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Gross Anatomical and Histometric Studies on the Stomach Glandular Sacs of the Dromedary Camel *(Camelus dromedarius)*

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ABSTRACT

Camel glandular sac areas were previously considered as water stores. Recently, these sacs were found to be glandular areas which are probably involved in absorption, fermentation and secretion functions. This investigation aimed to study the gross anatomical and histometry of the glandular sacs of camel stomach. It was conducted on fifteen adult camels and ten foetuses. The camel stomach composed of four compartments; compartment 1, compartment 2, compartment 3, and compartment 4. Compartment 1 which was the largest extended from the diaphragm to the caudal border of the 12th thoracic rib in foetuses and presented glandular cranioventral and caudodorsal sacs and non-glandular areas. The cranioventral sac was oval in shape with more or less smooth external surface. The caudodorsal sac was irregular and relatively larger and more sacculated. Each sac contained glandular pits which were formed by four walls; the walls originated from two longitudinal and two transverse pillars which surrounded the pit floor. The pit walls and floor consisted of four tunics; mucosa, submucosa, muscularis and serosa. The pit wall mucosa was non-glandular and the floor mucosa was glandular with serous glands. No significant histometric differences were observed between the cranioventral and caudodorsal sacs in the glandular size (glandular length and diameter) and thickness of wall tunics (tunica mucosa, submucosa, muscularis and serosa).

INTRODUCTION

Camel stomach is physiologically similar to that of typical ruminants in several aspects, such as regurgitation of ingesta and active microbial fermentation (Frandson, 1974). Many authors divided the dromedary stomach into four compartments as in typical ruminants: rumen, reticulum, omasum and abomasum (Hegazi, 1950; Hansen and Schmidt-Nielsen, 1957; Bohlken, 1960; Czerkawski, 1985; Smuts and Bezuidenhout, 1987 and Langer, 1984). Other authors considered the camel as pseudo-ruminant because it has only three compartments (Vallenas, *et al*., 1971; Church, 1976; Dougbag and Berg, 1980; Singh*et al*. 1996; Eerdunchaolu, *et al*.,1999; Abdel- Magied and Taha, 2003).

According to Osman (1999) the stomach of the dromedary camel was formed of four compartments; compartment 1, compartment 2, compartment 3 and compartment 4 depending on the external and internal features. Some authors reported three compartments in the dromedary stomach; compartment 1, compartment 2 and compartment 3 (Dougbag and Berg, 1980; Singh*et al*. 1996;Abdel- Magied and Taha, 2003). Eerdunchaolu*et al*. (1999) and Wang *et al*. (2000) described the stomach of Bactrian camel to be divided into three ventricles.

In typical ruminants, the first three compartments (rumen, reticulum and omasum) are non-glandular whereas, the fourth one (abomasum) is glandular which contains cardiac, fundic and pyloric glands (Banks, 1993; Dellman and Eurell, 1998). The glandular areas in the camel are found in compartments 1, 2 and 3. They were earlier considered as water stores or water cells that function as water tanks; these hypotheses hadbeen disproved (Hansen and Schmidt-Nielsen, 1957). Hegazi, (1950) reported that the dromedary rumen showed three groups of water sacs, the largest one was situated in front and to the right aspect of the rumen, while the third and the smallest one is located in the left side of the apex of the rumen. According to Purohit and Rathor (1962), Schmidt-Nielsen (1964) and Ramadan (1994), one of these sacs was situated at the cranioventral aspect of the rumen, being more to the right side, and the other sac is located in the medioventral aspect or lies on the floor of the abdominal cavity. Engelhardt and Holler, (1987), Engelhardt *et al.* (1992), observed a strong ventral and transverse muscular ridge which divided compartment 1 into cranial and caudal portions and there were no ventral and dorsal sacs.

The present work which aimed to investigate the gross anatomy and histometry of the glandular sacs in the camel stomach is intended to be a further contribution to the functional importance of these sacs in the camel.

MATERIALS and METHODS

Stomach specimens of 25 camels of both sexesat different ages, collected from Tamboul slaughterhouse, Sudan, were used in this study.

Gross anatomy:

Ten fresh stomachs ofadult camels of both sexes ofdifferent ages were fixed in 10% formalin and used to study the gross external and internal features of various stomach compartments. The transverse diameter, length and width of pits of the cranioventral and caudodorsal sacs were also measured. Ten whole foetuses of different developmental

stages were used to study the topography of stomach.

