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RESEARCH ARTICLE

Histopathological Evaluation of Intestinal *Eimeria* and *Ogmocotyle*-like Trematode Infections in Slaughtered Dromedary Camels

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ABSTRACT

Camelus dromedarius is a resilient, desert-adapted species; however, it remains susceptible to gastrointestinal parasitic infections that often go undiagnosed in clinically healthy individuals. This study investigated the occurrence, anatomical distribution, and histopathological impact of protozoan and helminth parasites in the small intestinal segments (duodenum, jejunum, and ileum) of 14 asymptomatic dromedaries slaughtered in Blida, Algeria. Histopathological analyses revealed subacute catarrhal enteritis, villous atrophy, epithelial degeneration, and inflammatory infiltration. Sexual stages of *Eimeria cameli* and *Eimeria dromedarii* were frequently identified, particularly within the crypts of Lieberkühn and villous epithelium, respectively. Overall, 78.57% of animals were found to be parasitized, with *E. cameli* present in 57.14%, and one individual harboring both species. Morphometric and Periodic Acid–Schiff (PAS) staining supported the identification of distinct developmental stages of both species. Notably, *Ogmocotyle*-like trematodes were detected in the duodenum of two camels, representing the first report of such organisms in this host. These flukes were associated with focal epithelial necrosis, eosinophilic infiltration, and luminal debris, underscoring their pathological significance. Despite the absence of molecular confirmation, histopathology, histochemistry, and morphometric analysis collectively enabled a detailed characterization of these infections. These findings highlight the importance of post-mortem surveillance and accurate parasitic identification in camels. Future studies should incorporate molecular tools to enhance species-level resolution and explore host–parasite immunological dynamics.

INTRODUCTION

The domesticated one-humped (*Camelus dromedarius*) and two-humped *(Camelus bactrianus*) camels serve as essential resources for transportation, meat and milk production, and cultural practices across arid regions such as North Africa and the Middle East (Faye and Konuspayeva, 2012; Mohandesan et al., 2017). Despite their remarkable physiological adaptations to desert conditions, camels remain susceptible to various infectious diseases, including gastrointestinal parasitic infections (Sazmand and Joachim, 2017; Dubey and Schuster, 2018).

Among these, coccidiosis caused by *Eimeria* spp. is a notable protozoan disease with both pathological and economic implications. While infected camels may show nonspecific signs such as diarrhea, weight loss, and reduced productivity, subclinical infections particularly in adults, are frequent and often overlooked despite active oocyst shedding (Parsani et al., 2008; Kheirandish et al., 2012; Bouragba et al., 2020). The main *Eimeria* species identified in dromedaries include *E. cameli, E. dromedarii, E. rajasthani*, and *E. pellerdyi*, with *E. cameli* being the most frequently reported (Hussein et al., 1987; El-Khabaz et al., 2019).

Histological identification of *Eimeria* developmental stages—such as microgamonts, macrogamonts, and oocysts—offers critical insight into the localization and progression of infection within the intestinal mucosa. However, misidentification remains a challenge in camelid coccidiosis literature, with some studies inaccurately classifying species or developmental forms (Luna, 1968; Dubey, 2019).

In addition to protozoan infections, helminthic parasites—especially trematodes—have occasionally been reported in camels. The most common species include *Fasciola hepatica*, *Paramphistomum* spp., and *Schistosoma* spp (Parsani et al., 2008). However, data on trematodes from the family Notocotylidae, such as *Ogmocotyle*, are lacking, and such organisms have not been previously documented in camels.

This study aimed to investigate the occurrence, anatomical distribution, and histopathological effects of protozoan and helminthic parasites in the small intestines of clinically healthy, slaughtered dromedary camels. By integrating histopathological, histomorphometric, and semi-quantitative techniques, we provide novel findings on the distribution of *Eimeria* species and report, for the first time, an *Ogmocotyle*-like trematode infection in this host species.

