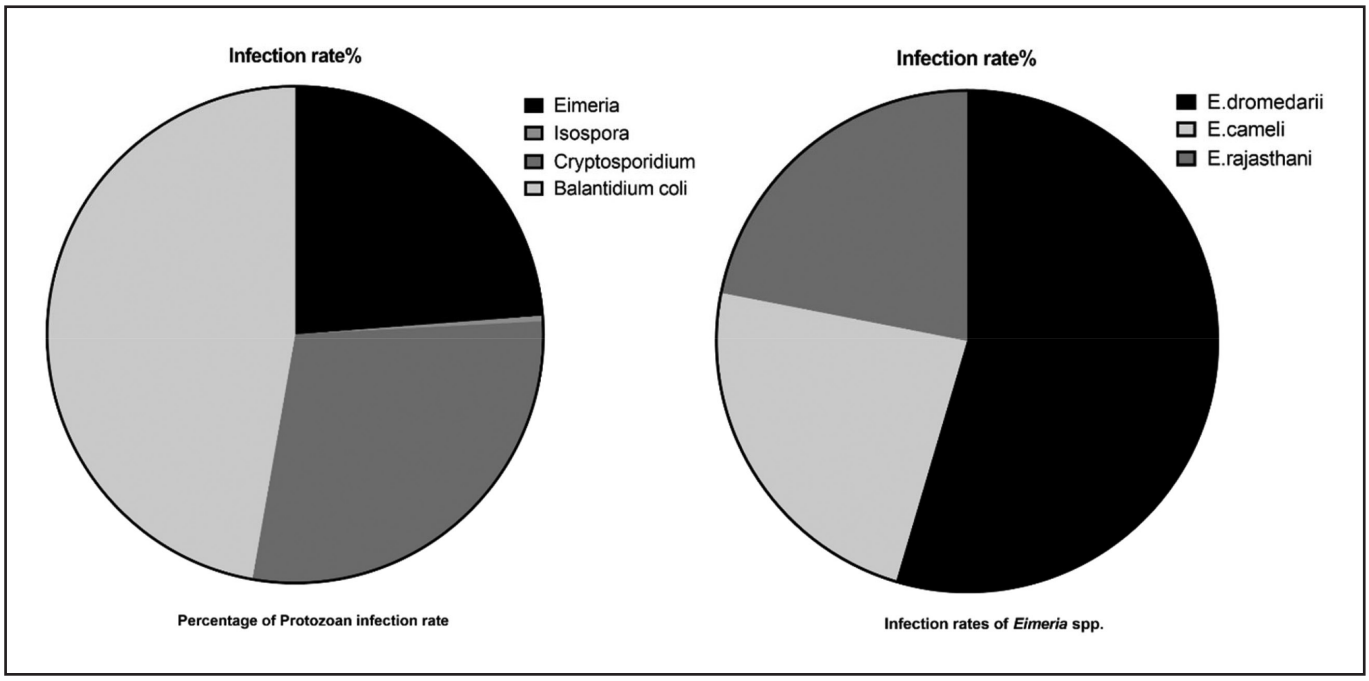

Figure 1. The total infection rates of protozoa in camels. Left panel: the total infection rates of different genera of protozoa. Right panel: the total infection rates of different species of *Eimeria*.

Table 1. Characteristics and measurements of recorded *Eimeria*, *Isospora* and *Cryptosporidium*

Protozoan species		*E. cameli*	*E. dromedarii*	*E. cameli*	*Isospora* sp.	*Cryptosporidium*
Oocyst measurement	length	68.6-93.1	24.5-36.7	22.05-29.3	26.4-27	4.1-5.5
	width	61.2-68.6	20.8-26.9	20.8-22.05	19.7-20.9	3.9-4.6
Shape of oocysts		Oval	Oval	Elliptical	Oval or 8 shape	Oval to spherical
Wall		Brown four layers	Two layers, the outer layer is light gray while the inner layer is brown	Two layers, the outer layer is light gray while the inner layer is brown	Thick one layer	Thin one layer
Micropyle		+	+	–	–	/
Polar cup		+	+	–	–	/
Sporocyst size		19.6-14.7	11.3-7.5	8.2-12	8.4-10.26	/
Sporocyst shape		Elliptical	Oval	Oval	Elliptical	/