Histometry:

Tissue samplesofcranioventral and caudodorsal sacs from five adult animals were used for the histometric measurements. The tissues were immediately collected after slaughteringand fixed in either 10% formaldehyde or Bouin's fluid. Dehydration, clearing and embedding were carried out for general histology (Culling, 1974). Sections (5 µm thick) were cut in a rotary microtome and stained conventionally with hematoxylin and eosin. Measurements were performed on transversely cut glandular tissue of cranioventral and caudodorsal sacs. Olympus microscope (CH20-Japan) with ocular micrometer lens X6 was used for measurements. The objective lens X40 was used to determine the measurements after calibrating the ocular scale of the microscope (Thienport *et al.*, 1986). Ten measurements of the glandular area diameter, glandular length, thickness of mucosa, submucosal, tunica muscularis and serosa were taken from each animal. Data of the different histometric parameters were statistically analyzed by the Student's t-test, and the difference was considered statistically significant at $p<0.05$.

RESULTS

Gross anatomy:

The camel stomach was divided into four compartments: compartment 1, compartment 2, compartment 3 and compartment 4 (Figures1 and 2). Compartment 1 was the largest and it was externally separated from compartment 2 by a groove; compartment 2 was separated from compartment 3 by a constriction and the tubular compartment 3 ended as an enlarged caudal part to form compartment 4.

Compartment 1 which was the largest part of stomach measured about 80 – 100 cm in length in adult animalsbut in foetuses it extended from the diaphragm at the level of 7th rib to the level of the caudal border of the 12th thoracic rib. It was situated in the left part of the abdominal cavity and was round in shape; its external surface was smooth except for two sacculated areas where the cranioventral and caudodorsal glandular sacs were located (Figures1and 2). Ventrally there was an oblique transverse groove separating the cranioventral sac from the caudodorsal sac.

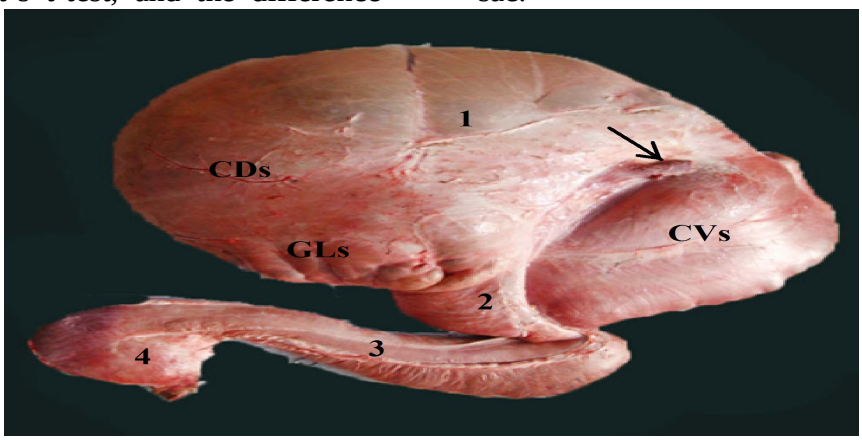

Figure 1: Right view of the adult camel stomach showing compartments 1, 2, 3 and 4;cranioventral sac (CVs), caudodorsal sac (CDs); esophagus (arrow) and glandular sacs (GLs).