MATERIALS AND METHODS

Animals and Sample Collection

This study was designed as an exploratory, abattoir-based investigation. The study was conducted on 14 clinically healthy dromedary camels (*Camelus dromedarius*) comprising 10 females and 4 males, aged between 6 and 14 years. The animals belonged to two local Algerian breeds: *Saharaoui* (n = 9) and *Targui* (n = 5) and were slaughtered at the Blida municipal abattoir. From each camel, approximately 10 cm-long tissue segments were collected from the duodenum, jejunum, and ileum. All samples were macroscopically examined for visible pathological alterations and immediately fixed in 10% neutral-buffered formalin for 72 hours.

Histopathological and Histochemical Procedures

Formalin-fixed samples were processed using an automated tissue processor (Leica TP1020, Germany), embedded in paraffin (Thermo Shandon EG1150H, Germany), and sectioned at 5 µm thickness using a rotary microtome (Shandon AS325, Germany). Sections were stained with hematoxylin and eosin (H&E) for general histopathological evaluation (Luna, 1968). For detection of glycogen, glycoprotein, and mono/polysaccharide contents within parasitic structures, selected sections were stained with Periodic Acid–Schiff (PAS) reagent (Bioptica AUS240, Italy).

Histomorphometric Analysis

Morphometric evaluation of parasitic developmental stages was performed as described by Dubey and Schuster (2018). Ten representative microgamonts, macrogamonts, and oocysts per slide were randomly selected, photographed under 1000× magnification, and measured using ImageJ software (NIH, USA). Results were expressed as mean ± standard deviation (SD).

Semi-Quantitative Scoring of Histopathological Lesions

Histological evaluation was performed on H&E- and PAS-stained sections. Lesions were scored semi-quantitatively based on the severity of villous atrophy, epithelial degeneration or necrosis, crypt/glandular changes, hemorrhage, hyperemia, and inflammatory infiltration. Ten random microscopic fields per intestinal segment were examined at 20× magnification. Lesion severity was graded as follows: 0 = none, 1 = mild, 2 = moderate, and 3 = severe, according to Dubey (2018). Mild lesions were defined as focal alterations affecting a limited portion of the examined field, moderate lesions as multifocal or more extensive changes, and severe lesions as diffuse or widespread alterations with marked disruption of tissue architecture.

Statistical Analysis

Differences in histopathological lesion scores among intestinal segments were analyzed using two-way analysis of variance (ANOVA), followed by Tukey's *post hoc* test. A p-value of < 0.05 was considered statistically significant. All statistical analyses were performed using GraphPad Prism version 8.0 (GraphPad Software Inc., USA).

Ethics Statement

The methodology protocols of the present study followed the ethical concepts in animal experimentation, recommended by FELASA and approved by the Algerian Ministry of Higher Education and Scientific Research (Executive Decree 10-90 supplementing the Algerian government decree 04-82) and the AASEA (45/DGLPAG/DVA.SDA.14).

RESULTS

Macroscopic Observations

All examined intestinal segments (duodenum, jejunum, and ileum) displayed varying degrees of wall thickening. Multiple small, whitish to yellowish pinpoint lesions were observed on the mucosal surfaces, particularly in the jejunum and ileum (Fig. 1A–B).

Histopathological Findings

Microscopic examination revealed subacute catarrhal enteritis across all intestinal regions. Key findings included villous atrophy, mucosal hyperemia, epithelial degeneration and necrosis, inflammatory infiltration, and occasional hemorrhages (Fig. 1C–F; Table 1). Developmental stages of coccidian parasites—namely, microgamonts, macrogamonts, and oocysts—were frequently detected, with the ileum showing the highest parasitic burden.

