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THE PECULIARITIES OF STOMACH OF THE ONE-HUMPED CAMEL (*Camelus dromedarius*)

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ABSTRACT

Thirteen complete stomachs of adult one-humped camel (*Camelus dromedarius*) were collected from the slaughterhouse. They were brought to the laboratory within two hours, cleaned, photographed and fixed in different fixatives for gross, light and electron microscopic studies. Fixation, processing and staining were carried out following standard histological procedures. Additionally, three embalmed, dissected and dried camels were studied and photographed. The stomach of the camel is multilocular compound. The rumen and the considerably reduced reticulum is one compartment (C1) and/are omasum (C2) and abomasum (C3) other two. It was found that all three compartments are glandular. Non-glandular regions were found only in the rumen part of C1.

The peculiar cellulae (previously called water sacs) in the wall are arranged in rows in the dorsal and ventral sacs of the rumen. The gastric groove ventral lip is formed by the right longitudinal pillar, which bounds the ventral part of the dorsal cellulae. The left longitudinal groove and pillar are absent. Histologically, there is no lamina muscularis mucosa in the wall with the exception of the regions of the cellulae where there is a thin smooth muscle layer present.

The omasum was found to have one type of lamellae (laminae) and is lined with simple columnar epithelium and contains simple straight tubular glands in its wall. The abomasum is very extensive and folded inside. The parietal cells were found to be much higher in number when compared to other cell types.

Key words: One-humped camel, peculiarities, stomach

The one humped camel stomach is considered a unique organ according to its anatomical shape, structure and function. Most of the old literature described the ability of the camel to withstand thirst in the desert and the stomach was mistakenly recognised for playing a role in water storage.

Camels are able to thrive in the hot, dry conditions of the desert because of adaptations, and not by misconception of water storage in the stomach. The camel consumes large amount of food, regurgitate for remastication, re-insalivation and re-swallowing with a rumination process similar to other true ruminants, such as cattle but motility pattern for the forestomach is slightly different from that of reticulorumen in ruminants. It aids in mixing of food particles and retention of larger food particles to allow fermentation of complex carbohydrates (Osman and Engelhardt, 1998 and Osman *et al*, 1999).

The stomach of the camel is classified as compound multilocular. Compound or composite because it contains both glandular and non glandular regions (Hansen and Schmidt-Nielsen, 1957 and Wilson, 1984). They described a reduced reticulum which was found to be a part of the rumen and concluded that the camel stomach is composed of three compartments. On the other hand, Smuts and Bezuidenhout (1987) described the camel stomach as having four definite compartments. In addition, glandular regions of the wall of the stomach were investigated by several researchers in both the dromedary and the bactrian (Dougbag and Berg, 1981; Eerdunchaolu *et al*, 1999; Wang *et al*, 2000; Abdel-Magied and Taha, 2003). This study was designed to describe the gross, light as well as the electron microscopical peculiarities of the one-humped camel (*Camelus dromedarius*) and to relate these peculiarities to their functions.

Materials and Methods

A total of 13 complete stomachs of adult one humped camels of both sexes were used in this study. For gross study, 5 complete stomachs were collected from the slaughterhouse and brought to the laboratory within two hours. Each stomach was tied at esophageal and duodenal ends after being

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flushed with water to remove food particles. The stomach was studied grossly from outside before it was filled with 10% neutral buffered formalin (NBF) solution for fixation. Three additional embalmed and dried complete camels were photographed inside the museum of the Faculty of Veterinary Medicine, Jordan University of Science and Technology.

For the light microscopic study, four stomachs were sampled. Samples were taken from different regions of each segment of the stomach in 10% NBF. Specimens were later processed routinely for light microscopic study using standard histological techniques. Sections of 5 µm thickness were collected on glass slides and stained with hematoxylin and eosin stain (Bancroft and Stevens, 1990). One sample of each segment from another camel stomach was fixed in 4% glutaraldehyde in phosphate buffer collected immediately after slaughtering for electron microscopy. A second fixative of osmium tetroxide was also used. Specimens were dehydrated with acetone, embedded in resin and sectioned by ultratome to prepare semi-thin and ultra-thin sections. Semi-thin sections were collected on glass slides and stained with toluidine blue. Ultra-thin sections were collected on copper grids, stained with lead citrate and uranyl acetate and examined under electron microscope.

