Journal of Applied Veterinary Sciences, 9 (2): 120-124 (April, 2024).
ISSN: Online: 2090-3308, Print: 1687-4072
Journal homepage : https://javs.journals.ekb.eg

Anatomical and Ultrastructural Studies on the Dromedary Camel Cecum

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ABSTRACT

The main functions of the mammalian cecum include microbial digestion of soluble and insoluble carbohydrates and the absorption of significant amounts of water and electrolytes. The present study was carried out to investigate the gross anatomy and electron microscopy of the cecum in adult camels (*Camelus dromedarius)*, which still needs to be clarified. The study was conducted using samples collected from camels slaughtered at an abattoir in Omdurman, Sudan. The camel cecum, which occupied the right part of the abdomen, was situated caudally to the abomasum and directed caudally to the pelvis. It was short and S-shaped and began largely at the ceco-colic junction at the level of the fifth lumbar vertebra and became smaller towards its apex. Morphometrically, camel cecum constituted 3.2% of the large intestine length, 1% of both the small intestine and large intestine length, and 0.10% of the long axis of the animal body. Ultra-structurally, the cecal mucosa showed several folds and was lined by a simple columnar epithelium with many intestinal cells (enterocytes) and goblet cells; two types of enterocytes were shown: type one contained a dark cytoplasm and type two had a light cytoplasm. In conclusion, the cecum in dromedary camels was generally similar in structure to other domestic animals; however, they have a shorter cecum compared to ruminants.

Keywords: Anatomy, Cecum, Dromedary camel, Animal Tissue, Ultrastructure.

Original Article:
DOI:https://dx.doi.org/10.21608/javs.2024.270202.1318
Received : 9 February, 2024.
Accepted :29 March, 2024.
Published in April, 2024.

J. Appl. Vet. Sci., 9(2): 120-124.

INTRODUCTION

The dromedary (*Camelus dromedarius*) has adapted to the harsh environment of the Sahara Desert, where it thrives on thorny plants with rough, tough stems **(Bello *et al*., 2012).** They have unique metabolic pathways that allow them to survive for a few days without water or food, making them suited to desert life **(Rezk *et al*., 2017).**

Camels efficiently digest dry materials **(Iqbal and Khan, 2001)** and their large intestine plays an important role in the absorption of electrolytes, water, and vitamins **(Sulaiman and Marciani, 2019).** The morphology of the large intestine in dromedary camels has previously been investigated (**Mohamed *et al*., 2013; ZhaXi *et al*., 2014; Mohamed *et al*., 2018; AL-Samawy *et al*., 2019; Aboodd, 2022; Yogi *et al*., 2022).** However, the reviewed literature revealed limited work regarding the morphology and electron microscopy of the dromedary camel cecum. Thus, the present study aimed to describe the gross anatomy and ultrastructure of the adult dromedary camel's cecum.

MATERIALS AND METHODS

Animals and Ethical approval

The study was conducted on cecum specimens of sixteen healthy adult dromedary camels (including one aborted fetus) slaughtered at Omdurman Slaughterhouse, Sudan. Animal handling and sample collection were performed according to the institutional

ethical guidelines of the Sudan University of Science and Technology, Khartoum, Sudan, and allocated a reference number of (SUST/DSR/IES/EA/2017).

Gross anatomical study

The anatomical investigation was performed using one foetus for position and relationship and five adult camels after being fixed in 10% formaldehyde and carefully dissected to study the cecal shape, position and relationship.

The cecum was measured using samples obtained from slaughtered fifteen healthy adult camels of both sexes (their ages were between 5 and 11 years and their weight between 400 and 690 kg) using a standard measuring tape. The long axis of the camel was determined by measuring the distance separating the occipital bone and the second coccygeal vertebra **(Mohamed *et al*., 2013).** The intestinal mesentery was removed, and the intestine was arranged in a straight line. The lengths of the small intestine and large intestine, together with the cecal width and length were measured.

Electron-microscopic study

For electron microscopy, the cecal samples were collected immediately after the camels were slaughtered and fixed in a fresh 2.5% glutaraldehyde (in Millonig's phosphate buffer, pH 7.4) **(Robinson and Gray, 1991**). For scanning electron microscopic analysis, specimens were dehydrated by increasing ethanol concentrations and critical point drying using liquid CO2. Dried specimens were put on an aluminum stub with silver paint sputter-coated with gold and then checked and photographed in a scanning electron microscope (JEOL840, Tokyo, Japan).

