Traditional Identification of Sarcocystis Spp. in Slaughtered Camels in Al-Najif Province, Iraq

Ola A. Aggar[1]*, Mohammed T.S. Al-Zubaidi [2]

Abstract

Background: *Sarcocystis* is one of the most important intracellular protozoan parasites which infect many domestic animals, including camels as an intermediate host resulting to variable economic looses in particular in asymptomatic cases.

Aim: This study was aimed for traditional detection of *Sarcocystis* spp. in tissue samples of slaughtered camels in Iraq.

Materials and methods: Totally, 200 slaughtered camels (*Camelus dromedarius*) of different ages and sexes were selected from the abattoir of Al-Najaf province (Iraq) during October (2021) to July (2022). After slaughter, fresh tissue samples collected from different organs were subjected for macroscopic inspection and then for microscopic examination using of trichinoscopy, squeezing and acid pepsin digestion test.

Results: Although, no positive samples were detected by macroscopic examination; the findings of microscopic examination reported that the infection rates with *Sarcocystis* spp. using the trichinoscopy, acid pepsin digestion method, and squeezing were 49%, 72.5% and 56%, respectively. Furthermore, the major risk factors related to the development of sarcocystosis in camels detected that the prevalence rate of *Sarcocystis* spp. was significantly higher in esophagus and diaphragm than skeletal muscle and heart; older aged (>4 years) than younger (≤4 years) camels, and in females more than males.

Conclusion: This study demonstrated the widespread prevalence of *Sarcocystis* spp. in slaughtered camels in Al-Najaf, Iraq. Considering the facts that the infection rate is massive, the impacts of *Sarcocystis* on musculoskeletal function, feeding, health, and productivity are necessary to study, especially its economical importance in the future. Also, the role of camel in transmission of the parasite between domestic animal and possibly to human requires to furthermore studying.

Keywords: Sarcocystosis, Acid pepsin digestion, Trichinoscopy, Squeezing, *Camelus dromedaries*

[1*, 2] Department of Parasitology, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq Emails: Ula.Abd1105a@covm.uobaghdad.edu.iq @covm.uobaghdad.edu.iq

***Corresponding author:-** Ola A. Aggar

*Department of Parasitology, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq Emails: Ula.Abd1105a@covm.uobaghdad.edu.iq @covm.uobaghdad.edu.iq

Introduction

Sarcocystis is one of the most prevalent protozoal infections in domestic animals which caused by Sarcocystidae family, Eucoccidiorina order of Apicomplexa phylum. The parasite was first observed by the Swiss scientist Friedrich Miescher as milky white threads in skeletal muscle of a deer mouse (Peromyscus) in 1843; and then, these threads were named "Miescher's Tubules" (More et al., 2016; Strazdaitė-Žielienė et al., 2022). After 124 years later (1967), *Sarcocystis* was first described by electron microscopy as spindle- or crescent-shaped bodies (bradyzoites) similar to those seen in other apicomplexan protozoa like *Toxoplasma* and *Eimeria*. In the 1970s, bradyzoites isolated from the sarcocysts of bird muscles were inoculated in mammalian cells to detect the development of asexual stage to sexual stages and oocysts (Al-Hyali et al., 2011; Nahed et al., 2014; Asal and Al Zubaidy, 2016; Verma et al., 2017).

In camels, there were six different names have been used to describe the main *Sarcocystis* species including *S. cameli*, *S. ippeni*, *S. camelicanis*, *S. camelocanis*, *S. miescheri* and *S. meischeri*. However, these studies showed that the taxonomy of *Sarcocystis* spp. of camels still debatable as a result of restricted collected samples and weak descriptions of structural features (Dubey et al., 2015a, b). To date, only sporocysts have been discovered in dog feces indicating that this animal act as a potential final host to infecting camel; however, the complete life cycle of *Sarcocystis* spp. in camels need to more investigation (Al-Khalidi et al., 1988; Omar and Hussain 2021; El-Mahdi et al., 2023). Additionally, distribution of *Sarcocystis* in intermediate hosts has been influenced by a number of variables including immunological condition of a host, quantity of oocysts and sporocysts consumed, and the species of *Sarcocystis* involved (Wernery et al., 2014;

Dubey et al., 2015a). Microscopic examination recorded that the cysts can be found in heart, tongue, skeletal muscles such as masseter and limb muscles, esophagus, diaphragm, and other tissues causing typically asymptomatic or subclinical form of disease in camels (Valentine, 2017; Gareh et al., 2020). Due to lack of commercially available standard diagnostic test, asymptomatic or unspecific clinical signs of disease with existence of microscopic sarcocysts embedded deeply within the muscles make the diagnosis of acute sarcocystosis in camels is difficult (Al-Taie and Abdulla, 2011; Saeed et al., 2018). Therefore, many serological assays such as Agar-gel diffusion tests (AGD), complement fixation tests (CFT), hemagglutination inhibition tests (HIT), indirect fluorescent antibody tests (IFA), sabin-feldman dye tests, isoenzymes electrophoresis, western blots, direct agglutination tests (DAT), and enzyme-linked immunosorbent assay (ELISA) have been developed in the past three decades to determine antibodies against the parasite; however, standardization of these techniques is greatly challenged (Zimmerman and Crisman, 2008; Nageib and Kuraa, 2018; Aghwan et al., 2021). Post slaughter, a variety of macroscopic and microscopic diagnostic methods were used to detect the presence of sarcocysts in inspected muscles (El-Dakhly et al., 2011; Bayati, 2021). In Iraq, neither studies nor information are available about the prevalence *Sarcocystis* spp. in camels. Hence, this represent the first Iraqi study that aimed to investigate the prevalence of *Sarcocystis* spp. in slaughtered camels by the traditional methods, with detection correlation between the rate of positive infections and different risk factors (age, sex, months and organ).