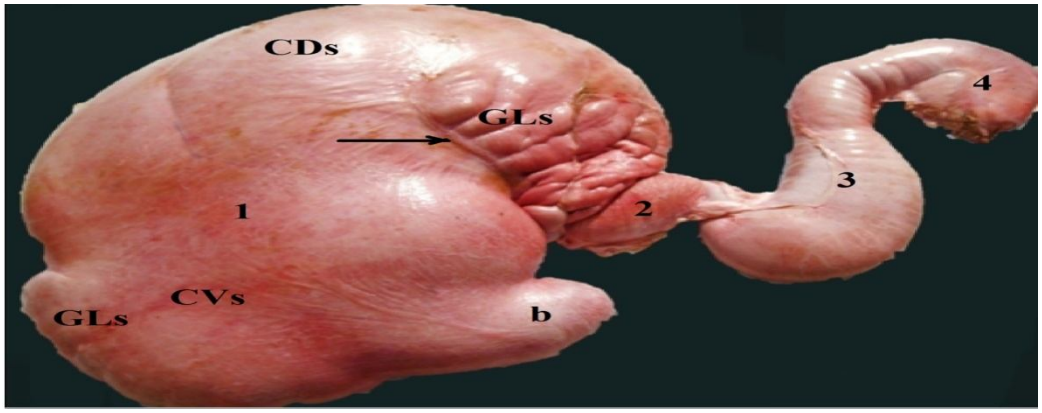

Figure 2: Left view of the adult camel stomach showing compartments 1, 2, 3 and 4; cranioventral sac (CVs), caudodorsal sac (CDs); blind sac (b), transverse groove (arrow) and glandular sacs (GLs).

Internally compartment 1 was divided into a dorsal part and a ventral part (Figure 3).The dorsal part was larger and subdivided into a non-glandular cranial part which consisted of folds arranged in different directions and a caudal part which was glandular forming the caudodorsal glandular sac. The ventral part was subdivided into an upper non-glandular part and a lower glandular part forming the cranioventral glandular sac.

A crescent-shaped pillar corresponding to the transverse groove separated the cranioventral sac from the caudodorsal sac. From this pillar originated smaller pillars dividing the caudodorsal sac into rectangular chambers (about nine chambers). The crescent-shaped pillar gave rise to a vertical pillar from which originated the rectangular chambers of the cranioventral sac (about seven chambers). Each chamber was furtherly sub-divided into smaller glandular pits by smaller pillars arranged into columns and rows (Figure 3).

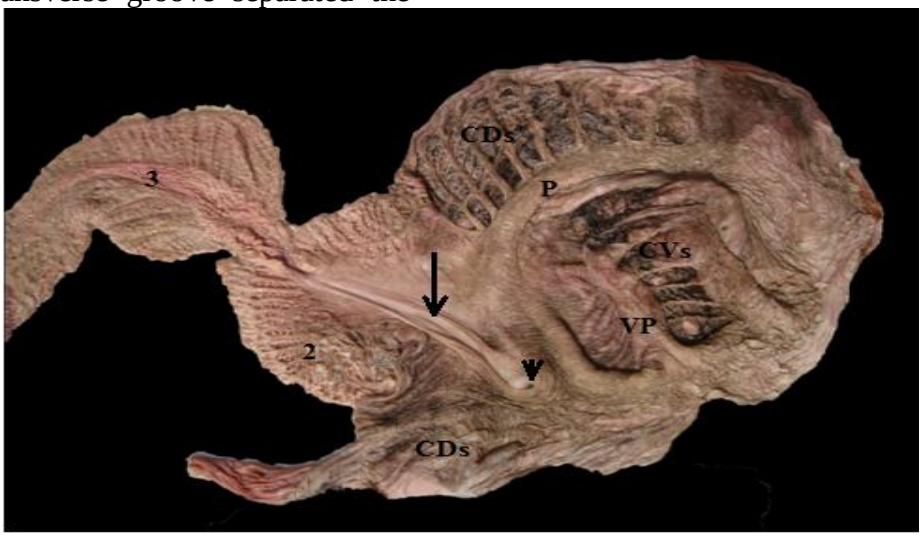

Figure 3:The interior of compartment 1 of adult camel, cranioventral sac (CVs), audodorsal sac (CDs), crescent-shaped pillar (P),vertical pillar (VP), gastric (esophageal)groove (arrow),esophagealopening (arrowhead). Note: compartment 2 and compartment 3.

Glandular sacs:

The linear measurements of the cranioventral and caudodorsal sacs are shown in Table 1.

Table 1: Mean linear measurements (cm) of glandular regions in cranioventral and caudodorsal sacs of adult camel.

	Sites				
Parameter	Peripheral craniventral	Central cranioventral	Peripheral caudodorsal	Central caudodorsal	Significant Level
Length	4.30 [a] ±0.3	3.50 [ab] ±0.5	4.57 [a] ±1.3	2.67 [b]±0.58	*
Width	4.83 [a] ±0.15	4.17 [a] ±0.76	5.20 [a] ±1.06	2.50 [b]±0.50	**
Depth	4.23 [a] ±0.68	2.87 [ab]±0.55	4 [a] ±1.0	2.5 [b]±0.5	*

[abc] Means on the same row with different superscripts are significantly different.