Results

The stomach of the one humped camel was found to be composed of 3 definite compartments: rumino-reticular C1 (combined rumen and reduced reticulum), omasum C2 and abomasum C3 (Figs 1 and 2).

The rumen portion of compartment 1 is composed of dorsal and ventral sacs with a clear line of demarcation on the right side due to the presence of right longitudinal groove and pillar. However, the left demarcation is not obvious due to the absence of the left longitudinal pillar and groove. It has no papillae on its interior wall and has two groups of pouches or cellulae (formerly defined as water sacs) in its dorsal and ventral sacs (Fig 3). These cellulae are arranged in row and surrounded by bundles of thick muscular cords. They are arranged in rows of large sized cellulae separated by longitudinal muscle bundles. Within each large cellula are smaller size cellulae surrounded by bundles of smooth muscle acting as sphincters. All longitudinal bands are thicker than the inside transverse bands. The lower portion of the transverse bands ends at the right longitudinal pillar. The gastric (ventricular or esophageal) groove continues from the esophageal opening with dorsal lip only and the right longitudinal pillar constitutes the ventral boundary of the groove inside the rumen. The groove has a clear ruminal segment, which extends into the next small portion the remnant of the reticulum.

The lining epithelium is stratified squamous which may vary in degree of keratinisation from animal to animal. There are dermal papillae in all sections examined. With electron microscopy, the *Stratum spinosum* of the ruminal epithelium is shown to be attached to each other by desmosomes and contain large numbers of mitochondria (Fig 4). The ventral sac of this portions has keratinised stratified squamous epithelium with low projections from its wall in certain areas. There are no lamina muscularis mucosae in the non-glandular part and the tunica propria submucosa is filled with blood vessels and nerve bundles. However, thin and interrupted lamina muscularis mucosa is present in the wall of the cellulae under the glands. There is also a thick muscular tunic composed of several layers of smooth muscle bundles. However, the lining epithelium of the cellulae are always simple columnar epithelium and contain simple straight tubular glands with the exception of the longitudinal muscle bundles sites (outer surface of the cellulae) where stratified squamous epithelium is present (Fig 5). There is a thin lamina muscularis mucosa which is composed of smooth muscle cells surrounding loose connective tissue core filled with blood vessels and nerve fibres.

The reduced reticulum is part of the compartment 1 (Fig 6) with few honeycomb cells. It is lined by simple columnar epithelium with simple straight tubular glands filling the lamina propria. The lamina muscularis mucosa follows the slightly elevated folds of the mucous membrane. It is discontinuous at some areas where large lymphatic nodules present within the lamina propria. Tunica submucosa is loose connective tissue filled with blood vessels and nerve bundles. Myenteric ganglia and plexus are observed between the two muscular layers of the tunica muscularis. The tunica serosa is relatively thick connective tissue fibres covered by mesothelium.

The compartment 2 (omasum) is a large dilated sac situated in front of the rumen part of C1 against the diaphragm and extends to the right side of the intrathoracic portion of the abdominal cavity between the diaphragm and the floor of the abdominal cavity.