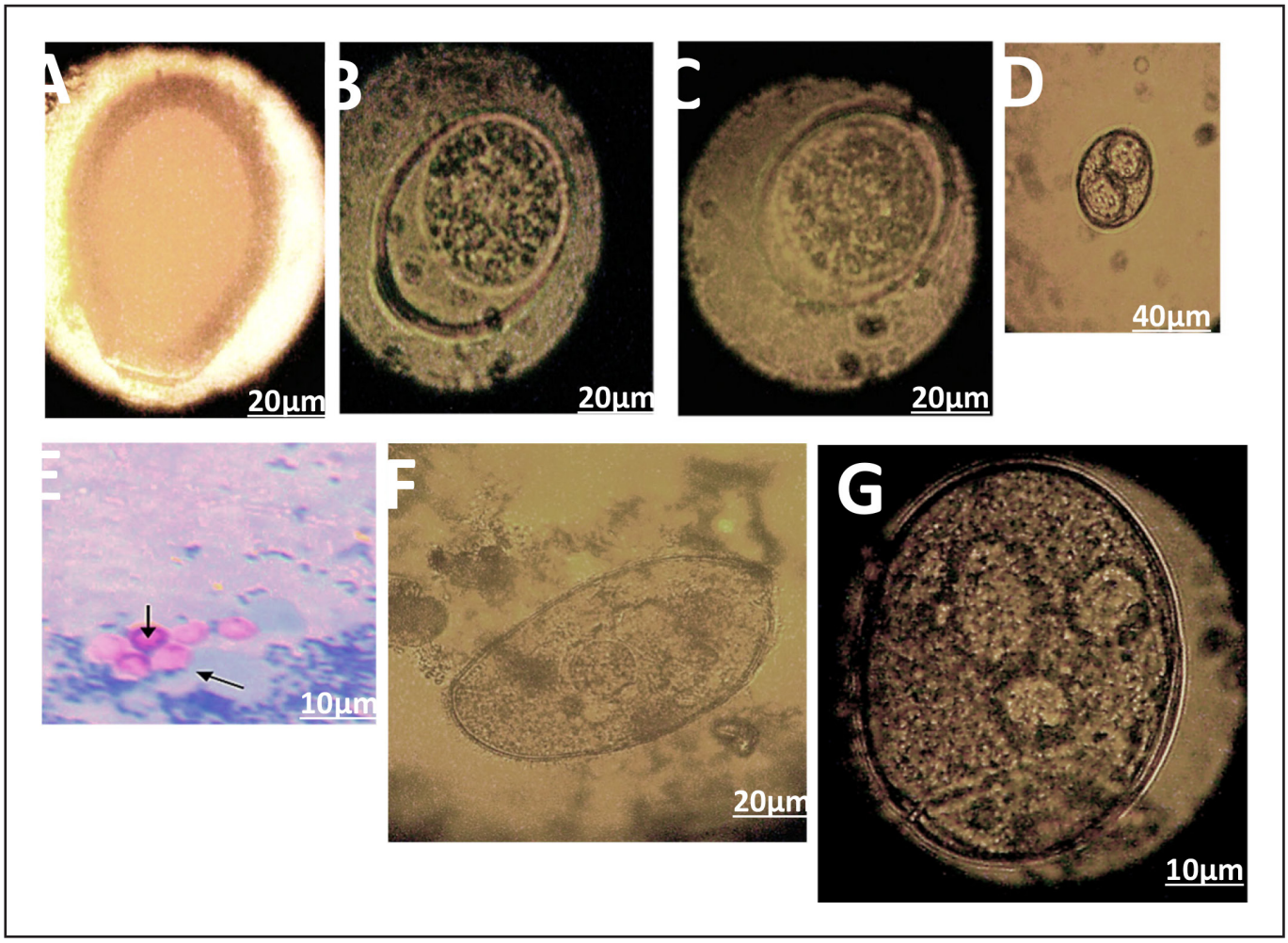

Figure 2. Microscopic pictures of the recorded protozoa. Different types of protozoa were recorded using ethyl acetate precipitation technique or modified Ziehl–Neelsen staining acid fast staining. The imaged protozoa were *E. cameli* (A), *E. rajasthani* (B), *E. dromadari* (C), *Isospora* (D), *Cryptosporidium* (E) and *Balantidium coli* (F). all the images were taken under the microscope, X400 except for *Cryptosporidium* as the power was X1000.

Table 2. Clinical signs of single infected camels

Protozoa	Mono infection number	Infected camels with clinical signs		Clinical signs
		No.	%	
Eimeria spp.	36	8	22.22	Emaciation, Light greenish diarrhea with mucus and sometimes bloody
Isospora sp.	2	–	–	–
Cryptosporidium spp.	53	16	30.18	Yellowish greenish diarrhea with bad smell
Balantidium coli	125	18	14.40	Emaciation, Loss of appetite, greenish diarrhea

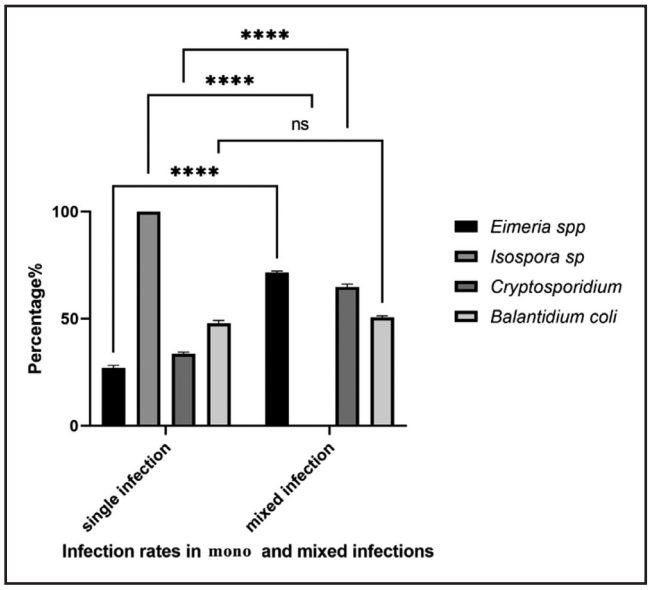

Figure 3. Mono and mixed infections comparison. The infection rates were categorized as a mono and mixed infections. The recorded results were compared. The differences were analyzed using Qi square, P≤0.05.

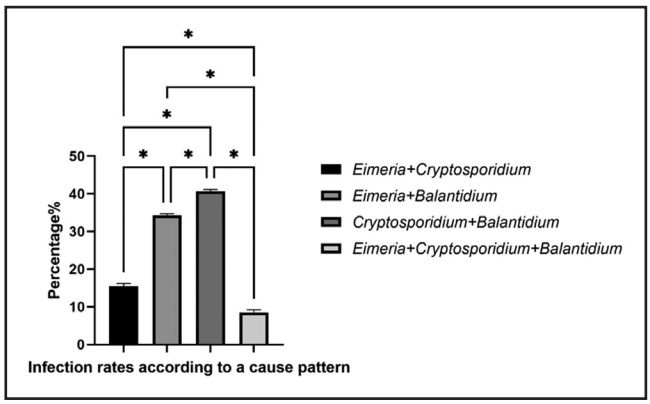

Figure 4. Mixed infections causes and pattern. The causes of protozoal mixed infection were recorded and analysed using Qi square, P≤0.05.

Clinical signs

Out of the total 36 animals infected with a mono-infection, 8 animals (22.22%) showed clinical signs, and they were represented by mild diarrhoea and light green color faeces accompanied by bloody mucus in some emaciated animals (Table 2).

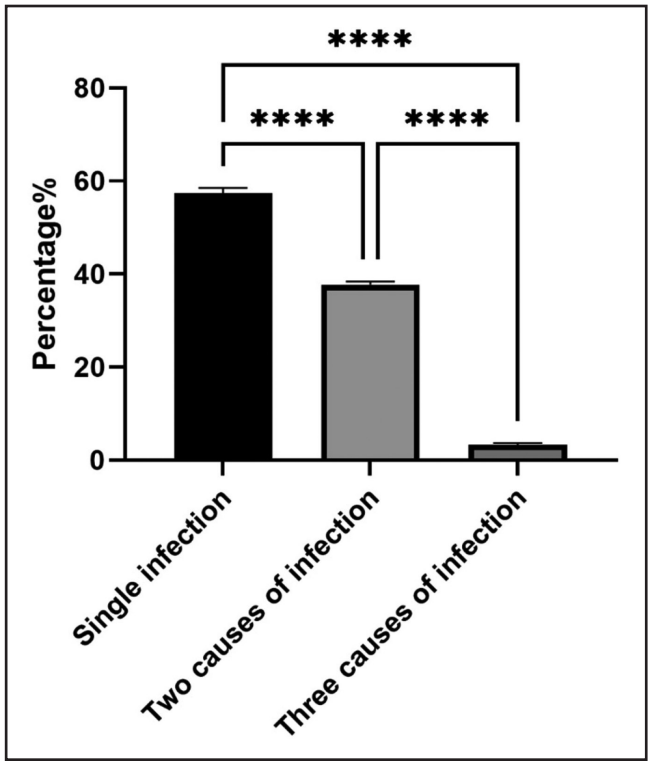

Figure 5. The infection pattern of enteric protozoa. The single and multiple infections due to two or three causes were recorded. The results were analysed using Qi square, P≤0.05.