Materials and methods

Ethical approval

The current study was licensed by the Scientific Committee of the Department of Parasitology in the College of Veterinary Medicine (University of Baghdad, Baghdad, Iraq).

Study animals and sampling

Totally, 200 slaughtered camels (*Camelus dromedarius*) of different ages (< 2 years - ≤ 5 years) and sexes (107 males and 93 females) were selected randomly from the abattoir of

Al-Najaf province (Iraq) during October (2021) to July (2022). Approximately, 100 grams of fresh tissue samples were collected from different organs (each esophagus, diaphragm, skeletal muscle and heart) of each slaughtered camel into individual plastic labeled containers for the macroscopic and microscopic examinations.

Traditional examination

Macroscopic inspection

All fresh meat samples that collected from the esophagus, diaphragm, skeletal muscle and heart were tested by naked eye to detect the presence of sarcocysts in these organs (Gareh *et al*., 2020).

Microscopic examination

1. Trichinoscopy: Small piece of each esophagus and diaphragm samples was crushed strongly between two glass slides and examined microscopically to detect the sarcocystes (Kamil and Faraj, 2020; Castro-Forero *et al.*, 2022).
2. Acid Pepsin Digestion Test: According to method described by different researchers, a total 20 grams of each muscle sample were crushed, digested in digestion fluid, incubated, filtered through gauze, and finally centrifuged. The sediment was smeared on a slide, stained by Giemsa stain, and examined microscopically (Mavi *et al*., 2020).
3. Squeezing: This method was carried out using approximately 3-5 grams of each sample which ripped and pressed to extract the meat juice. A drop of meat juice of each sample was transferred on a slide, stained with Giemsa stain and examined microscopically to detect the presence of bradyzoites (Al-Saadi *et al.*, 2020).

Statistical analysis

The findings of present study were analyzed using the GraphPad Prism version 6.0.1.298 (*GraphPad Software Inc., USA*) Software. Chi-square (x^2) was applied to detect significant differences between values of traditional diagnostic methods; while, Odds ratio was applied to estimate statistical association between age, sex and month with the positive traditional. Values were represented as percentage (%), and statistical differences in obtained results were considered significant at $P<0.05$ (Gharban, 2023).

Results

Among totally 200 meat samples collected from the slaughter camels, no positive samples were detected by macroscopic examination. However, the infection rate with *Sarcocystis* spp. using the acid pepsin digestion method was 72.5% (145/200) which significantly ($P<0.05$) higher than detected by trichinoscopy [49% (98/200)] and squeezing [56% (112/200)] (Table 1). The morphometric description of *Sarcocystis* spp. using the microscopic trichinoscopy technique revealed that the presence of elliptical form of the parasite in esophagus, which showed the cyst septa dividing the internal compartments that appeared as dark structures (Figure 1). Morphologically, bradyzoites (cystizoites) stained by the Giemsa stain were appeared having the characteristics of dark blue banana-shape with different sizes and little pointed anterior end with rounded posterior end. Nucleus was located near the last third part in close to the posterior end were not clear obviously (Figure 2).

Table (4.1): Total infection rate of sarcocystosis in camel's meat by traditional methods

Sample	**Total No.**	**Trichinoscopy**	**Squeezing**	**Acid pepsin digestion**
Meat	200	98 (49%)	112 (56%)	145 (72.5%)
Chi-Square (χ^2)		6.153 *		
Significance * ($P<0.05$)				