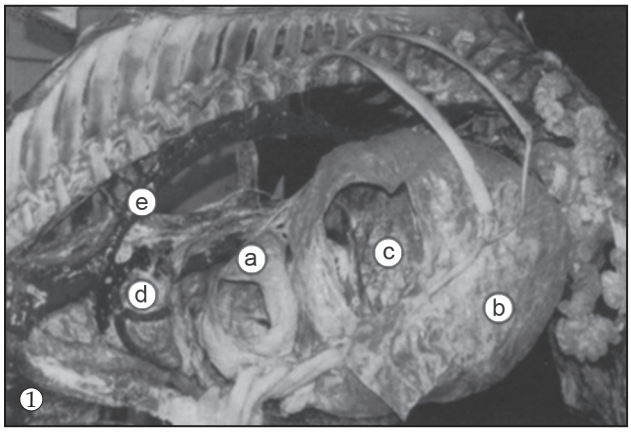
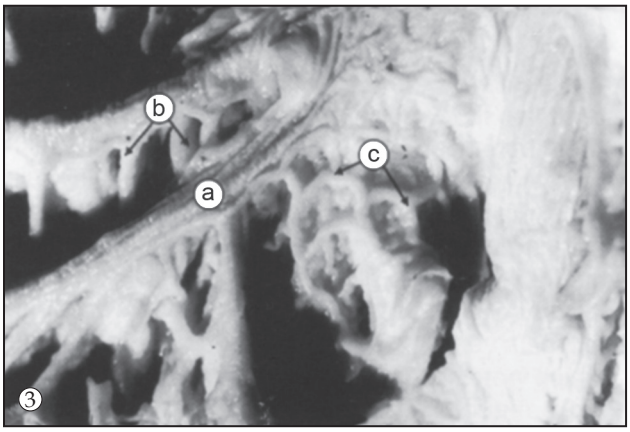


Fig 1. Left lateral view of the thoracic and abdominal cavities of the one-humped camel. The camel was embalmed, dissected and dried. Colours were used to highlight the blood vessels and nerves. THe thoracic and abdominal walls were removed in addition to most of the ribs to show the detailed anatomical structures. a) Omasum (C2) observe the lamellae inside its wall; b) rumino-reticular (C1); c) Cellulae; d) Heart; e) Thoracic aorta.

Fig 2. Complete stomach of one-humped camel dissected and removed out after being cleaned and partially filled with water. a) Oesophagus, b) Rumino-reticular (C1), c) Cellulae, d) Omasum (C2), e) Abomasum, f) Duodenum.



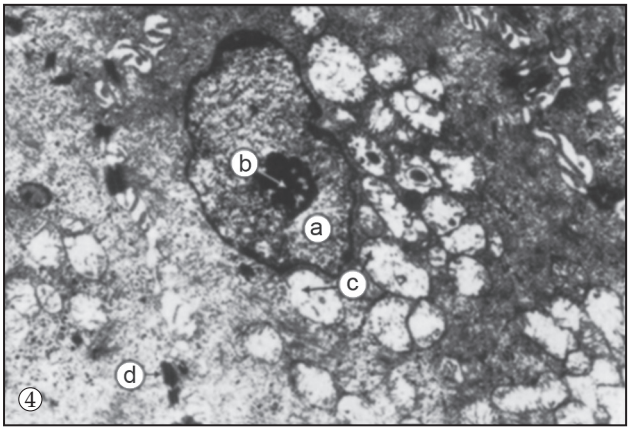


Fig 3. Cellulae inside the wall of the rumen dorsal sac at the junction with the reticulum. a) Longitudinal muscular bands, b) Transverse muscular bands, c) Honeycomb cells within the remnant portion of the the reticulum wall.

Fig 4. Electron micrograph of the spinosum layer of the rumenal wall. 1000 X. a) Nucleus, b) Nucleolus, c) Mitochondria, d) Desmosomes.

It has very low lamellae (folds) and they are almost similar in height throughout the whole organ (Fig 7). It is lined by simple columnar epithelium with branched tubular glands in the lamina propria. It has thin lamina muscularis mucosa and thin tunica muscularis.

The abomasum (C3) is relatively long and it has the characteristic features of the true monolocular simple stomach of other domestic animals (Fig 1). A large number of lysosomes and phagosomes predominate the lamina propria of both the C2 and the C3 (Fig 8). It is easy to delineate the beginning of the C3 by the constriction of the C2 and the characteristic features of the dark coloured folds or rugae of its wall. It is lined by simple columnar epithelium and simple branched tubular glands reaching the relatively thin well developed lamina muscularis mucosa. However, the shape and distributions of these glands vary in different regions of the C3. The glands are relatively short; simple branched tubular and mucous in nature within the cardiac gland region (which is the proximal portion of the abomasum). These glands are very extensively branched with typical short neck, long body and slightly dilated end in the fundic gland region. At this region, the C3 changes colour and become darker and more folded. Parietal cells seem to dominate the fields when compared to other types of cells (chief and neck) (Fig 9). Electron microscopic study revealed that these cells are joined by cell to cell junctions and contain a large number of secretory granules at their apical parts. Microvilli are also present on their apical surfaces (Fig 10). Loose connective tissue