Eimeria cameli was widely distributed in the lamina propria and submucosa, particularly within the crypts of Lieberkühn. In contrast, *E. dromedarii* was confined to the villous epithelium (Table 1; Fig. 1A–D). Infections with *E. dromedarii* and *Ogmocotyle*-like trematodes were associated with pronounced epithelial disruption, necrotic debris accumulation, and dense inflammatory infiltrates in the duodenum (Fig. 1E-F).

Inflammatory responses consisted primarily of lymphocytes and macrophages, with moderate eosinophil presence and occasional plasma cells and neutrophils. The ileum exhibited the most intense inflammation (96.4%), particularly in camels infected with *E. cameli* (Fig. 2; Fig. 3A–B). Trematode-associated lesions featured eosinophil-rich infiltrates and extensive necrosis of the columnar epithelium in the duodenum.

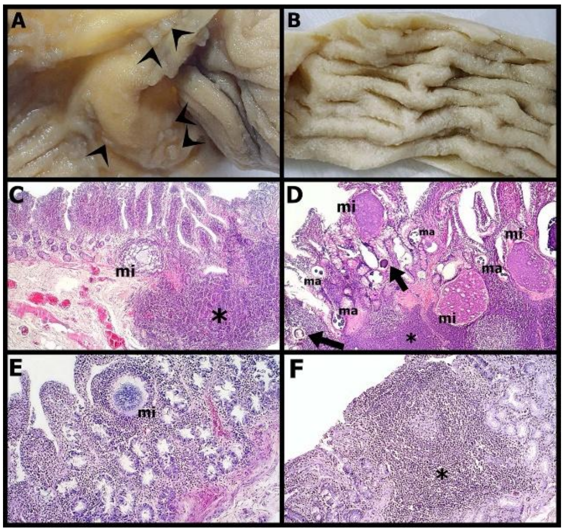

Figure 1. Macroscopic and histopathologic images of *Eimeria cameli*. A, B) Macroscopic view of pinhead-sized whitish foci (arrowhead) and thickening of the intestine in formalin fixed small intestinal section. C, D) Large microgamonts (mi), macrogamonts (ma), and oocysts (arrow) of *Eimeria cameli* in lamina propria and submucosa, with mild to severe mononuclear cell infiltration (asterisk) and congestion in the ileum. Hematoxylin and eosin staining. Magnification: x100. E) Villous atrophy with large microgamonts (mi) of *Eimeria cameli* in lamina propria in jejunum. Hematoxylin and eosin staining. Magnification: x100. F) Villous atrophy, necrotic cell surrounded with inflammatory cell infiltration (asterisk) in the duodenum. Hematoxylin and eosin staining. Magnification: x100.

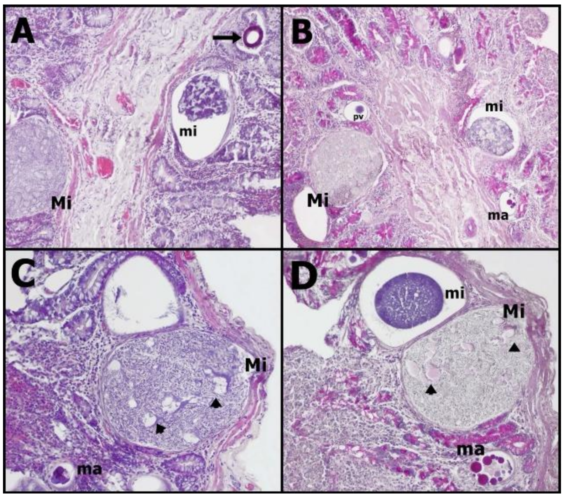

Figure 2. Different developmental stages of *Eimeria cameli* in the small intestine of naturally infected dromedaries A, C) Hematoxylin and eosin staining. Magnification: x200. B, D) Periodic Acid–Schiff reaction with hematoxylin counterstaining. Magnification: x200. Early microgamont located in large parasitophorous vacuoles (pv). Large microgamonts (mi), large microgamonts with PAS-positive amorphous material vacuoles (arrowheads) (mi), early macrogamont containing PAS-positive amylopectin granules (ma) and oocyst (arrow) in the submucosa.