Pattern of infection

The mono-infection with this parasite appeared in 36 (27.90%) animals, and the mixed infection appeared in 93 animals, or 72.09% (Figure 3,4,5).

The effect of age, sex, and months of the year

a- Age groups

The current study showed that there is an inverse relationship between the age of the animal and infection rates. Out of a total of 82 animals examined, 36 (43.9%) positive cases appeared in the age group of less than two years. The age groups showed a significant effect on the infection rate under the probability level of P<0.05 (Table 4, Figure 6).

b- The sex of the animals

The results indicated that the rates of infection in females and males were close to each other, as the number of males infected with this parasite reached 21 (23.59%) of the total 89 animals tested, while the females were 108 (21.64%) of the total 499 tested animals, and

Table 4. Number and percentages of infected camels according to the age group

Age groups (Year)	Number of examined camels	Number and percentage of infected camels							
		Eimeria spp.		*Isospora* sp.		*Cryptosporidium* spp.		*Balantidium coli*	
		No.	%	No.	%	No.	%	No.	%
Less than 2	82	36*	43.90	-	-	24	29.26	22*	26.82
2-4	151	36	23.84	-	-	47	31.12	58	38.41
5-6	140	22	15.71	-	-	43	30.71	65	46.42
7-8	106	15	14.15	2	1.88	20	18.86	50	47.16
9-10	45	3*	6.66	-	-	9	20	23	51.11
More than 10	64	17	26.56	-	-	12	18.75	38*	59.37
Total	588	129		2		155		256	

* Significant differences, P<0.05

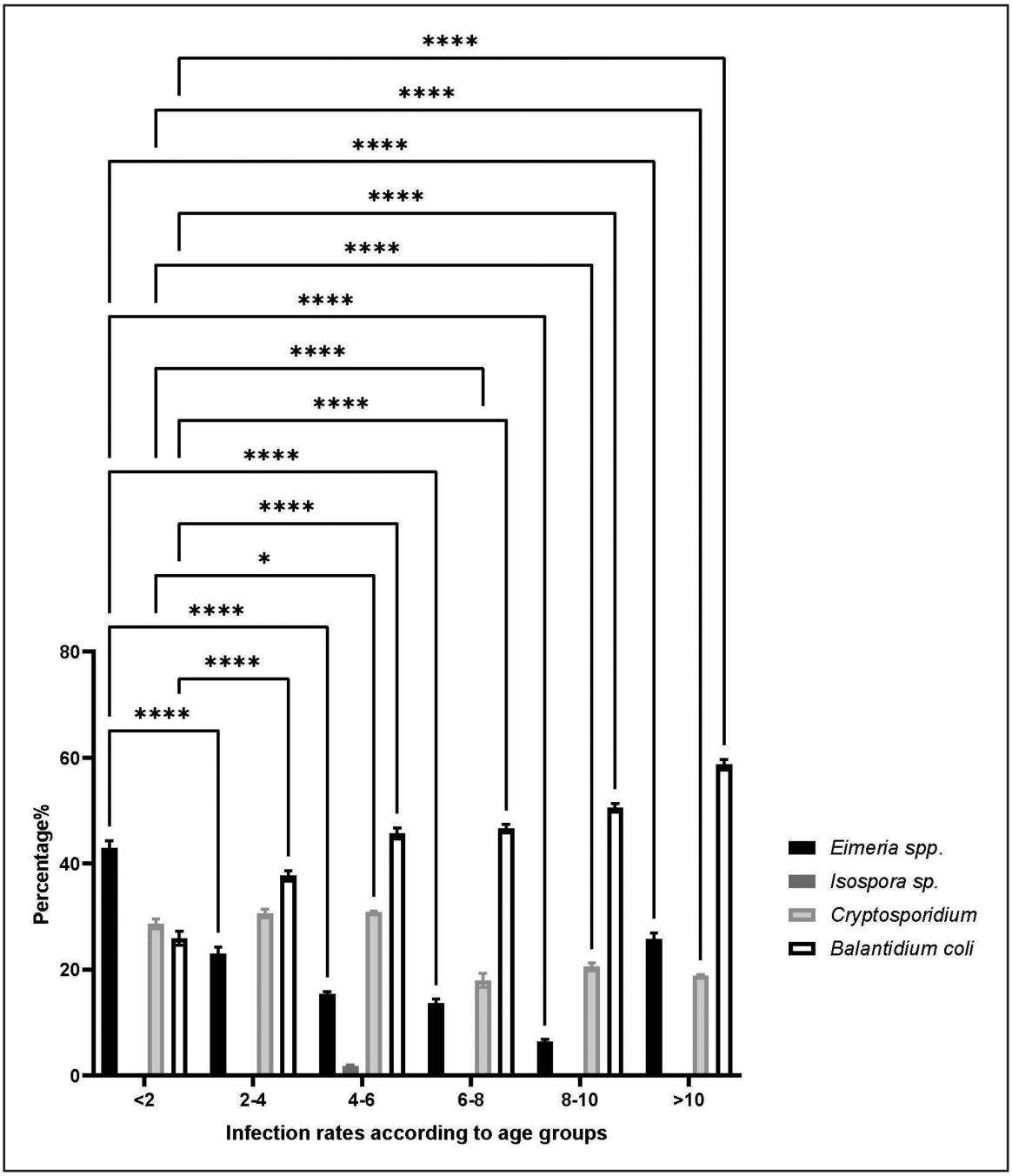

Figure 6. Effect age on the infection rates. The collected samples were categorized according to age group. The results were analysed using Qi square, P≤0.05.

the animal's sex did not show any significant effect on the percentage of the tested animals (Table 5, Figure 7).

c- Months of study
It was found that the months of the year had a significant effect (P<0.05) on the incidence of, where the highest infection rate was in November, followed by March then April (33.96%, 33.92%, and 32.72%), respectively, while the lowest infection rate was in July (3.70%) (Table 6, Figure 8).

Isospora
Two samples appeared positive (0.34%) by flotation method with Scheicher's sugar solution (Figure 1).

Shape and description
The length of the egg oocysts ranged between 26.4-27 µm, the width was 19.7-20.9 µm, the color was brown, the polar cap was absent, the wall was bilateral, and the shape of the parasite was oval (Table 1, Figure 2).

Clinical signs
No clear clinical signs were observed in animals infected with this parasite during the study period.

Pattern of infection
Through the study, it was found that the mono-infection was only recorded (Figure 3,4,5).

Effect of age, sex, and months of the year

a- Age:
The infection appeared in the age group 6- 8 months, with an infection rate of 1.88% (Table 4, Figure 6).

b- Sex:
The infection did not appear in males and the number of infected females was 2 (0.40%) (Table 5, Figure 7).

c- Months of the year:
The infection was recorded for one month only in March at an infection rate of 3.57%, and it did not appear in the other months (Table 6, Figure 8).