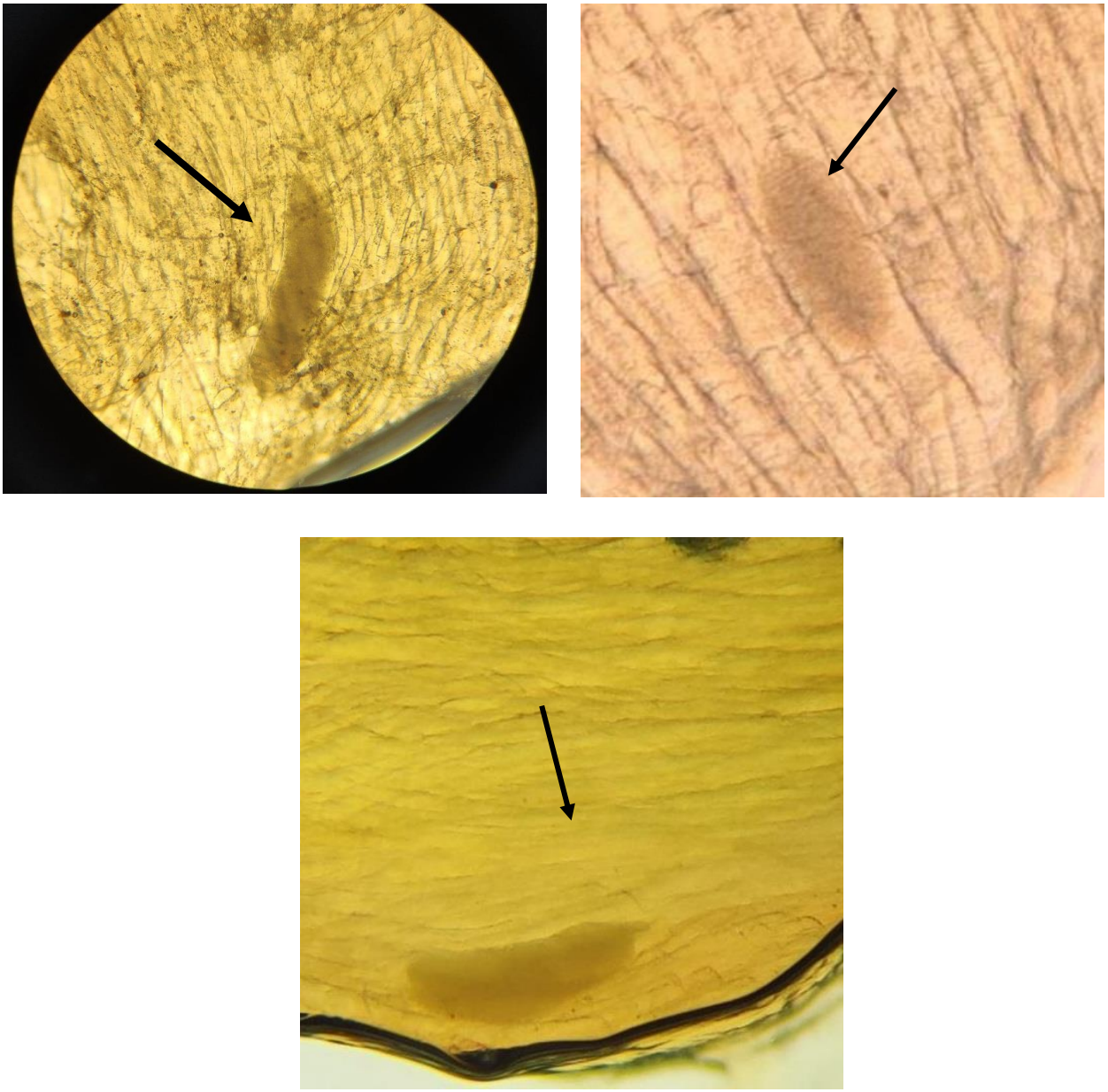
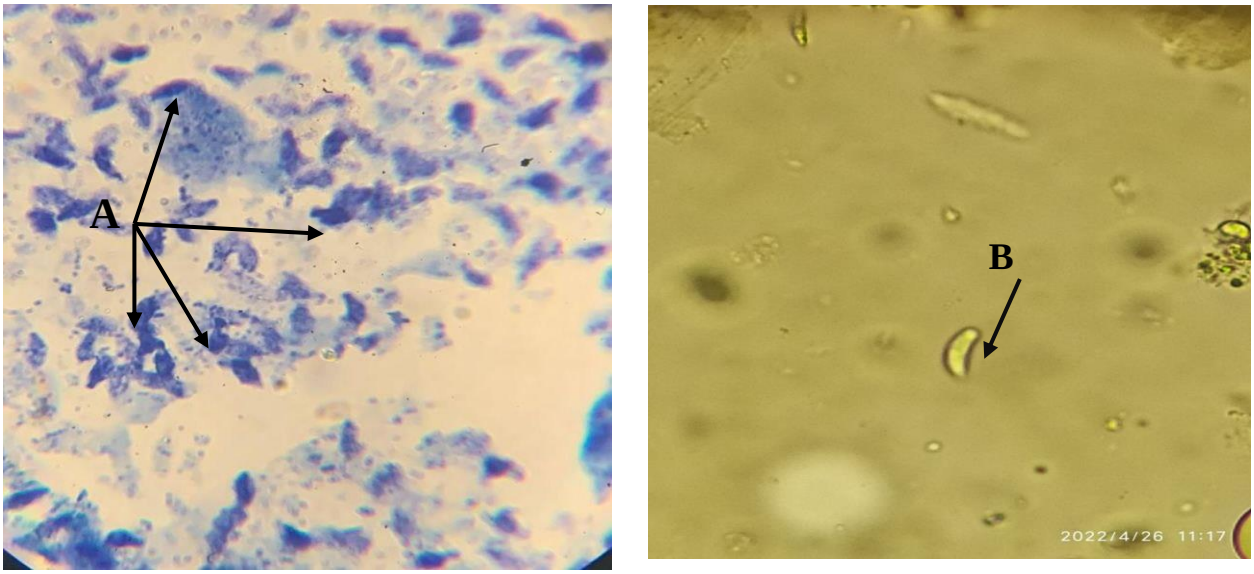


Figure (1): *Sarcocystis* spp. in tissue samples of esophagus by trichinoscopy (10 X)