Vascular changes included mild-to-moderate hyperemia across all segments, while focal hemorrhages were typically observed around small vessels. Statistical analysis revealed significant differences in lesion severity between intestinal segments ($p < 0.05$) (Table 1).

Table 1. Lesions (Mean±Standard Error) counted totally and separately within different gut parts.

Histopathological findings MEAN±SE, N=*14*	DUODENUM	JEJUNUM	ILEUM	ALL PARTS
Villus epithelium	50±8.69	57.69±5.2	55.76±7.57	54.76±4.01
Inflammation	82.14±7.14	83.92±4.97	96.42±2.42	83.37±4.03
Necrosis/deg	30.35±8.76	85.0±9.34	95.0±7.62	70,11 ± 8,57
Hemorrhage	25.0±6.93	25.0±8.28	23.21±7.62	25±4.49
Hyperemia	51.78±8.87	64.28±8.16	73.21±7.62	63.09±4.83
Total lesions	47.85±10.06	65.32±12.15	54.36±14.26	59,26±10.80

Parasite Identification and Distribution

Parasitic infection was detected in 11 of 14 animals (78.6%). Of these, 8 camels (57.1%) harbored *E. cameli*, while one Targui-breed camel (7.1%) exhibited co-infection with both *E. cameli* and *E. dromedarii*. Sexual developmental stages were observed in different regions: *E. cameli* primarily in the jejunum and ileum, and *E. dromedarii* localized to the ileum (Fig. 3A–D).

Morphometric analysis indicated mean diameters of 38.3 ± 11.3 µm for *E. cameli* microgamonts and 83.7 ± 12.6 µm for macrogamonts. PAS staining revealed intracellular amylopectin granules in mature macrogamonts. Truncate-shaped oocysts measured 102.7 ± 16.3 µm in length with a wall thickness of 13.6 µm.

Eimeria dromedarii microgamonts and macrogamonts had average dimensions of 65.8 ± 5.5 µm and 81.0 ± 6.1 µm, respectively. Oocysts were elongate-oval and measured 74.5 ± 6.4 µm. PAS-positive features such as wall-forming bodies in macrogamonts and basophilic nuclei in microgamonts were clearly evident (Fig. 3A–D).

Interestingly, *Ogmocotyle*-like trematodes were identified in the duodenum of two female Saharaoui camels (14.3%). These trematodes exhibited a single oral sucker and lacked a ventral sucker, consistent with members of the Notocotylidae family. Based on morphological features and anatomical location, they were tentatively classified as *Ogmocotyle*-like species (Fig. 3E–F).