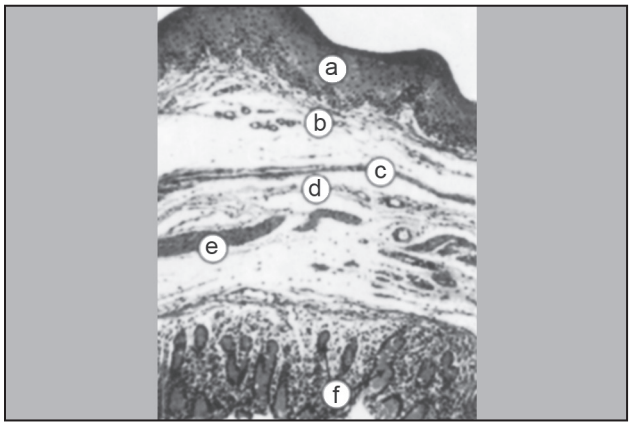


Fig 5. Microphotograph at the level of the cellulae in the rumen of one-humped camel. Hematoxylin and Eosin stain, Mag. 160 X. a) Rumen epithelium (keratinised stratified squamous), b) Lamina propria, c) Lamina muscularis mucosa, d) Tunica submucosa, e) Tunica muscularis, f) Glandular tissue filling the lamina proria.

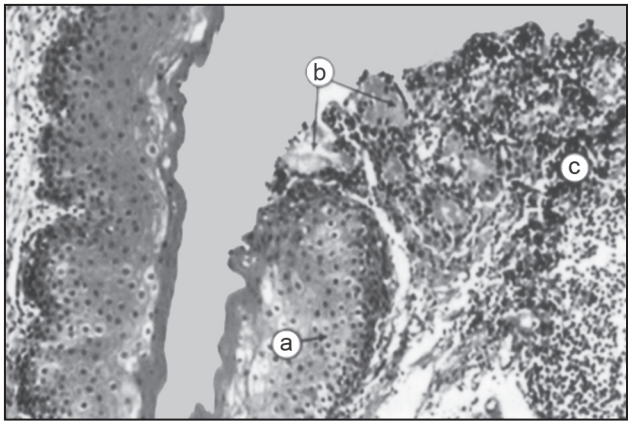


Fig 6. Microphotograph at the junction of the rumen with the reticulum. Hematoxylin and Eosin stain, Mag. 200 X. a) Keratinised stratified squamous epithelium, b) Glandular epithelium of the reticulum, c) Lymphocytic infiltration.

constitutes the tunica submucosa filled with adipose tissue, blood vessels and nerve bundles. A thick inner circular smooth muscle layer and relatively thin outer longitudinal muscle cell layer constitutes the tunica muscularis. These two layers are separated by thin connective tissue which is filled with blood vessels, myenteric ganglia and plexus. The pyloric gland region close to the *torus pyloricus* is characterised by the presence of the tubular glands in the lamina propria.

Discussion

The ruminant stomach is described as multilocular compound (Nickel *et al*, 1975; Dellmann and Eurell, 1998). This is due to the presence of both glandular and non glandular regions where the glands are present only inside the abomasum.