Cryptosporidium
Examining faecal samples by flotation methods with Scheither's sugar solution and using the modified Ziehl–Neelsen method, the infection appeared in 155 animals (26.36%) (Figure 1). Shape and description:

The dimensions of *Cryptosporidium* oocysts were 4.1-5.5 µm and 3.9-4.6 µm. Shape of both species was oval to spherical, with thin wall (Table 1, Figure 2).

Clinical signs
The clinical signs of *Cryptosporidium* infections appeared in 16 animals (30.18%). The main signs were yellowish green diarrhea with foul smell. The animals look dehydrated (Table 2).

Table 5. Number and percentages of infected camels according to the sex of camels

Sex of camel	Number of examined camels	Number and percentage of infected camels							
		Eimeria spp.		*Isospora* sp.		*Cryptosporidium* spp.		*Balantidium coli*	
		No.	%	No.	%	No.	%	No.	%
Male	89	21	23.59	-	-	33*	37.07	38	42.69
Female	499	108	21.64	2	0.40	122	24.44	218	43.68
Total	588	129	21.93	2	0.34	155	26.36	256	43.53

* Significant differences, P<0.05

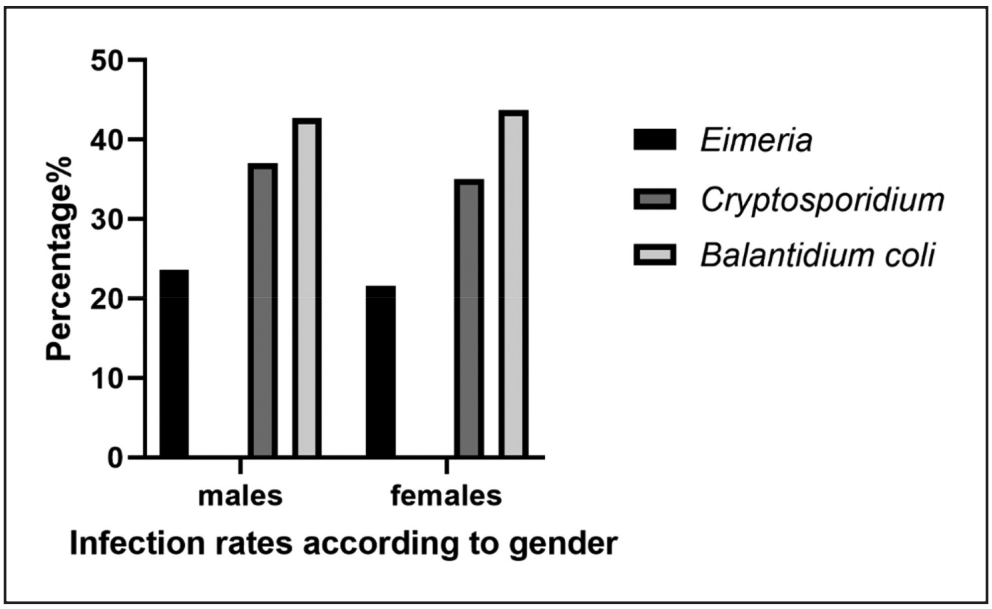

Figure 7. Effect sex on the infection rates. The collected samples were categorized males and females. The results were analysed using Qi square, P≤0.05.

Table 6. Number and percentages of infected camels according to months of the year

Months	Number of examined camels	Number and percentage of infected camels							
		Eimeria spp.		*Isospora* sp.		*Cryptosporidium* spp.		*Balantidium coli*	
		No.	%	No.	%	No.	%	No.	%
January	50	15	30	-	-	4*	8	23	46
February	53	18*	33.96	-	-	3*	5.66	22	41.50
March	55	16	29.09	-	-	3*	5.45	16*	29.09
April	50	6	12	-	-	10	20	28	56
May	51	7	13.72	-	-	12	23.52	31*	60.78
June	56	19*	33.92	2	3.57	25*	44.64	35*	62.50
July	55	18	32.72	-	-	20	36.36	33*	60
August	57	13	22.80	-	-	24*	42.10	15*	26.31
September	56	10	17.85	-	-	23*	41.07	15*	26.78
October	54	2*	3.70	-	-	17	31.48	18	33.33
November	51	5*	9.80	-	-	14	27.45	20	39.21
December	588	129	21.93	2	0.34	155	26.36	256	43.53