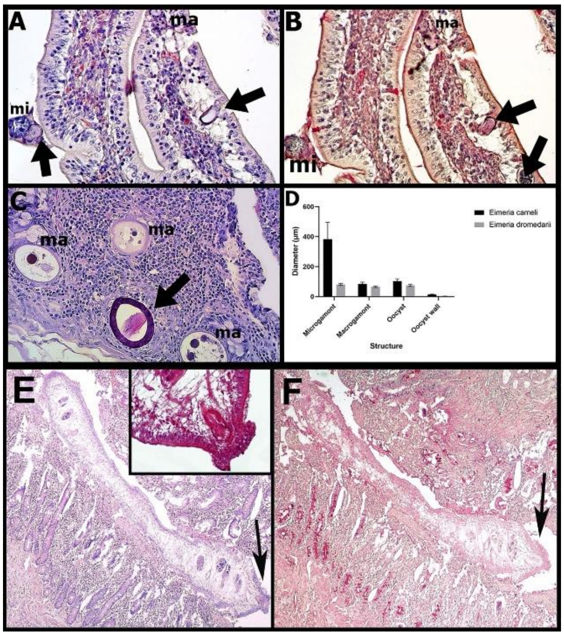

Figure 3. Different developmental stages of *Eimeria dromedarii* and *Eimeria cameli* in naturally co-infected dromedary. A) *Eimeria dromedarii* microgamonts (mi), macrogamonts (ma) and oocyst (arrow) in the ileum. Hematoxylin and eosin staining. Magnification: x200 B) *Eimeria dromedarii* microgamonts (mi), macrogamonts (ma) and oocyst (arrow) in the villous epithelium of the ileal segment of the small intestine. PAS staining. Magnification: x200. C) *Eimeria cameli* macrogamonts (ma) and oocyst (arrow) in the ileal submucosa. Hematoxylin and eosin staining. Magnification: x200. D) Comparison between *Eimeria dromedarii* and *Eimeria cameli* sexual developmental stages diameter. E-F) *Ogmocotyle*-like structures in the duodenal part of the small intestine. E) Oral sucker (arrow and inset panel) of trematode and necrotic debris around the parasite. Hematoxylin and eosin staining. Magnification: x40. F) Oral sucker (arrow) of trematode and necrotic debris around the parasite. Periodic Acid–Schiff reaction with hematoxylin counterstaining. Magnification: x40.

DISCUSSION AND CONCLUSION

Although *Camelus dromedarius* exhibits remarkable physiological resilience to extreme desert conditions, it remains susceptible to gastrointestinal parasitic infections, many of which are subclinical yet capable of inducing significant histopathological changes (Sazmand and Joachim, 2017; Dubey and Schuster, 2018; Bouragba et al., 2020). This study provides novel insights into the occurrence, distribution, and tissue-level pathology associated with coccidian (*Eimeria cameli, E. dromedarii*) and helminthic (*Ogmocotyle*-like) infections in asymptomatic dromedary camels, underscoring the importance of routine subclinical surveillance in camel health management. Although *Ogmocotyle*-like trematodes have not been previously documented in camels in Algeria, their detection in this study may reflect environmental contamination, interaction with migratory wildlife, or indirect transmission via intermediate hosts shared across regional ecosystems. Further molecular and ecological studies are warranted to elucidate their origin and transmission pathways.

Eimeria cameli was the most frequently identified species, detected in over half of the animals, followed by *E. dromedarii*, which—although less prevalent—was associated with pronounced epithelial damage, particularly in the ileum. These findings are in line with previous studies reporting that *E. cameli* predominantly localizes within the crypts of Lieberkühn, whereas *E. dromedarii* targets the villous epithelium (Hussein et al., 1987; Kheirandish et al., 2012; El-Khabaz et al., 2019). The morphometric analysis corroborated established morphological characteristics, and the PAS staining highlighted amylopectin granules in mature gamonts—an often-overlooked diagnostic feature (Dubey and Schuster, 2018).

Histopathologically, lesions such as villous atrophy, crypt damage, epithelial necrosis, and eosinophilic and mononuclear infiltration were consistently observed in sections containing parasitic developmental stages, supporting a spatial association between parasite presence and mucosal injury. Similar alterations have been reported in experimental coccidiosis models, where intracellular parasite replication leads to epithelial disruption, inflammation, and regenerative failure (Parsani et al., 2008; Dubey, 2018). Semi-quantitative scoring in this study revealed significant differences in lesion severity among intestinal segments, reinforcing the concept of region-specific parasitic tropism along the gut. Although *Eimeria* spp. are classically regarded as epithelial parasites, their endogenous stages are often closely associated with crypt epithelium, and in heavily affected tissues they may appear to extend into deeper mucosal compartments because of crypt involvement and distortion of local mucosal architecture.