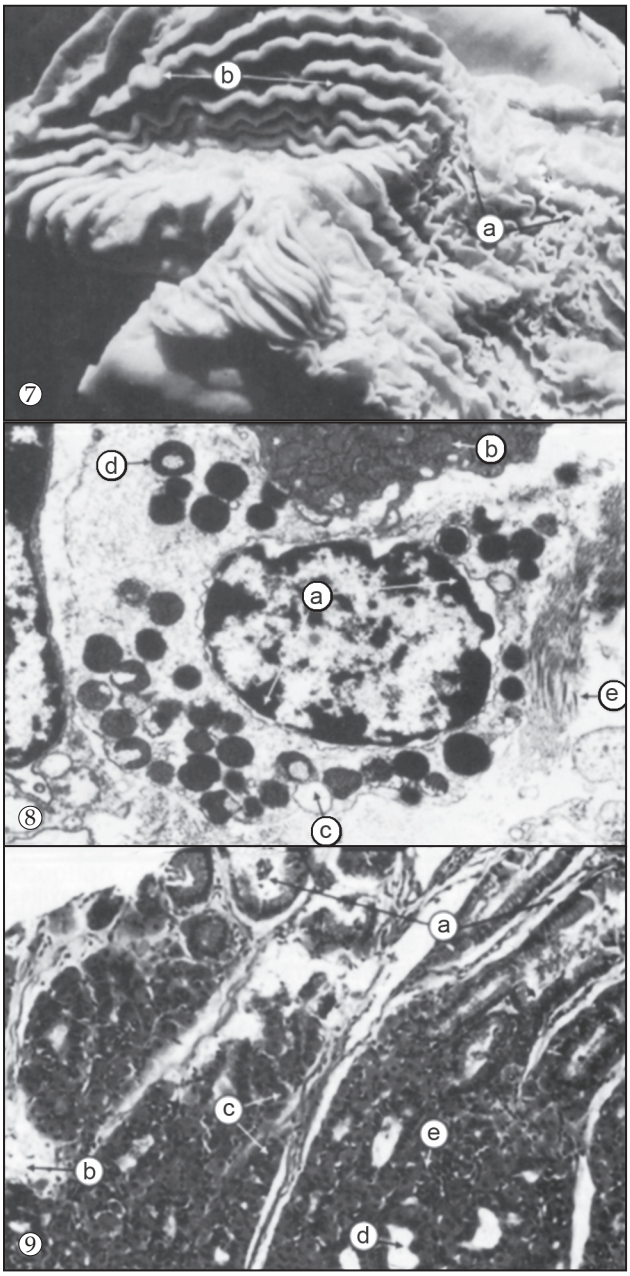


Fig 7. The site of transition betwen the omasum and the abomasum. a) Omasum with omasal folds, b) Abomasum with abomasal rugae (folds).

Fig 8. Electronmicrograph of the wall of the omasum. Mag. 5000 X. a) Nucleus, b) Mitochondria, c) Secretory granules, d) Phagosomes, e) Collagen fibres.

Fig 9. Photomicrograph of the wall of the abomasum. Hematoxylin and Eosin. Mag. 200 X. a) Tubular glands, b) Lamina propria, c) Parietal cells, d) Duct, e) Chief cells.

The camel stomach is a multilocular compound but different from ruminants by the reduction of one compartment i.e. rumen and reticulum are combined. Most researchers agree on this issue with the exception of Smuts and Bezuidenhout

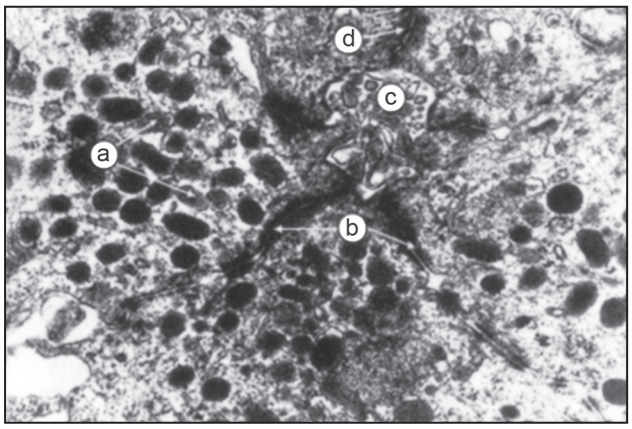


Fig 10. Electron micrograph of the secretory cells of the glands of the abomasum. Mag. 12500 X. a) Secretory granules, b) Desmosomes, c) Lumen containing secretory materials.