For transmission electron microscopy, specimens were post-fixed using 1% osmium tetroxide for 60 minutes, washed in Millonig's buffer, dehydrated in ethanol concentrations and propylene oxide, and then embedded in Epon. Ultra-thin sections (50–90 nm thick) were obtained, mounted on uncoated grids, and stained using lead citrate and uranyl acetate. A transmission electron microscope (Philips XL, Eindhoven, Netherlands) was used to examine the stained sections and the results **(Robinson and Gray, 1991**).

RESULTS

Gross Anatomy

The cecum in dromedary camels was a blind-ended cylindrical sac with an S-shape that started at the ceco-colic junction (cecal base); it was situated ventral to the right side of the abdominal cavity, caudal to the abomasum, and directed caudally to the pelvic inlet **(Figs. 1&2);** its rounded apex, which represented the widest part of the large intestine, was medioventrally directed. The ileocecal fold connected the ileum with the cecum, and it extended from the cecal base until beside the cecal apex **(Fig. 3).**

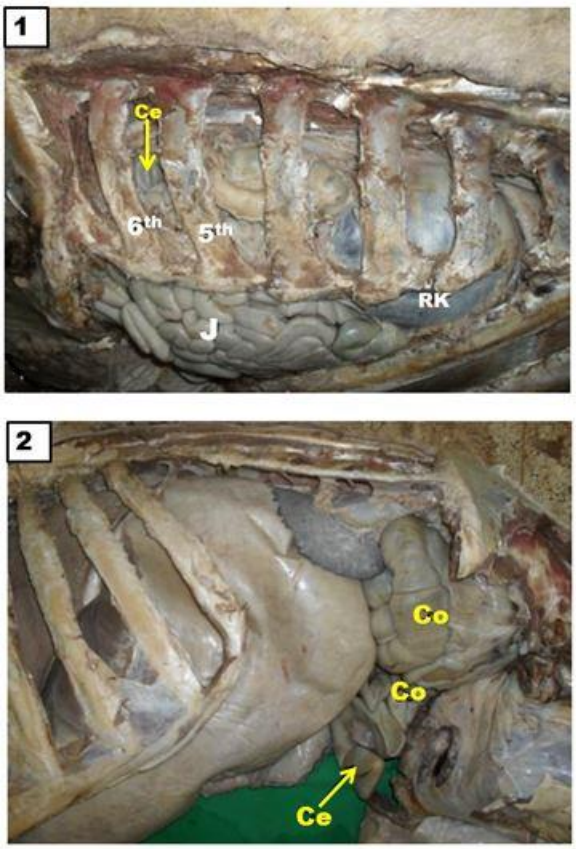


Fig. 1: Dorso-lateral part of the camel right abdominal cavity presenting the ceco-colic junction (Ce) starting ventral to the 5th and 6th transverse processes of lumbar vertebrae. J, jejunum; Rk, right kidney. **Fig. 2:** The left camel abdominal cavity presenting the S-shape cecum (Ce). Co, proximal loop of ascending colon.

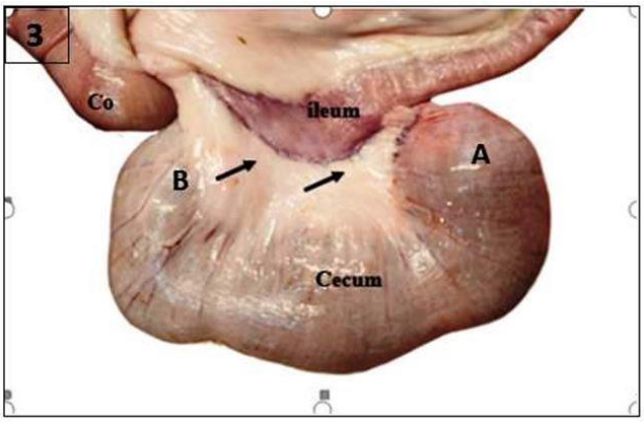


Fig. 3: Photograph of the camel cecum presenting the ileo-cecal fold (arrow) connecting the cecum with the ileum. Notice the cecal apex (A), cecal base (B) and the proximal loop of the ascending colon (Co).

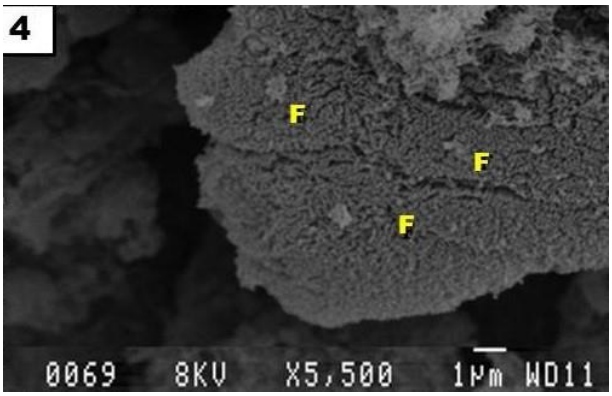
As shown in **table 1**, the cecum started with a diameter of 20.25± 2.1 cm at the level of the fifth lumbar vertebra; the diameter decreased a little approaching the apex, reaching 16.25 cm with a mean of 29± 4 cm and 18.25± 1.3 cm in length and diameter, respectively. The cecal length was 3.2% of the large intestine length and 1% of both the length of the large intestine and small intestine with its ratio to the body's long axis being 0.10.