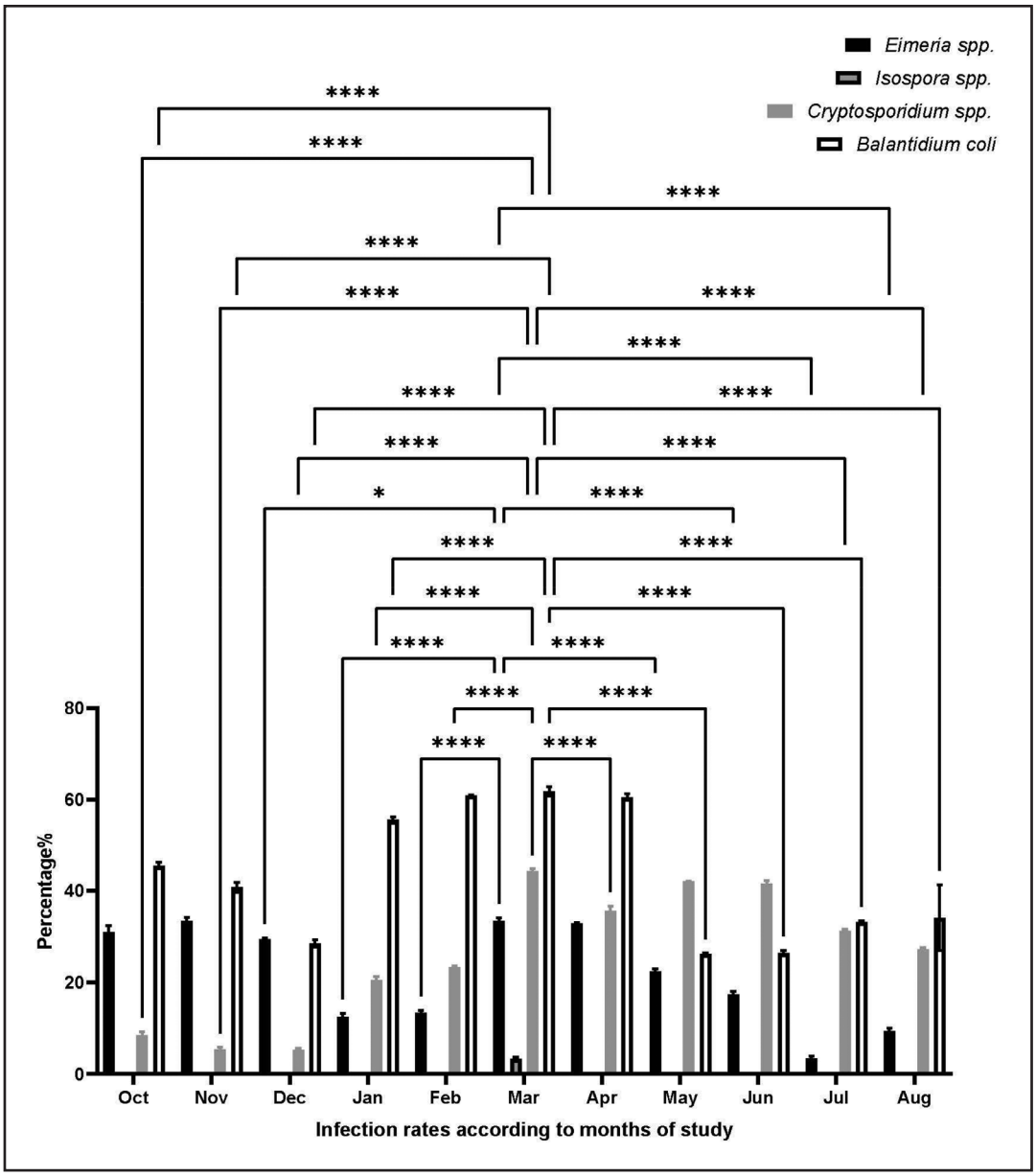

Figure 8. Effect of months on the infection rates. The infection rates were recorded from October 2020 to August 2021. The differences were analysed using Qi square, $P \leq 0.05$.

Pattern of infection
The mono-infection appeared in 53 animals (34.19%) while the mixed form of infection appeared in 102 animals (65.80%) (Figure 3,4,5).

The effect of the age and sex of the animal and the months of the year

a- Age of the animals:
There is a significant effect P<0.05 of animal age on the infection rate. The highest infection rate was recorded in the age group 2-4 years old (31.12%). While the lowest infection rate was in the age group 10 years and above (18.75%) (Table 4, Figure 6).

b- Sex of the animal
There is no significant effect (P>0.05) of the sex on the rates of infection with this parasite. The infection rates of males and females were 37.07% and 24.44% respectively (Table 5, Figure 7).

c- Months of the year
The months of the year had a significant effect (P<0.05) on the prevalence of infection. The highest rate of infection was in March, then May, and June (44.64%, 42.10%, 41.07%, respectively). However, the lowest rates of infection were in November and December (5.66% and 5.45%, respectively) (Table 6, Figure 8).

Balantidium coli
The results of faecal samples examination using direct swab using iodine dye and precipitation with ethyl acetate solution showed the appearance of infection in 256 animals (43.53%) (Figure 1).

Shape and description
Two phases were found (trophozoites and cysts). The dimensions of trophozoites were 63-134 µm and 46-70.4 µm, and their shapes were oval covered with cilia that increase in clarity and length around the mouth opening and the anterior end of the parasite (Table 1, Figure 2). The diameters of cysts ranged between 49-61.2 µm, circular in shape with the presence of a large nucleus that takes an oval shape and cytoplasmic granular (Table 1, Figure 2).

Clinical signs
The recorded clinical signs appeared clearly in 18 animals (14.40%). The faeces were greenish diarrhoea accompanied by lack of appetite (Table 2).

Pattern of infection
Of the total 256 animals infected with *B. coli*, the mono infection appeared in 125 animals (48.82%) while the mixed infection appeared in 131 animals (51.17%) (Figure 3,4,5).

Effect of the age and sex of the animals and the months of the year

a- Age:
The age groups have a significant effect (P<0.05) on parasitic infection rates. There is a direct relationship between age and infection rates, where the highest infection rate (59.37%) was recorded in the age group 10 years and above while the lowest infection rate (26.82%) was recorded in the age group less than two years (Table 4, Figure 6).

b- Sex:
There was no significant effect (P>0.05) of animal sex on infection rates. The number of infected animals of males with this parasite was 38 (42.69%), while females were 218 (43.68%) (Table 5, Figure 7).

c- The months:
It was shown that the months of the year have a significant effect (P<0.05) on infection rates. The highest infection rates were recorded during March, followed by February and April (62.50%, 60.78%, 60%, respectively) while the lowest infection rate was in May (26.31%) (Table 6, Figure 8).

Relationship between species and phase of protozoa and infection rates
Of the total 125 animals infected with a mono infection, the highest percentage (44.44%) that showed diarrhoea were due to the vegetative form, while the cysts had the highest percentage (76.63%) in the cases with no signs (Figure 9).

Types of intestinal protozoa
The mono infection was appeared in 216 animals (58.06%), while the mixed infection appeared in 156 animals (41.93%). The mixed infection was caused by two causes in 142 animals, at a rate of 38.17%, and they were as follows:

- (*Eimeria* spp and *Cryptosporidium* spp) in 25 animals, or 16.02%.
- (*Eimeria* spp and *B. coli*) in 54 animals, or 34.61%.
- (*Cryptosporidium* spp and *B. coli*) in 63 animals, or 40.38%.
- (*Eimeria* spp and *Cryptosporidium* spp) in 25 animals, or 16.02%.
-(*Eimeria* spp and *B. coli*) in 54 animals, or 34.61%.
-(*Cryptosporidium* spp and *B. coli*) in 63 animals, or 40.38%.

While the mixed infection appeared with three causes, namely (*Eimeria* spp and *Cryptosporidium* spp and *B. coli*) in 14 animals, or 8.97% (Figure 9).

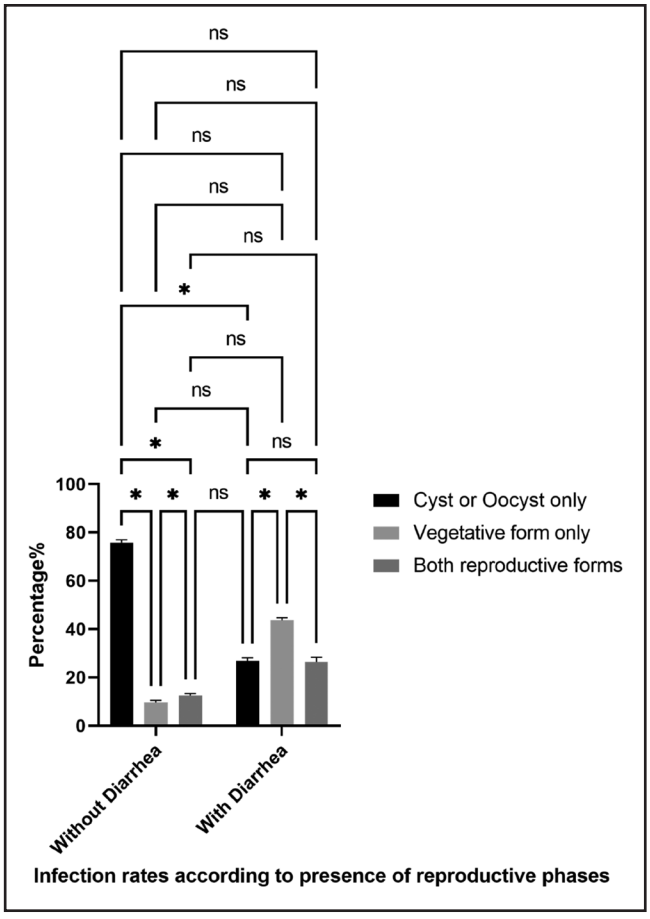

Figure 9. The relation of diarrhea and the reproductive phases. The figure showed the effect of cysts, oocysts and trophozoites on the appearance of diarrhea the main clinical sign during the enteric protozoal infections. The results were analysed using Qi square, P≤0.05.