* = P < 0.05 ** = P < 0.01

Cranioventral sac:

The cranioventral sac was situated between the 7th rib cranially and 9th rib caudally and related to the diaphragm, left lobe of liver, compartment 2, compartment 3, compartment 4, spiral loop of ascending colon and lesser omentum (Figures 4 and 5). It was small and oval in shape with more or less smooth external surface (Figures 1 and 2). A caudally directed blind sac was present in its caudal part (Figure 2).

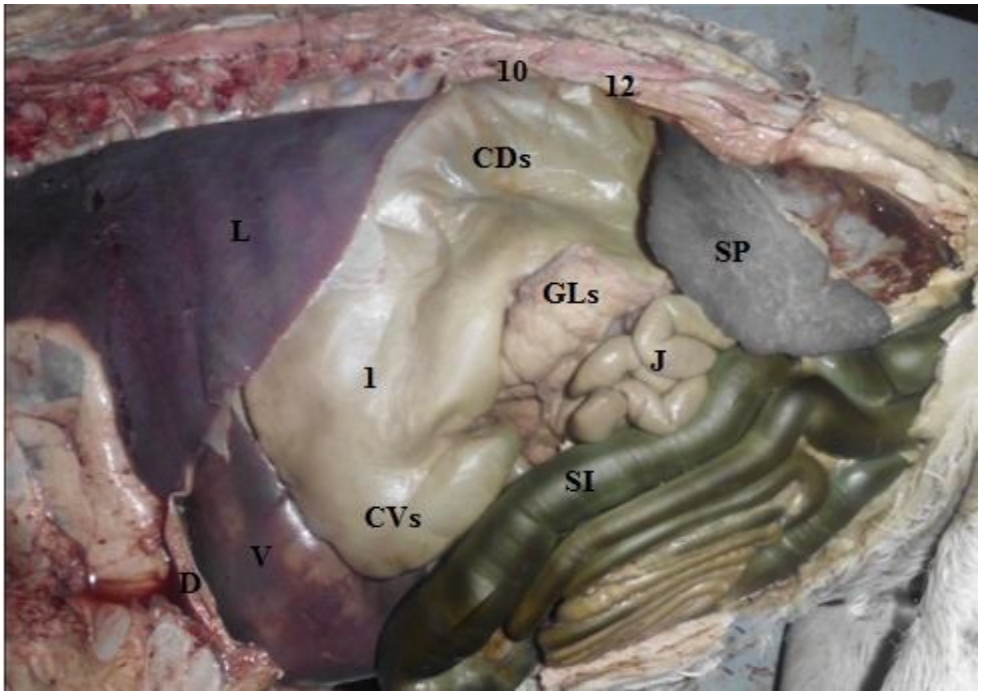

Figure 4: Left view of the foetal abdominal cavity showing the caudal lobe of left lung (L), compartment 1, diaphragm (D) (cut), liver (V), cranioventral sac (CVs), caudodorsal sac

(CDs), glandular sac (GLs) covered by lesser omentum, jejunum (J),spleen(Sp), spiral loop of ascending colon (Sl) and bodies of 10th to 12th thoracic vertebrae.