Table 1: Presenting the average cecal length/cm, animal body, diameter of small and large intestines and diameter of cecum in dromedary camel.

	Cecal length	Cecal diameter	Body long axis	Small intestine length	Large intestine length	Total length of intestine
	29± 4	18.25	287± 15	1097± 66	905± 53	2002± 119

Electron microscopy

According to scanning electron microscopy, the cecal mucosa was highly folded and lined by columnar epithelial cells with many goblet cells; the apical surface of the mucosa contained numerous villi (Figs. 4-5).



Figs. 4: Scanning electron photomicrograph displaying many cecal atypical luminal mucosal folds (F). X500.

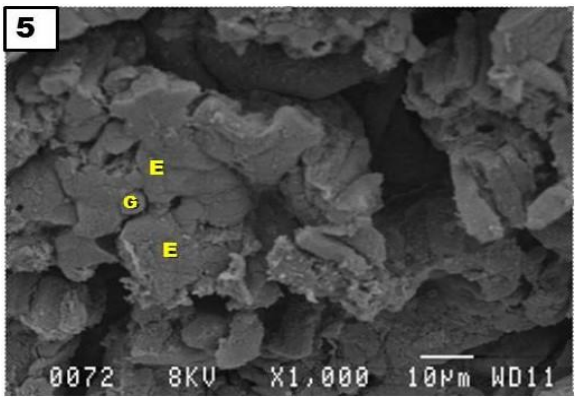
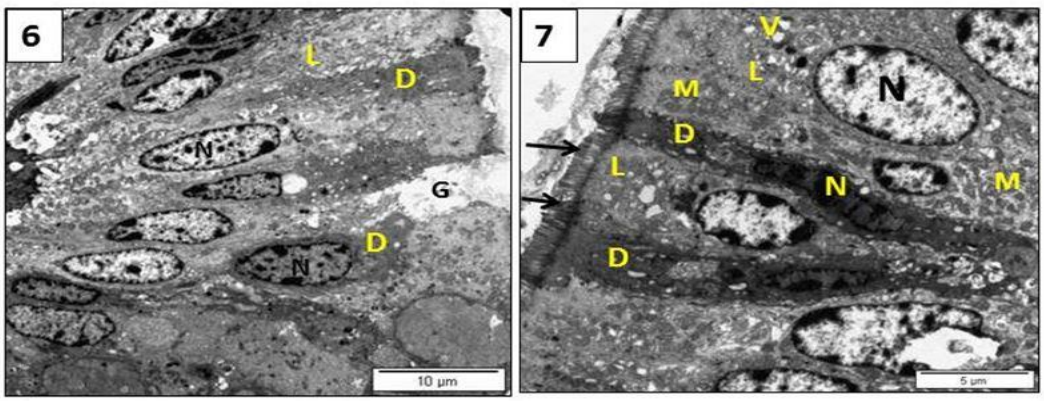


Fig. 5: Scanning electron photomicrograph showing cecal mucosal epithelium (E) and goblet cells (G). X1000.

Transmission electron microscopic results revealed that the dromedary cecum had many intestinal cells (enterocytes) and many goblets (basket) cells in the epithelial layer of the tunica mucosa. The enterocytes appeared in two types: the first one was more abundant and was made up of cells showing different sizes with folded peripheral cell membranes (brush borders); the cells had light cytoplasm and basally located oval nuclei; a few transparent and thick vesicles and mitochondria were found in the enterocytes cytoplasm **(Figs. 6, 7).** The second type of enterocytes was narrow and small with black cytoplasm and elongated basal nuclei; the cytoplasm contained a few vesicles and the cell membrane exhibited many peripheral microvilli **(Figs. 6, 7).** The mucosal goblet lacked microvilli as compared to enterocytes; their supra-nuclear cytoplasm had large numbers of light-coloured and spherical mucin granules **(Fig. 6).**



Figs. 6 and 7: Transmission electron photomicrograph showing the cecal mucosa with light (L) and dark (D) enterocytes. Note the enterocyte nuclei (N), vesicles (V), mitochondria (M), brush borders (arrows) and Goblet cells (G) with supra-nuclear mucous granules (light color). Scale bar is shown in each photomicrograph.