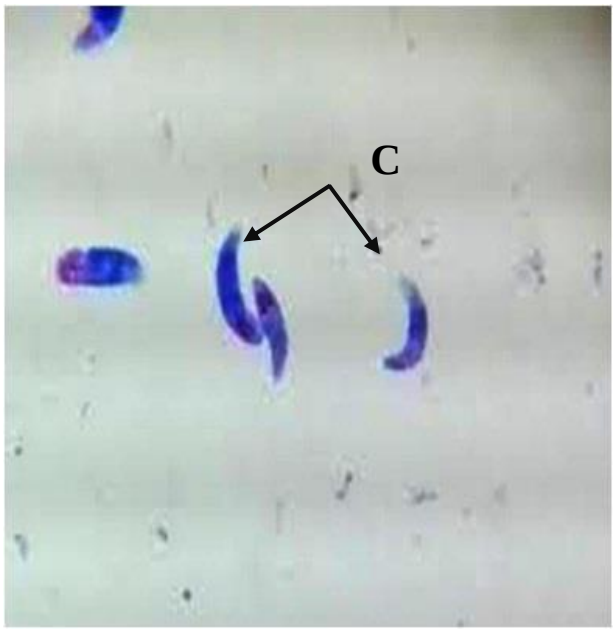


Figure (2): (A and B): Bradyzoites (Cystizoites) of *Sarcocystis* spp. in tissue samples stained with Giemsa stain; (C): Nucleus

B. Infection rate according to organ

Microscopically, the high infection rate were showed in esophagus (84.29%) and diaphragm (79.17%) when compared to values of other organs; skeletal muscle (64%) and heart (50%), (Figure 3).

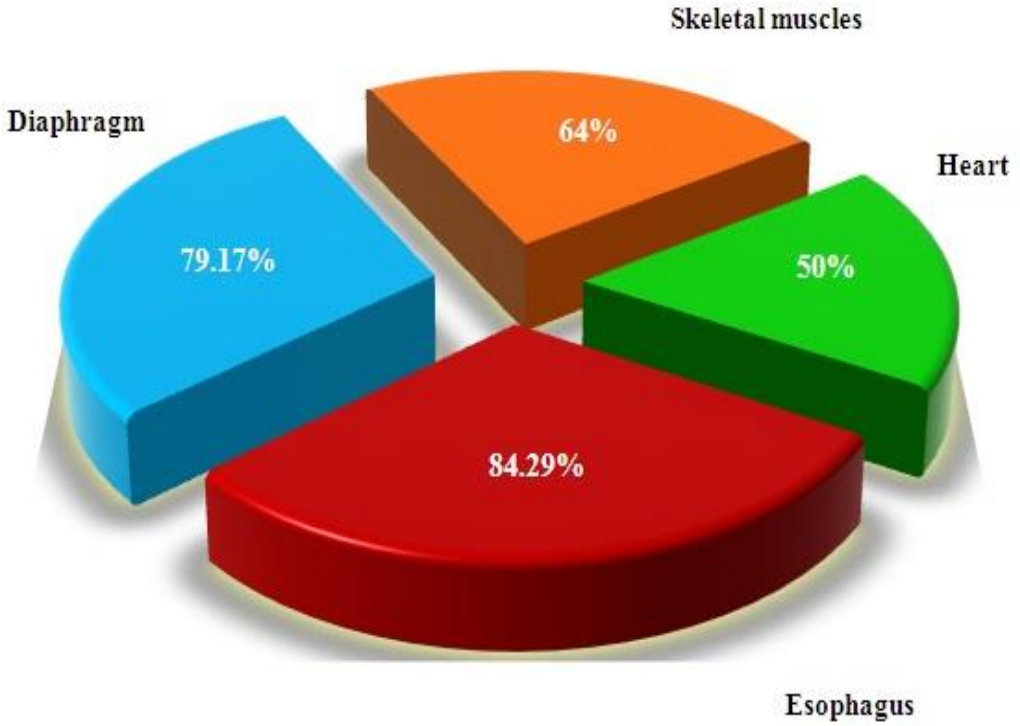


Figure (3): Total infection rate of sarcocystosis in camels by traditional method according to organ

C. Infection rate according to age

Concerning age, camels aged > 4 years old were revealed significantly (P<0.05) a higher infection rate (89.6%) of *Sarcocystis* spp. than those aged ≤ 4 years old (44%), (Table 2).

Table (2): Total infection rate of sarcocystosis in camels by traditional method according to age

Age (year)	Total No.	Positives	
		No.	%
≤ 4	75	33	44
> 4	125	112	89.6 *
Total	200	145	72.5
Chi-Square (χ^2)	-	-	5.793
Vertical comparison between values (%) refers to significant differences at (P<0.05) *			

D. Infection rate according to sex

In comparison between both sex groups, significant prevalence (P<0.05) of sarcocystosis in camels was higher in females (76.67%) than males (69.09%), (**Table 4.3**).