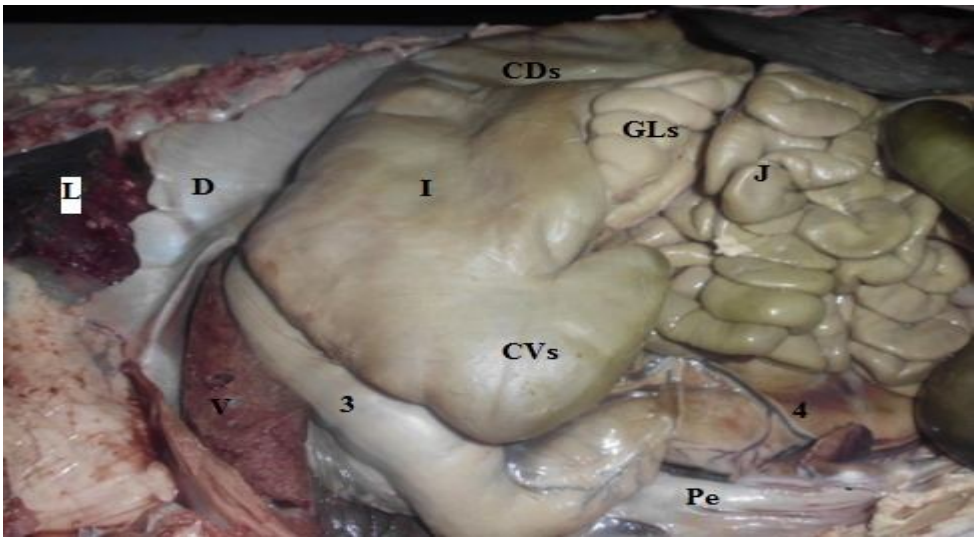

Figure 5: Left view of the fetal abdominal cavity showing the caudal lobe of left lung (L) (cut), compartment 1, 3 and 4, diaphragm (D), liver (V) (cut), cranioventral sac (CVs), caudodorsal sac (CDs), clearly sacculated glandular sac (GLs), jejunum (J) and peritoneum (Pe).

The internal surface of cranioventral sac consisted of large glandular pits and contained two types of mucosae; a non-glandular mucosa which covered the peripheral rows and columns of the sac, and a glandular mucosa which covered the central rows and columns. Each pit was bounded by pillars; two thick longitudinal pillars and two thin transverse pillars which formed the four walls of the pit. The floor was surrounded by the bases of the four walls. The pits were furtherly subdivided into smaller pits by smaller longitudinal folds (Figures 6 and 7).

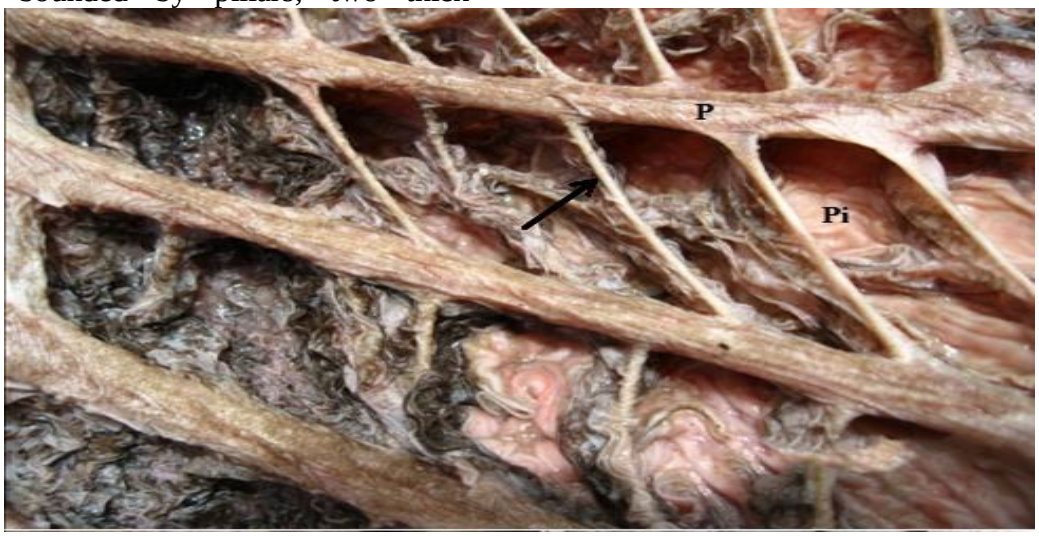

Figure 6: The interior of cranioventral sac of adult camel; Note that the glandular pits (Pi) consist of pillars (P), and folds (arrow).