One of the most notable findings of this investigation was the detection of an *Ogmocotyle*-like trematode in the duodenum of two camels. To the best of our knowledge, this represents the first report of a notocotylid trematode in *C. dromedarius*. Members of this family have previously been recorded in yaks, Japanese macaques, and Korean water deer, where they are known to inhabit the small intestine and induce mucopurulent enteritis (Bandyopadhyay et al., 2010; Choe et al., 2011; Iwaki et al., 2012; Junker et al., 2015). The observed morphology, including the presence of a single oral sucker and the absence of a ventral sucker, together with the associated epithelial necrosis and eosinophilic infiltration, highlights their pathological relevance and suggests a broader host range than previously recognized.

The presence of these flukes in camels may reflect environmental exposure through shared pastures, migratory birds, or undocumented wildlife interactions. Further studies are needed to clarify their transmission dynamics, host range, and epidemiological significance in Algerian camel production systems.

Beyond direct tissue damage, coccidian infections have been implicated in modulating host immunity, particularly by dampening pro-inflammatory cytokine responses and facilitating microbial imbalance (Zhao et al., 2018). Although cytokine profiling was beyond the scope of this study, the histological evidence of immune cell infiltration, especially in *E. cameli*-infected ileal segments, supports active host-parasite interaction and indicates the potential for future immunopathological investigation.

Misidentification of *Eimeria* species has historically led to taxonomic confusion in camelids (Dubey and Schuster, 2018). This study addresses that limitation by integrating histopathological, morphometric, and histochemical techniques to accurately identify parasite species and developmental stages. To our knowledge, this is the first study reporting histomorphometric and PAS-based characterization of Eimeria developmental stages in naturally infected camels combined with semi-quantitative lesion scoring. However, the parasite identifications presented here should be regarded as morphology-based, and definitive species-level confirmation, particularly for the *Ogmocotyle*-like trematodes, will require additional morphological and/or molecular characterization. Future studies incorporating such approaches are recommended to strengthen taxonomic resolution and better elucidate parasite diversity.

Collectively, these findings reveal a significant and underappreciated burden of protozoan and helminthic infections in clinically healthy camels. The consistent detection of sexual coccidian stages in asymptomatic animals advocates for routine post-mortem screening in abattoirs. Furthermore, the first-time report of *Ogmocotyle*-like trematodes in camels opens new avenues for research into their life cycle, host specificity, and potential pathogenic mechanisms.

This study demonstrates a high occurrence of *E. cameli*, *E. dromedarii*, and *Ogmocotyle*-like trematodes in the small intestines of clinically healthy dromedary camels. The detection of all sexual stages of *Eimeria* spp., along with segment-specific histopathological damage especially in the ileum indicates a substantial subclinical parasitic burden. The identification of an *Ogmocotyle*-like trematode in camels represents a novel finding and contributes valuable data to camelid parasitology. Although molecular and immunological analyses were not performed, the combined use of histopathology, histochemistry, and morphometry provided robust diagnostic evidence. In routine abattoir investigations, the combined use of H&E, PAS histochemistry, and morphometric assessment may serve as a practical first-line diagnostic approach, while molecular tools should be used for definitive species-level confirmation whenever feasible. These results highlight the need for routine intestinal surveillance and species-level identification to improve health monitoring and management in camel populations from endemic regions.

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The authors declare that there are no acknowledgements.

Ethical Declaration

The methodology protocols of the present study followed the ethical concepts in animal experimentation, recommended by FELASA and approved by the Algerian Ministry of Higher Education and Scientific Research (Executive Decree 10-90 supplementing the Algerian government decree 04-82) and the AASEA (45/DGLPAG/ DVA.SDA.14).

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authorship contributions

Concept: T.A., R.B., M.E.A., Design: T.A., R.B., M.E.A., Data Collection or Processing: R.B., B.B., M.C., N.S., Analysis or Interpretation: S.G., O.K., Literature Search: M.B.T., G.Y., S.B.K., T.S.Y., Writing: T.A., M.E.A.

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Additional Informations

This study does not cover any thesis. This study has not been previously presented at any congress/symposium or published in another journal.

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