Table (3): Total infection rate of sarcocystosis in camels by traditional method according to sex

Sex	Total No.	Positives	
		No.	%
Male	110	76	69.09
Female	90	69	76.67 *
Total	200	145	72.5
Chi-Square (χ^2)	-	-	4.002
Vertical comparison between values (%) refers to significant differences at (P<0.05) *			

Discussion

Among the most common parasites in domestic ruminants, *Sarcocystis* spp. can generate significant economic losses when causing clinical and subclinical disease. Up to now, at least five species of *Sarcocystis* have been named in camel (Dubey et al., 2015a). Macroscopic examination of collected tissue samples revealed that no gross lesions were observed in all tested sample tissues as reported by many studies (Valinezhad et al., 2008; Motamedi et al., 2011; Hamidinejat et al., 2013; Gareh et al., 2020), but in contrast with others (Latif et al., 1999; Rabie et al., 2021).

As shown in the present study, the prevalence of *Sarcocystis* infection in slaughtered camels in Al-Najaf province using the microscopic examination was 72.5%, 56% and 49% by acid pepsin digestion, squeezing and trichinoscopy, respectively. In comparison with the results of other previous and current studies, the prevalence rate of *Sarcocystis* spp. was 91.6% in Iraq (Latif et al., 1999); 47.3-66.3% in Afghanistan (Kirmse and Mohanbabu, 1986); 42.3% (Mandour et al., 2011), 75% (Gareh et al., 2020) and 85.5% (Rabie et al., 2021) in Egypt; 52.3% (Rahbari et al., 1981), 52.6% (Shekarforoush et al., 2006), 83.6% (Valinezhad et al., 2008) and 51.5% (Hamidinejat et al., 2013) in Iran; 6.18% in Jordan (Al-Ani and Amr, 2017); 100% in Mongolia (Fukuyo et al., 2002); 47.32% in Morocco (Kirmse 1986); 88.4% (Fatani et al., 1996); 41.3-50% (Omer et al., 2017) and 40.54% (Metwally et al., 2020) in Saudi Arabia; 82.5% in Somalia (di Sacco, 1989); 45.45% in Southern Ethiopia (Woldemeskel and Gumi, 2001); 81% in Sudan (Hussein and Warrag, 1985); and 50% in United Arab Emirates (El-Afifi et al., 1963). Differences between the reported infection rates could be attributed to various factors, including degree of contact between camels and dogs since some camel pastoralists are not using dogs in camel rearing (camels are reared on a free-range basis in the desert). Furthermore, different husbandry management systems, as well as diagnostic methods could influence the infection rate. However, the high infection rate in intermediate hosts is attributed to the fact that the farm animals are raised in close association with guard dogs which contaminate pastures with *Sarcocystis* sporocysts. Latif et al. (1999) mentioned that

the infected dogs could shed about 200 million sporocysts during the course of infection. The sporocysts are infective already when passed in the feces and this factor plays an important role in the epidemiology of sarcocystiosis (Dubey et al., 2015a, b).

Analysis of results on distribution of *Sarcocystis* spp. in different organs showed that researches on camel have reported dissimilar tissue patterns. The results of this study that *Sarcocystis* spp. was found in all tested organ, but significantly more prevalent in esophagus and diaphragm are in consistent with that reported other studies as *Sarcocystis* spp. can infect usually the muscular tissue of the heart, tongue, esophagus, and diaphragm (Wahba et al., 2014; Ahmed et al., 2016). Some studies reported that sarcocystosis is more prevalent in the cremaster muscle of an animal with orchitis, which observation encouraged us to investigate sarcocysts in testicular tissue samples (Bucca et al., 2011; SAĞLAM and KELEŞ, 2016). Meanwhile, some studies found the diaphragm of camels to be the most commonly affected site (Al-Ani and Amr, 2017), whereas another study identified the heart as the most commonly infected organ (Shekarforoush et al. 2006). Oryan et al. (2010) seen that the predilection sites for *Sarcocystis* spp. appear to be the esophagus, tongue, and heart. Gareh et al. (2020) observed that dissemination of *Sarcocystis* in different organs was especially in the esophagus with a prevalence rate of 49%; whereas, Rabie et al. (2021) observed that *Sarcocystis* was found in esophageal, heart and ocular muscles, with a higher infection rate in esophagus (85.5%). Asopa et al. (2023) show the prevalence of *Sarcocystis* spp. in dromedary camels from Bikaner district of Rajasthan was in tongue and esophagus. However, variations in distribution of *Sarcocystis* among camel organs could be explained by different *S. cameli* strains or differences in definite host species (Hamidinejat et al., 2013).

Age was another significant risk factor associated with infection. In this study, infection rate was increased significantly in old camels (>4 years) when compared to the younger ones (≤4 years). Similar findings were reported by other studies in Egypt (El-Bahy et al. 2019), Iran (Hamidinejat et al. 2013), and Saudi Arabia (Omer et al. 2017). The higher prevalence of *Sarcocystis* infection in aged camels may likely reflect the higher rate of slaughtering of aged camels compared with younger animals, slow development of detectable cysts may explain the lower prevalence in young camels (Valinezhad, et al. 2008, Hamidinejat et al. 2013, Omer et al. 2017). Additionally, some owners kept the young camels indoor for breeding, and therefore, the young camels might be less exposed to infection than older ones (Valinezhad, et al. 2008, Hamidinejat et al. 2013).