Other microbiological findings

Bovine viral diarrhea

Our results showed that BVDV antibodies were detected in 7 camels (12.6%) of the 55 camel serum samples tested. Regarding the sex, there were no significant (P>0.05) differences (Table 3).

Physiological changes/Hematology

By using a blood analyzer, the hematological values were calculated for the selected parameters. The control healthy animals showed the highest RBC values (Figure 10) compared with that in the infected group with protozoa and virus which showed significant differences. WBCs represent a significant increment during protozoal infections compared with control and BVDV groups (Figure 10). Both Hb and PCV levels were the highest in healthy animals when compared with either protozoal or viral infections (Figure 11).

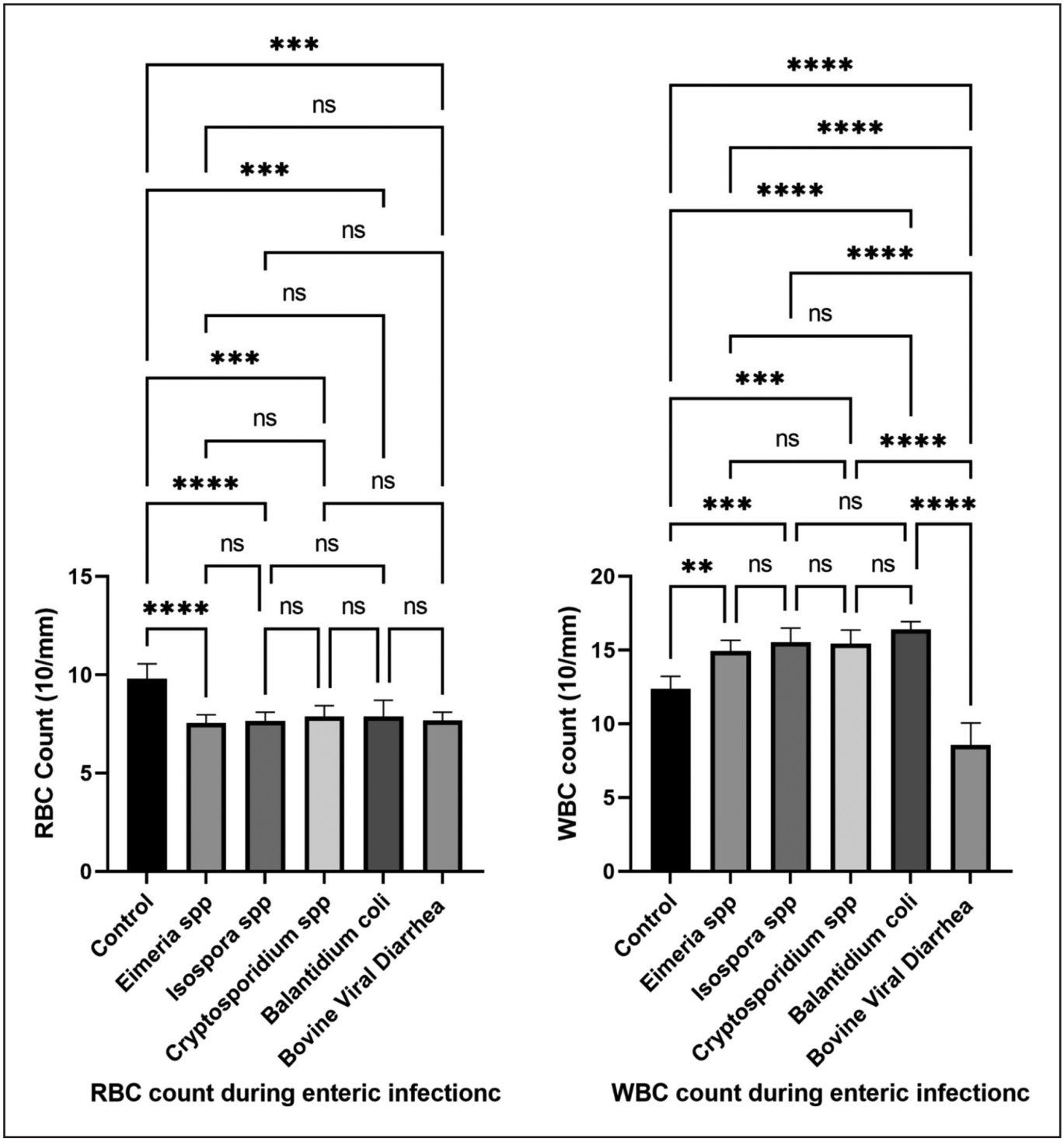

Figure 10. Blood cell count analysis during enteric infections in camels. The blood samples were collected during enteric protozoal and viral infections. The differences either between RBCs (left panel) or WBCs (right panel) during *Eimeria, Isospora, Cryptosporidium, Balantidium* and BVD were calculated and analyzed using Two Way ANOVA P≤0.05.