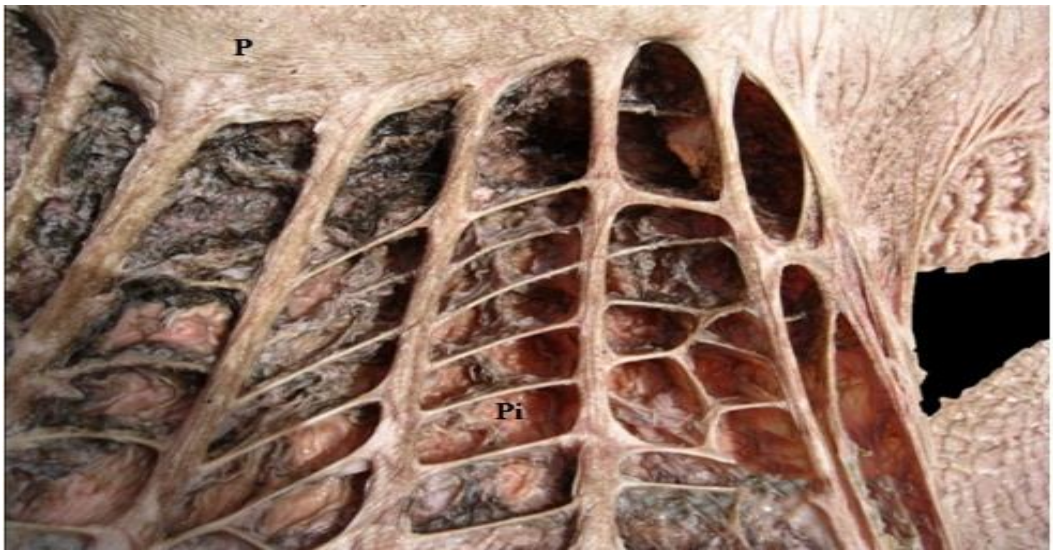

Figure 7: The interior of caudodorsal sac of adult camel with smaller and numerous pits (Pi), larger pillars (P) compared to the cranioventral sac in Figure 6.

Caudodorsal sac:

The caudodorsal sac was relatively larger and more sacculated than the cranioventral sac. About 10 small sacs; 7 horizontal and 3 ventral sacs were observed externally (Figure 5).The sac was related dorsally to longus coli muscle at the level of the bodies of 8^{th} - 12^{th} thoracic vertebrae. Caudodorsally it was attached to the visceral surface of the spleen by a ligament. It was also related to the spleen, duodenum and jejunum caudally. It opened in compartment 2 through a short canal which was a continuation of the esophageal groove (Figure 3).

Internally, the structure of caudodorsal sac was similar to the cranioventral sac but it contained smaller and numerous pits (59) and larger pillars in comparison to the cranioventral sac which had 21 pits and smaller pillars (Table 1and Figure 7).

Histometry:

The general histometric measurements of cranioventral and caudodorsal sacs are shown in Table 2.

There were no significant differences between the cranioventral and caudodorsal sacs in the different measurements of their glandular structures which included the glandular length, glandular diameter and thickness of layers of glandular wall (tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa).

Table 2: Histometric measurements of structures in the glandular regions of Cranioventral and Caudodorsal sacs (µm)

Parameter	Craniventral sac	Caudodorsal sac
Glandular length	158.34±61.83	217.50±33.83
Glandular diameter	69.60±15.13	62.14±14.64
Mucosal thickness	235.60±28.10	285.70±42.72
Submucosa thickness	1124.16±521.41	982.75±490.20

Muscular thickness	1826.02±349.91	1788.90±817.44
Serosa thickness	263.60±142.75	143.90±67.92

DISCUSSION

Gross anatomy:

The present study shows that the stomach of the dromedary camel is formed of four compartments; compartment 1, compartment 2, compartment 3 and compartment 4 depending on the external. Although, this is in agreement with the findings of Osman (1999), yet some authors divided the stomach of the dromedary camel into three compartments; compartment 1, compartment 2 and compartment 3 (Dougbag and Berg, 1980; Singh*et al*. 1996). The stomach in the alpaca (Vaughan, 2008) and Lama Glama (Vallenas*et al*., 1971; Lazuli*et al*. 2004) also consisted of three compartments.

The present study shows that the camel foetal stomach extends between the diaphragm and cranial border of the 7th rib to the caudal border of the 12th rib caudally on the left side. Erden *et al.* (1998) claimed that the stomach of the adult camel extended from the diaphragm to the pelvic inlet and occupied the major portion of the abdominal cavity, this coud be attributed to gradual growth of stomach.