(1987) who described four compartments. Besides, all three compartments in the camel are glandular with the exception of regions inside the rumen part of C1 where non glandular areas are present. Other ruminants have four definite compartments. Therefore, the three compartments (C1, C2, C3) adhere to the most befitting description mentioned in few literatures (Wang *et al*, 2000; Boas, 1980; Shahrasbi and Radmehr, 1974). Engelhardt (2004) argued that due to the differences in gross anatomy, histology, and ultra-structure of the camel forestomach the description used for ruminants had not been passed on to the camelids' forestomach. Furthermore, the rumen and reticulum are so intimately related in structure and function that many prefer to describe a combined rumino-reticular compartment even in ruminant (C1) (Dyce *et al*, 1987). The lining epithelium of the rumen is keratinised stratified squamous while that of the cellulae are simple columnar epithelium. The keratinisation differs from one animal to another depending on the animal age and type of food. Keratinisation usually tends to increase with age, however, this fact is not documented in the literature. The peculiar anatomic features of the ruminal part of the camel are the presence of the dorsal and ventral rows of cellulae. Hansen and Schmidt-Nielsen (1957) described them as glandular sac areas while Schmidt-Nielsen (1964) stated that emphatically they are not, indeed are large enough to function as water storage compartments. In this study, it is suggested these cellulae with their glandular walls act as reservoir for food particles during the fermentation process. They may also aid in mixing of the food particles with the secretory fluids from the glands within. They are surrounded by bundles of smooth muscle cells which are thought to act as sphincters around the cellulae. However, Wilson (1984) claimed that not to be the case. The gastric groove has dorsal and ventral lips in ruminant animals inside the rumen (Church, 1988), however, in one humped camel only one lip is present because the ventral one is substituted by the right longitudinal pillar. This pillar is also the ventral boundary of the dorsal row of cellulae, therefore when the rumen is contracted the cellulae will be emptied partially or completely depending on the force of contraction.

The ruminal spinosum layers were found to be attached with each other by large number of desmosomes to protect the wall from harsh food particles ingested by the animal. It also revealed that these cells contain large numbers of mitochondria. These mitochondria are indicative of its high metabolic activity.

The glands present in all regions of the stomach were given several functions including the absorption of the fermentation products or the production of much of the fluid inside the stomach (Wilson, 1984). However, their distribution in different regions of the stomach was described by few researchers.

The C3 (omasum) is larger in size as compared to abomasum of other ruminants and it has one type of low height laminae (lamellae). On the other hand, the ruminant's omasum has three to four different types of laminae (primary, secondary, tertiary) (Dellmann and Eurell, 1998). They are uniquely arranged in special fashion to squeeze the food particles and push the water first. This decreases, in turn, the dilution process which then takes place in the abomasum when the gastric juices are secreted. It has been concluded that regardless of the anatomical differences and variations in the motility patterns between ruminants and the camel, the fermentation processes in the forestomach in these two species are basically similar (Bhatia and Ghosal, 1992; Engelhardt *et al*, 1992; Holler *et al*, 1989; and Osman and Engelhardt, 1998 and Osman *et al*, 1999).

The C3 (abomasum) of the camel is long and tubular in shape. The wall is thrown into low rugae and folds. The colour of the lining surface changes as it approaches the fundic gland region where it becomes dark in color due to the presence of many glands. There is larger number of parietal cells similar to those described in ruminant (Church, 1988) which may compensate or encounter the effect by increasing the secretion of hydrochloric acid

to facilitate digestion. Wilson (1984) described the proximal two thirds having fundic glands, while the distal has pyloric glands. The recent publication of Abdel-Magied and Taha (2003) provided a good description of these regions; however, the area occupied by the fundic gland region they reported seems to be extremely low to perform sufficiently. This study revealed that the fundic gland region is extensive grossly with the presence of folds apart from unusual increase in the number of parietal cells. These factors indicate augmentation of the function of the camel stomach in the absence of all other factors present in ruminant animals.

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