The sex of the animal found to be a significant variable associated with infection. Our results reported the higher prevalence of females compared to males, which in constable with that seen by other many studies in southern Ethiopia (Woldemeskel and Gumi 2001), Iran (Valinezhad et al. 2008), and Egypt (Rabie et al., 2021) as the male camels being at higher risk of infection than females. Omer et al. (2017) male camels were less than two years old when they were slaughtered while females were over 4 years old, and the prevalence of *Sarcocystis* infections in older camels was much higher than that of younger camels and the same applies for sex as the prevalence of parasite in females was much higher than in males. This difference might be attributed to the fact that most female animals are kept indoor for reproduction under good and clean management, whereas most of the males are left for grazing outdoor and used by owners for hard work; they may therefore be more exposed to the infection (Romero et al. 2017). No significant difference in frequency of sarcocystosis between male and female camels was identified by Hamidinejat et al. (2013). Lack of relationship between sex and infection rates has shown in similar studies on camels (Woldemeskel and Gumi 2001; Shekarforoush et al. 2006; Valinezhad et al. 2008).

Conclusion

This study demonstrated the widespread prevalence of *Sarcocystis* spp. in slaughtered

camels in Iraq. Considering the facts that the infection rate is massive, the impacts of *Sarcocystis* on musculoskeletal function, feeding, health, and productivity are necessary to study, especially its economical importance in the future. Also, the role of camel in transmission of the parasite between domestic animal and possibly to human requires furthermore studying.

Authors' contribution

OAA: Collection of tissue samples, extraction of DNAs and preparation of Mastermix tubes; MTSA: PCR analysis, sequencing and statistical analysis of obtained results. All authors have written of the manuscript and approved on the final copy of it.

Acknowledgments

The authors are thankful to the Colleges of Veterinary Medicine, University of Baghdad for providing the necessary facilities for the study. However, all materials used in this study were purchased by the authors and no external funds were received for this study.

Competing interests

No

References

1. Aghwan, S. S., Al-Bakri, H. S., and Albaqqal, S. M. (2021). Comparison the efficiency of different techniques for the diagnosis of Toxoplasma gondii infection in slaughtered ewes. *The Iraqi Journal of Veterinary Medicine*, *45* (1), 19-23.
2. Ahmed, A.M., Elshraway, N.T., and Youssef, A.I. (2016). Survey on Sarcocystis in bovine carcasses slaughtered at the municipal abattoir of El-Kharga, Egypt. *Veterinary World*, *9*(12), 1461.
3. Al-Ani, F.K., and Amr, Z. (2017). Sarcocystis spp prevalence in camel meat in Jordan. *Dairy Vet. Sci. J*, *4*, 1-3.
4. Al-Hyali, N. S., Kennany, E. R., and Khalil, L. Y. (2011). Fate of macrosarcocyst of Sarcocystis gigantea in sheep. *The Iraqi Journal of Veterinary Medicine*, *35*(2), 87-91.
5. Al-Khalidi, N.W., Daoud, M. S., Shubber, A.H., and Al-Alousi, T.I. (1988). A survey for internal and external parasites in dogs in Mosul (Iraq). *Iraqi Journal of Agricultural Sciences*, *53*(3), 9-17.
6. Al-Saadi, S.A., Al-Mussawi, K.A., and Muhammed, H.A. (2020). Molecular Identification of Sarcocystis Species Infection in Sheep in Karbala Governorate–Iraq. *Medico Legal Update*, *20*, 889-895.
7. Al-Taie, L. H., and Abdulla, S. H. (2011). Seroprevalance of toxoplasmosis in sheep and goat: Iraq/Sulaimania. *The Iraqi Journal of Veterinary Medicine*, *35*(1), 16-24.
8. Asal, S. N., and Al Zubaidy, I. A. (2016). Seroprevelance study of Toxoplasma gondii in horses and camels animal in Wasit province. *The Iraqi Journal of Veterinary Medicine*, *40*(1), 177-182.
9. Asopa, S., Joshi, A., Dadhich, H., and Vyas, I. (2023). Prevalence of Sarcocysts in Tongue and Oesophagus of Dromedary Camels from Bikaner district of Rajasthan. *Indian Journal of Veterinary Sciences and Biotechnology*, *19*(1), 96-98.
10. Bayati, S. M. (2021). In Vitro Genotoxic Effects of Sarcocystis gigantea Cystizoites Acetone Powder Extract on Sheep Lymphocytes. *The Iraqi Journal of Veterinary Medicine*, *45*(2), 41-45.
11. Bucca, M., Brianti, E., Giuffrida, A., Ziino, G., Cicciari, S., and Panebianco, A. (2011). Prevalence and distribution of Sarcocystis spp. cysts in several muscles of cattle slaughtered in Sicily, Southern Italy. *Food Control*, *22*(1), 105-108.
12. Castro-Forero, S.P., Bulla-Castañeda, D.M., LÓPEZ BUITRAGO, H.A., Díaz Anaya, A.M., Madeira de Carvalho, L.M., and Pulido-Medellín, M.O. (2022). SARCOCYSTIS SPP., A PARASITE WITH ZOONOTIC POTENTIAL. *Bulgarian Journal of Veterinary Medicine*, *25*(2), 1-15.
13. di Sacco, B. (1989). Sarcocystis in Somali camel. *Parassitologia*, *31*(2-3), 133-136.