The current study is in agreement with Osman (1999) that compartment 1 in dromedary camel is round in shape and it is the largest part of stomach which is situated on the left part of the abdominal cavity. Its external surface is smooth except in the two sacculated areas of cranioventral and caudodorsal glandular sacs which are separated by an oblique transverse groove. Moreover, a groove separates compartment 1 from compartment 2. However, Lechner-Doll*et al.* (1995) stated that in camelids, compartment 1 was divided by a strong transverse muscular ridge into a cranial and a caudal portion and the relatively small compartment 2 (C2) was not completely separated from Cl. In contrast, Engelhardt and Holler (1987) and Engelhardt *et al.* (1992) had observed a strong ventral and transverse muscular ridge which divided compartment 1 into cranial and caudal portions in camelids. In llama and guanaco, however, compartment 1 was partially divided into a cranial (forward) sac and a caudal (rearward) sac; the saccules of C1 were deeper than in C2 which gave the appearance of a distinct and regular pattern of mounds when viewed from outside the chamber (Vallenas *et al.* 1971).

According to Hegazi (1950) the interior of the dromedary rumen was formed of three groups of water sacs, the largest one was situated in front and to the right aspect of the rumen, whereas the third and the smallest one is located in the left side of the apex of the rumen. The present study reports two glandular sacs in compartment 1; a caudodorsal sac which extends between the 8th and the 12th thoracic vertebrae and a cranioventral sac which extends between the 7th rib cranially and the 9th rib, externally. Internally they were separated by a crescent-shaped pillar corresponding to the external transverse groove. The rumen was also described to be having two glandular sacs (Hansen and Schmidt-Nielsen, 1957; Shahrasbi and Radmehr, 1974; Langer, 1988; Smuts and Bezuidenhout, 1987). One of these sacs was situated at the cranioventral aspect of the rumen, being more to the right side, and the other sac was located in the medioventral aspect

or lies on the floor of the abdominal cavity (Purohit and Rathor, 1962; Schmidt-Nielsen, 1964; Ramadan, 1994). Wilson(1989)stated that the glandular sacs consisted of a number of small chambers separated by folds of mucosa and considered to be the water store of the camel.

The internal surface of cranioventral and caudodorsal sacs as observed in this study consists of large glandular pits and contains two types of mucosae; a non-glandular mucosa which covers the peripheral rows and columns of the sac, and a glandular mucosa which covers the central rows and columns. Each pit is bounded by pillars; two thick longitudinal pillars and two thin transverse pillars which form the four walls of the pit. The floor is surrounded by the bases of the four walls. The pits are furtherly subdivided into smaller pits by smaller longitudinal folds. This is in accord with Wilson (1989) and Erden*et al.*, (1998) in dromedary camel, and Wang*et al.*, (2000) in Bactrian camel. On the other handAbdel- Magied and Taha, (2003) described eight different grossly identifiable mucosal regions in the dromedary stomach; three of them were in compartment 1.

Histometry:

The review of literature revealed that little work has been done on the histometric measurements of the glandular sacs in camelidae.

The present study shows that the glandular mucosal thickness of camel cranioventral sac (235.60±28.10 µm) is insignificantly lower than that in the caudodorsal sac (285.70±42.72 µm). However, Abdel Magied and Taha (2003) stated that in the dromedary the thickness of non-glandular mucosa of the dorsal surface of cranioventral sac was about (200µm) and the glandular mucosa of the cranioventral sac was about 250 µm thick.

The present studyreveals that there is no significant difference between the glandular length of cranioventral sac and that of caudodorsal sac. The glandular diameter also shows no significant difference in the current study which is (69.60±15.13 µm) in cranioventral sac and (62.14±14.64 µm) in caudodorsal sac. According to Abdel Magied and Taha (2003) the glandular length in region 2 (cranioventral sac) is (120 µm).

In the current study there are also no significant differences between the cranioventral and caudodorsal sacs in the different measurements of their glandular diameter, glandular length and glandular structures which included the thickness of mucosa, submucosa, muscularis and serosa.

CONCLUSION

The present results reveal that the stomach of the dromedary camel consist of four compartments. No significant differences are observed between the gross anatomy and histometry of cranioventral and caudodorsal sacs except that the pits in the cranioventral sac are larger than that in the caudodorsal sac.

RECOMMENDATION

Further studies are needed to investigate the immunohistochemistry of cranioventral and caudodorsal sacs. Comparative morphological studies are also recommended to elucidate structural and histochemical differences between the glandular tissue of the sacs and those of other compartments of camel stomach.

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