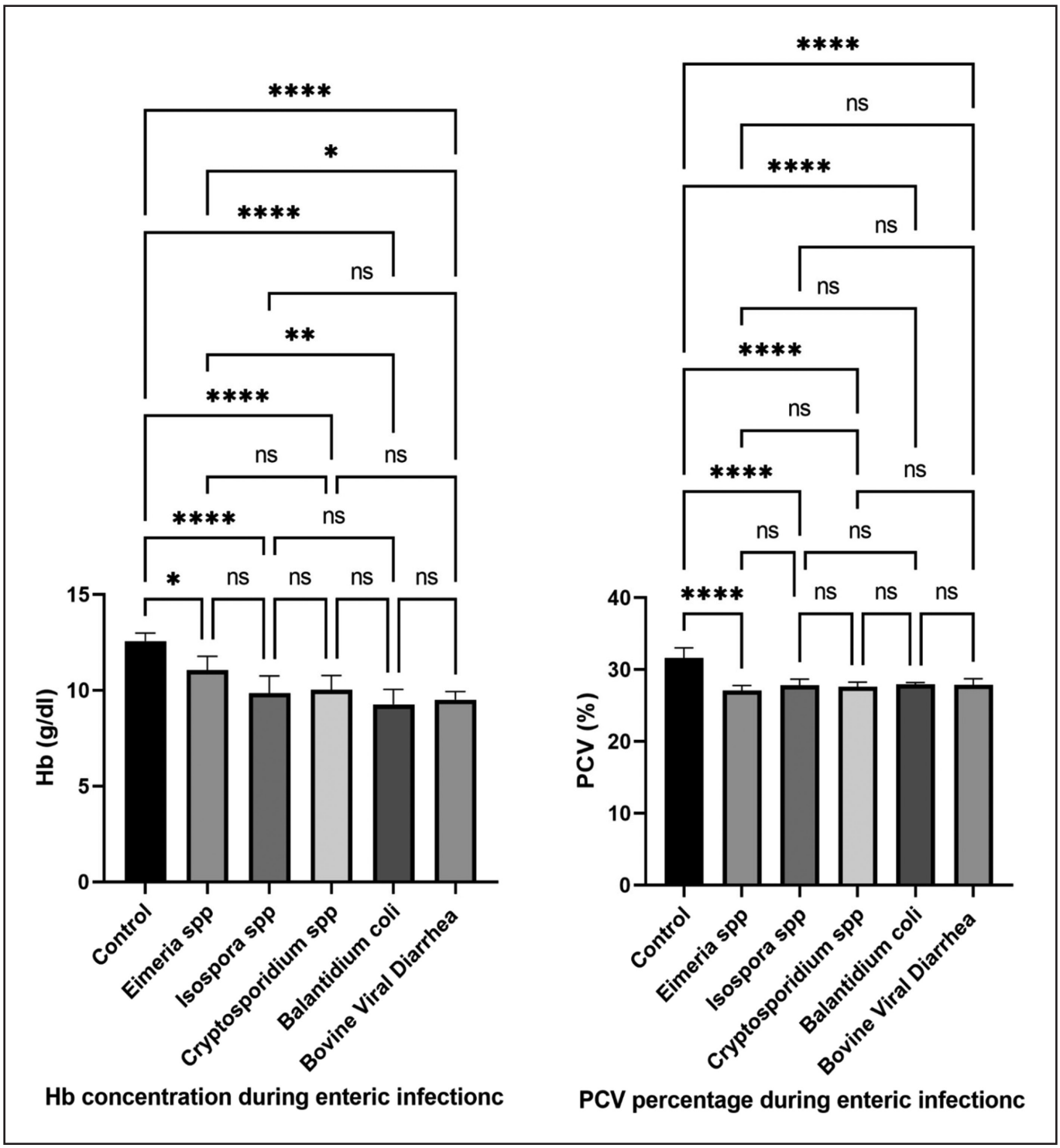

Figure 11. Hb and PCV analysis during enteric infections in camels. The blood samples were collected during enteric protozoal and viral infections. The differences either between Hb (left panel) or PCV (right panel) during *Eimeria*, *Isospora*, *Cryptosporidium*, *Balantidium* and BVD were calculated and analyzed using Two Way ANOVA $P \leq 0.05$.

DISCUSSION

This study reports the infection of intestinal protozoa and viruses in camels regarding Physiological (hematological) and epidemiological factors. In this study, four genera of intestinal protozoa were diagnosed, namely *Eimeria*, *Isospora*, *Cryptosporidium* and *Blantidium*. The prevalence of *Eimeria* in camels was 21.93% which is lower than that recorded by Mirza & AL-Rawas (1976) in Iraq (41.66%, 86% respectively) and in Saudi Arabia in Riyadh and Al-Qassim were 33.89% (40/118) and 38.46% (35/92), respectively (Metwally *et al*., 2020). The rate found by (Partani *et al*., 1999) in India was 25% and (Bouragba *et al*., 2020) at a rate of 17.02% in Algeria. However, the rates were higher than that obtained by Kinne & Wernery (1997) in the UAE (17.2%). The suggested causes of these differences may belong to the time period that the study took place, the type of parasite, the environmental conditions, the difference in temperature and humidity, the geographical location around the world, the methods of management and care, and the use of prevention and treatment methods.

This study diagnosed three types of *Eimeria* that infect camels, namely *E. dromedarii, E. cameli*, and *E. rajasthani*, and the infection rates were 55.81%, 24.03%, and 22.42%, respectively. The last type was recorded for the first time in Iraq. Mirza (1969) recorded *E. dromedarii* and *E. cameli* for the first time in Iraq, with infection rates of 34.3% and 30.6%, respectively. *E. dromedarii* appeared at the highest infection rate compared to other species of *Eimeria*. *E. dromedarii* is more present in the camels of Iraq compared to other species (Mirza & AL-Rawas, 1976), while the lowest percentage was for the type *E. rajasthani* and this is consistent with (Dubey & Pande, 1964) results reported that this type is common in India and less prevalent in other regions. The obtained results showed that the measurements and specifications of cysts are close to what was recorded by Dubey & Pande (1964), Mirza (1969), and Dubey (2018).

The rates of *Eimeria* infections varied according to the age of the camels, as it appeared that the highest infection rate was 43.90% for the age group less than two years, and it could be due to the sensitivity of young ages to infection as the immune system still immature or it may be gained from their infected mothers that excreted eggs in the feces, which provides the opportunity to infect the young.

The results showed a slight discrepancy in the infection rates between males without a significant difference in all recorded protozoa. This is due to live of males and females together and under the same conditions, and this result was similar to that found by Lyons *et al*. (1991) and Maingi & Munyua (1994).

The current study found that the months of the year have a significant effect on the rates of infection with the enteric protozoa, and the highest rate of infection was during November, followed by March, then April, and its lowest was recorded in the month of July.

The high rate of infection in the months of November, March, and April is attributed to the temperatures in Iraq during these months which are closer to the average temperature suitable for the maturation of oocysts and cysts of protozoa. The lowest levels in July may relate to the high temperatures and drought during the summer and low relative humidity. These conditions are not suitable for the maturation and development of parasite egg oocysts in the environment, which leads to the cessation of the maturation process and the destruction of egg oocysts (Al Se, 2013).

The mono-infection appeared with *Eimeria* species by 27.90%, while the mixed infection was 72.09%. The same result was found by Kasim *et al*. (1985), who indicated that mixed *Eimeria* infections were more prevalent. The recorded clinical signs were similar to the result mentioned by Hussein *et al*. (1987).

This study recorded *Isospora* for the first time in Iraqi camels. Kinne & Wernery (1997) reported that the infestation of camels with this parasite was accidental. The mentioned measurements of the *Isospora* oocysts in this study were like what was found by Schuster *et al*. (2017) in Dubai. No infection appeared in males, and the number of infected females was 2 i.e. 0.40%. The suggested interpretation of this result could be the accidental infection in camels with this parasite and also the number of females examined is much greater than the number of males.