14. Dubey, J.P., Calero-Bernal, R., Rosenthal, B.M., Speer, C.A. and Fayer, R. (2015a). Sarcocystosis of animals and humans. 2nd Ed, CRC Press. Pp: 235-238.
15. Dubey, J.P., Hilali, M., Van Wilpe, E., Calero-Bernal, R., Verma, S.K., and Abbas, I.E. (2015b). A review of sarcocystosis in camels and redescription of Sarcocystis cameli and Sarcocystis ippeni sarcocysts from the one-humped camel (Camelus dromedarius). *Parasitology*, *142*(12), 1481-1492
16. El-Afifi, A., Abden, A.H., and El-Sawah, H.M. (1963). Incidence of sarcosporidiosis in United Arab Emirates. *Vet Med J Giza*, *8*, 195-201.
17. El-Bahy, N., El-Bagory, A.E.R., AbouLaila, M., Elkhatam, A., and Mady, H.M. (2019). Prevalence of *Sarcocystis fusiformis* and Hydatid cyst among Different Ruminants at Menofia Governorate, Egypt. *Journal of Current Veterinary Research*, 1(1): 1-10.
18. El-Dakhly, K.M., El-Nesr, K.A., El-Nahass, E.S., Hirata, A., Sakai, H., and Yanai, T. (2011). Prevalence and distribution patterns of Sarcocystis spp. in buffaloes in Beni-Suef, Egypt. *Tropical animal health and production*, *43*, 1549-1554.
19. El-Mahdi, M., Rabie, S.A., Hassanine, R.M.E.S., Hassan, A.A., Abo Elhussien, O.F., Ghoneum, M., and El-Gerbed, M.S. (2023). Molecular Identification, Pathogenesis, and Life Cycle of Sarcocystis cruzi from Cattle (Bos taurus) in New Valley Governorate, Egypt. *Journal of Parasitology Research*, *2023*.
20. Fatani, A., Hilali, M., Al-Atiya, S., and Al-Shami, S. (1996). Prevalence of Sarcocystis in camels (Camelus dromedarius) from Al-Ahsa, Saudi Arabia. *Veterinary parasitology*, *62*(3-4), 241-245.
21. Fukuyo, M., Battsetseg, G., and Byambaa, B. (2002). Prevalence of Sarcocystis infection in meat-producing animals in Mongolia. *Southeast Asian journal of tropical medicine and public health*, *33*(3), 490-495.
22. Gareh, A., Soliman, M., Saleh, A.A., El-Gohary, F.A., El-Sherbiny, H. M., Mohamed, R.H., and Elmahallawy, E.K. (2020). Epidemiological and histopathological investigation of Sarcocystis spp. in slaughtered dromedary camels (Camelus dromedarius) in Egypt. *Veterinary Sciences*, *7*(4), 162.
23. Gharban, H.A. (2023). Molecular prevalence and phylogenetic confirmation of bovine trichomoniasis in aborted cows in Iraq. *Veterinary world*, *16*(3), 580-587.
24. Hamidinejat, H., Hekmatimoghaddam, S., Jafari, H., Sazmand, A., Haddad Molayan, P., Derakhshan, L., and Mirabdollahi, S. (2013). Prevalence and distribution patterns of Sarcocystis in camels (Camelus dromedarius) in Yazd province, Iran. *Journal of Parasitic Diseases*, *37*, 163-165.
25. Hussein, H.S., and Warrag, M. (1985). Prevalence of Sarcocystis in food animals in the Sudan. *Tropical Animal Health and Production*, *17*(2), 100-101.
26. Kamil, J.K., and Faraj, A.A. (2020). Identification of Sarcocystis spp. in Imported Beef by Traditional and Molecular Technique. *Plant Archives*, *20*(2), 25-36.
27. Kirmse, P. (1986). Sarcosporidiosis in equines of Morocco. *British Veterinary Journal*, *142*(1), 70-72.
28. Kirmse, P., and Mohanbabu, B. (1986). Sarcocystis sp. in the one-humped camel (Camelus dromedarius) from Afghanistan. *British Veterinary Journal*, *142*(1), 73-74.
29. Latif, B.M.A., Al-Delemi, J.K., Mohammed, B.S., Al-Bayati, S.M., and Al-Amiry, A.M. (1999). Prevalence of Sarcocystis spp. in meat-producing animals in Iraq. *Veterinary parasitology*, *84*(1-2), 85-90.
30. Mandour, A.M., Rabie, S.A., Mohammed, N.I., and Hussein, N.M. (2011). On the presence of Sarcocystis mieschери sp. nov. in camels of Qena Governorate. *Egyptian Academic Journal of Biological Sciences, E. Medical Entomology and Parasitology*, *3*(1), 1-7.