DISCUSSION

In mammals, including dromedary camels, the cecum has been described as the blind pouch of the large intestine, which is followed by the colon and rectum **(Smuts and Bezuidenhout, 1987; Mohamed *et al.*, 2013; Mohamed *et al.*, 2018; AL-Samawy *et al.*, 2019; Aboodd, 2022; Yogi *et al.*, 2022).** The current study showed that the cecum was a wide blind-ended sac located in the right and ventral parts of the dromedary camel abdominal cavity and connected to the ileum by the ileocecal fold. These findings are similar to those observed in the same species **(Mohamed *et al.*, 2018; Tharwat, 2020).** However, the ox cecum extends caudo-dorsally along the right part of the flank region, and its rounded blind end lies at the right part of the pelvic entrance (Sisson et al., 1975). The dog cecum is cranio-caudally directed even though its blind end could ultimately point in any other direction **(Dyce and Wensing, 2002).**

In the current study, the cecal length was 29±4 cm, which constituted 3.2% of the length in the large intestine, 1% of the length of the small intestine and large intestine, and 0.10% of the long axis of the animal body. However, it has been shown that the cecal length of the alpaca and dromedary camel is 14.8±2.6 cm **(Pérez *et al.*, 2016)** and the mean length was 51.35±6.40 cm **(Mohamed *et al.*, 2018).** These measurement variations could be due to animal breeds, age, size or the measurement tool used.

In the mature cow, the cecal length was about 3 feet **(Parish, 2011).** In cats, the cecum is smaller and grossly undifferentiated as compared with most herbivores because it is considered a primitive organ in these animals (Snipes 1984). The cecal length is found to be 2–3 cm in cats **(Angelou *et al.*, 2023)** and 7.6 cm in dogs **(Abd-El-Hady *et al.*, 2013).** In all domesticated mammals except giraffes and humans, the cecum is the shortest segment in the large intestine (**Habel, 1975; Nickel *et al.*, 1979; Pérez *et al.*, 2009; Hounnou *et al.*, 2002).** In this respect, the dromedary camel is not different from other domestic mammals.

Scanning electron-microscopic structure in this study revealed that the luminal surface in the dromedary camel cecum showed many irregular folds. These folds were covered by a simple columnar epithelium with many goblet cells. Similarly, mucosal luminal folds have also been reported in dromedary camel cecum by **Mohamed *et al.*, (2013).** According to **Kotze and Soley (1990),** the cecum of a horse lacks mucosal villi but it has regularly-spaced crypt openings, each of which is encircled by an elevated circular mound. In the mice's cecal mucosa, there are short squat folds **(Geissinger and Abandowitz, 1977).**

The ultrastructure of the cecal epithelial layer in dromedary camels in the present study showed two types of intestinal cells (enterocytes) that were rich in organelles and goblet cells. The dominant enterocyte type had large cells with pale cytoplasm that had clear and dense vesicles and basally located oval nuclei; the cells of the other type of enterocytes were fewer in number, tiny, and narrow-shaped; they had dark cytoplasm, fewer transparent vesicles and elongated nuclei. These enterocytes are similar to those reported by **Abdel-Magied *et al.*, (1994)** in the same species. Furthermore, the cytoplasm in both enterocyte types contains large numbers of mitochondria, which could indicate active digestion and absorption in the cecum **(Shiner, 1983; Wille, 2001).** The ultrastructure of cecal goblet cells in this study revealed that their cell membrane lacked microvilli and that presence of many light and spherical mucin granules in the supra-nuclear cytoplasm. These findings are in accordance with those reported by **Mohamed *et al.*, (2019)** in dromedary camels.

CONCLUSION

It could be concluded that the cecum is short and it occupies the right side of the dromedary camel's abdominal cavity; which might be beneficial in the intestinal surgery of this animal species. Nevertheless, electron-microscopic findings in this study did not reveal any considerable difference between the dromedary camel and other species.

Acknowledgment

Thanks to the Department of Anatomy and Physiology staff, Faculty of Veterinary Science, University of Pretoria, South Africa and Faculty of Veterinary Medicine, University of Khartoum, Sudan, for their help in executing the practical work. I am also deeply indebted to the College of Veterinary Medicine, Sudan University of Science and Technology, Sudan, for their financial support.

Conflict of interest

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

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How to cite this article:
Elseory, A.M.A., Ali, A.M., Taha, A.A.M., Elhassan, M.O., Ibrahim, Z. H., Alshanbari, F.A. and Althnaian A., 2024. Anatomical and Ultrastructural Studies on the Dromedary Camel Cecum. Journal of Applied Veterinary Sciences, 9 (2): 120-124.
DOI:https://dx.doi.org/10.21608/javs.2024.270202.1318