The infection rate of *Cryptosporidium* is 26.36%. In Iran, the infection rate in *Camelus dromedarius* was 10% (Yakhchali & Moradi, 2012) while in another study was 24% (Bouragba *et al*., 2020). This discrepancy is due to the animal's species and age, the number of models examined, and the diagnostic methods used, as well as the climatic conditions and breeding methods during the study times, which negatively or positively affect the levels of study.

The average measurements were 4.8 x 4.2 µm. *Cryptosporidium* appeared spherical in shape and its sizes were close to what was recorded by (Al-Amery & Al-Amery, 2022) in water buffaloes in Babylon province, Iraq. There is a significant effect of age on the rate of infection with this parasite. The highest rate of infection was in the age group 2- less than 4 years, followed by the age group 4- less than 6 years and then the group less than two years. The infection rate of this study differs from the results of the study of *Cryptosporidium* in calves which was done by (Al-Azzawi, 2003; Al-Zubaidi, 1994). This difference may be attributed to the small number of examined camels with an age group of fewer than two years compared to the rest of the ages because they are sold for slaughter purposes. In addition, the difference in the type of animal and the presence of chronic and parasite-carrying cases in which the animal continues to throw oocysts with feces (Fayer *et al*., 1991).

The lowest rate of infection appeared in the age group of 10 years and above. Similar results were found by (Al-Azzawi, 2003; Yakhchali & Moradi, 2012), who found that infection rates decrease with age increase. The reason can relate to the acquired immunity in some animals which is developed due to repeated exposure to the infection. There is no significant effect of animal sex on infection rates (Fayer *et al*., 1991).

There is a significant effect of the months on the rates of *Cryptosporidium* infection. The highest infection rate appeared in March, followed by May and then June, and this result is consistent with (Snyder *et al*., 1978; Rahaman *et al*., 1984) observations. This abundance of parasitic infections in these months could relate to several reasons such as the increase the rain and the births during the spring and also the frequent gathering of camels around drinking water sources which can increase the water contamination with infected camel feces, thus helps the spread of the parasite (Razavi *et al*., 2009; Sazmand *et al*., 2012).

The infection rate decreased during the winter months until reached the lowest level in December, which is similar to Al-Azzawi (2003) results. This increase can be attributed to the decrease in the average temperature in this month, as the decrease in temperature to less than 5°C leads to the suspension of the life cycle of the parasite inside the host and the destruction of oocysts in the environment (Faubert & Litvinsky, 2000).

The results of our study did not agree with the findings of Al-Zubaidi (1994), who noticed that the highest percentage of infection rates was in August, while the lowest infection rate was in March. Another Iraqi researcher: Al-Ta'i (1997) found that the highest rate of infection in cows, sheep, and goats was in November (Faubert & Litvinsky, 2000) and the lowest percentage was in February. The reason for these differences could be the difference in the studied hosts and the birth seasons, as the rates of infection with the parasite increase with the increase in the number of newborn animals. In addition, the continuous movement of camels from agricultural villages to the desert and vice versa might increase the chance of getting an infection. Another important factor that can interpret these differences is the current study period, as our study lasted 11 months.

The parasitic infection rate reached 43.53%, which is higher than the rate found by (Sabaa, 1989) in buffaloes in Iraq (1.01%), by (Maleky, 1998) in humans in Iran (4.03%), (Devera *et al*., 1999) Venezuela in pigs (33.3%), and (Al-Haris, 2001) in horses in Iraq (2.07%). The measurements and specifications of the parasite studied in this study are close to that mentioned by Adam *et al*., (1971), Schwarts & Clarkson (1999), Wernery & Kaaden (2002) and Zaman (1998).

It was found that age had a significant effect on infection rates, as the highest infection rate was recorded in the age group of more than 10 years while the lowest infection rate was in the group less than two years old. It is noted that the parasite infection rates are directly proportional to the age of the animal. This result agrees with results obtained Marti & Hale (1986) in the United States and Pakandl (1994) in the Czech Republic in pigs, and Al-Haris (2001) in Iraq's horses. It was noted that there was no significant effect on the rates of infection between females and males (43.68% and 42.69% respectively). This could be due to grazing the females and males in the same pasture.

The months of the year showed a significant effect on infection rates, as the highest infection rate was in March, followed by February and April, and the lowest infection rate was in May. The highest infection rate was in August and the lowest was in March.

In Iraq, the wet seasons are February, March, and April. This may interpret why the highest infection was in these months as the ability of cysts to stay viable from several days to several weeks in wet stools and non-hot climates. The vegetative phases are less resistant, as they destroy within 15-30 minutes at 40°C and 10-15 minutes in cold weather (Schwarts & Clarkson, 1999) and this indicates that the parasite is highly affected by hot seasons.

Clinical signs appeared in 14.40% of examined animals. The clinical signs did not appear in all infected animals which could relate to the presence of parasites in a commensal relationship in the gut of camels (Sengar & Singh, 2005). This result is consistent with the results mentioned by Ali & Abdelaziz (1982); Kayum *et al*. (1992); Shommein & Osman (1987); Vosdingh & Vanniasingham (1969) who reported that there were small numbers of camels that showed clinical signs of infection with the parasite *B. coli*.

It was found through the study that trophozoites were the predominant phase in diarrheic cases in the feces as the responsibility of trophozoites for the emergence of clinical signs (Sengar & Singh, 2005). However, in non-diarrheic cases, the cysts were the most abundant.

CONCLUSION

The study was carried out for eleven months from October 2020 up to the end of August 2021 and included the collection of feces and blood from camels of Al-Muthanna Province in Iraq. Different techniques were used for analyzing and testing samples such as Sheather's sugar solution, sporulation, sedimentation with ethyl acetate solution, ELISA and blood analyzer. The authors succeeded in recording of *Eimeria rajasthani*, *Isospora orlovi* for the first time in Iraqi camels that showed clinical signs of diarrhea, dehydration, and emaciation. There was a significant effect of age on infection rates of *Eimeria* spp. as the highest *Eimeria* ratio was in ages of less than two years animals. The infection rates were also affected with months which reached the highest ratios of *Eimeria* in October while the lowest ratio of *Eimeria* was recorded in July. BVDV infection rate was 12.6% in camels that suffered from diarrhea. There is no significant effect of sex on the onset of the viral disease in camels. For hematological parameters, there were significant differences in RBCs, WBCs, Hb, and PCV values in protozoal and BVDV infections.

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Data availability Statement

All data generated or analysed during this study are included in this published article.

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Conflict of interest

The authors declare that they have no conflict of interests either financial or non-financial interests.

Author contributions

Mohenned A. Alsaadawi: The conception and design of the study, interpretation of data and final approval of the version to be submitted and collecting the samples and designing the study. Ali Mosa Rashid Al-Yasari: acquisition of data and drafting the article, preparing and reading the histopathology slides. Nawar Jassim Alsalih: collecting the samples and designing the study and methodology and drafting the article and revising it critically for important intellectual content.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Veterinary Medicine College Ethical Approval Committee (Application Number: 202002).

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