31. Mavi, S.A., Teimouri, A., Mohebali, M., Yazdi, M.K.S., Shojaee, S., Rezaian, M., and Keshavarz, H. (2020). Sarcocystis infection in beef and industrial raw beef burgers from butcheries and retail stores: A molecular microscopic study. *Heliyon*, *6*(6), e04171.
32. Metwally, D.M., Al-Otaibi, T.T., Al-Turaiki, I.M., El-Khadragy, M.F., and Alajmi, R.A. (2020). Identification of Sarcocystis spp. in one-humped camels (Camelus dromedarius) from Riyadh and Dammam, Saudi Arabia, via histological and phylogenetic approaches. *Animals*, *10*(7), 1108.
33. More, G., Regensburger, C., Gos, M.L., Pardini, L., Verma, S.K., Ctibor, J., and Venturini, M.C. (2016). Sarcocystis masoni, n. sp. (Apicomplexa: Sarcocystidae), and redescription of Sarcocystis aucheniae from llama (Lama glama), guanaco (Lama guanicoe) and alpaca (Vicugna pacos). *Parasitology*, *143*(5), 617-626.
34. Motamedi, G.R., Dalimi, A., Nouri, A., and Aghaeipour, K. (2011). Ultrastructural and molecular characterization of Sarcocystis isolated from camel (Camelus dromedarius) in Iran. *Parasitology Research*, *108*, 949-954.
35. Nageib, B., and Kuraa, H. (2018). Microscopical and serological studies with ultrastructure description of Sarcocystis species in sheep in Assiut. *Assiut Veterinary Medical Journal*, *64*(157), 46-55.
36. Nahed, H., Ghoneim, W.M., and Nader, M.S. (2014). Occurrence of zoonotic sarcosporidiosis in slaughtered cattle and buffaloes in different abattoirs in Egypt. *Global Veterinaria*, *13*(5), 809-813.
37. Omar S.S., and Hussain S.B. (2021). Recent advances in molecular characterization of Sarcocystis species in some meat producing animals: An updated review. *Iraqi Journal of Agricultural Sciences*, 55 (2), 41-47.
38. Omer, S.A., Alzuraiq, A.A., and Mohammed, O.B. (2017). Prevalence and molecular detection of Sarcocystis spp. infection in the dromedary camel (Camelus dromedarius) in Riyadh city, Saudi Arabia. *Biomedical Research (0970-938X)*, *28*(11).
39. Oryan, A., Ahmadi, N., and Mousavi, S.M.M. (2010). Prevalence, biology, and distribution pattern of Sarcocystis infection in water buffalo (Bubalus bubalis) in Iran. *Tropical animal health and production*, *42*, 1513-1518.
40. Rabie, S., Hassanine, R.M.E.S., A Hassan, A., Abo Elhussien, O., and BM EL-Mahdi, M. (2021). Morphological and molecular characterization of Sarcocystis cameli and Sarcocystis ippeni from the muscles of One-Humped Camel (Camelus dromedarius) in New valley Governorate, Egypt. *SVU-International Journal of Veterinary Sciences*, *4*(3), 103-118.
41. Rahbari, S., Bazargani, T.T., and Rak, H. (1981). Sarcocystosis in the camel in Iran. *J Fac Vet Med Univ Tehran*, *37*, 1-10.
42. Romero, S., Carletti, T., Franco, C.D., Moré, G., Schnittger, L., and Florin-Christensen, M. (2017). Seropositivity to Sarcocystis infection of llamas correlates with breeding practices. *Veterinary Parasitology: Regional Studies and Reports*, *10*, 65-70.
43. Saeed, M.A., Rashid, M.H., Vaughan, J., and Jabbar, A. (2018). Sarcocystosis in South American camelids: The state of play revisited. *Parasites and vectors*, *11*(1), 1-11.
44. SAĞLAM, K., and KELEŞ, H. (2016). Sarcocystosis in the Cremaster Muscle of an Infertile Bull, Spermiostasis and Orchitis. *Kocatepe Veterinary Journal*, *9*(3), 252-254.
45. Shekarforoush, S.S., Shakerian, A., and Hasanpoor, M.M. (2006). Prevalence of Sarcocystis in slaughtered one-humped camels (Camelus dromedarius) in Iran. *Tropical Animal Health and Production*, *38*(4), 301.
46. Strazdaitė-Žielienė, Ž., Baranauskaitė, A., Butkauskas, D., Servienė, E., and Prakas, P. (2022). Molecular Identification of

Parasitic Protozoa Sarcocystis in Water Samples. *Veterinary sciences*, *9*(8), 412-
47. Valentine, B.A. (2017). Skeletal muscle. *Pathologic basis of veterinary disease*, 908.
48. Valinezhad, A., Oryan, A., and Ahmadi, N. (2008). Sarcocystis and its complications in camels (Camelus dromedarius) of eastern provinces of Iran. *The Korean Journal of Parasitology*, *46*(4), 229.
49. Verma, S.K., Lindsay, D.S., Grigg, M.E., and Dubey, J.P. (2017). Isolation, culture and cryopreservation of Sarcocystis species. *Current protocols in microbiology*, *45*(1), 20D-1.
50. Wahba, A., Ayoub, M., Soliman, K. (2014). Light and ultrastructure of Sarcocystis spp. of camels and associated pathological changes. Anim. Health Res. J., 2, 143–158.
51. Wernery, U., Kinne, J., & Schuster, R. K. (2014). *Camelid infectious disorders*. OIE (World Organisation for Animal Health).
52. Woldemeskel, M., and Gumi, B. (2001). Prevalence of Sarcocysts in One-humped Camel (Camelus dromedarius) from Southern Ethiopia. *Journal of Veterinary Medicine, Series B*, *48*(3), 223-226.
53. Zimmerman, K.L., and Crisman, M.V. (2008). Diagnostic equine serology. *Veterinary Clinics of North America: Equine Practice*, *24*(2), 311-334.