Sudan University of Science and Technology

College of Graduate Studies

Morphological and Histochemical Studies on the Stomach with special emphasis on the Glandular Sacs of the Camel *(Camelus dromedarius)*

دراسات مورفولوجية وكيمياء نسيجية عن معدة الجمل وحيد السنام بالتركيز على الأكياس الغدية

By

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قال تعالى: ((أَفَلَا يَنظُرُونَ إِلَى الْإِبِلِ كَيْفَ خُلِقَتْ))

الغاشية 17

DEDICATION

To

The soul of my mother

my father

my sisters and brothers.

with my great love.

Ibrahim Ahmed Abuagla

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Praise is to Alla who gave us health and strength and patience to conduct this work.

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Abstract

Camel glandular sac areas were previously considered as water stores. Recently these sacs are found to be glandular areas which probably perform absorption, fermentation and secretion functions. This investigation which was conducted on thirty five adult camels and ten camel fetuses which were collected from Tamboul slaughterhouse during the period 2|2013 – 2|2014, aimed to study the morphology (gross anatomy, histology, ultrastructure, histometry) and histochemistry of camel glandular sacs.

The camel stomach was 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 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 in shape and it was larger and more sacculated. Compartment 2 was small and bean-shaped and smaller than compartment 1. Compartment 3 was long and tubular. Compartment 4 was bean-shaped and smaller than compartment 3 and divided into fundic and pyloric regions.

Compartment one contained both non glandular and glandular regions. Cranioventral and caudodorsal sacs formed the glandular region of compartment 1; they contained glandular pits. The four walls of each pit were formed by 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 lined by keratinized stratified squamous epithelium; the floor mucosa contained serous secreting glands which were lined by simple columnar epithelium. The mucosa of compartment 2 was

mainly glandular and the glands opened in shallow pits and lined by simple columnar epithelium. The mucosae of compartment 3 and 4 were glandular.

No significant histometric differences were observed between the cranioventral and caudodorsal sacs in the glandular size and thickness of wall tunics.

In scanning electron microscopy the surface of the glandular region of cranioventral and caudodorsal sacs was folded and contained cup-shaped, cap-shaped and flower-shaped glands. In transmission electron microscopy the glandular columnar cells of cranioventral and caudodorsal sacs were closely packed together and contained Golgi apparatus, dense bodies and numerous secretory granules especially in the apical cytoplasm.

The glandular epithelial cells of cranioventral and caudodorsal sacs showed strong positive PAS reaction; glycogen digestion was detected in glandular tissue. Blue cells, red cells and purple cells were also observed in the glands following PAS and AB reactions. Alkaline phosphatase reaction was positive in glandular tissue of cranioventral and caudodorsal sacs especially in the luminal parts of epithelial cells.

The results revealed no significant differences between the morphology of cranioventral and caudodorsal sacs except that the pits of cranioventral sacs were larger than those of caudodorsal. Histochemically, these sacs are suggested to secrete neutral mucopolysacharides. In addition, some cells secrete both neutral and acid mucopolysacharides and others showed glycogen in some glandular tissue.

المستخلص

أعتقد سابقاً ان الاكياس الغدية فى معدة الجمال تعمل كمخازن للمياه، غير أن الدراسات الحديثة أثبتت وجود وظائف افرازية لهذه الأكياس حيث تلعب دوراً هاماً فى الإمتصاص و التخمير.

أستخدمت خمسة وثلاثون من الإبل البالغة وعشرة أجنة تم جمعها من مسلخ تمبول فى الفتره من 2|2013 – 2|2014م تم عليها إجراء الدراسة المورفولوجية (تشريح عيانى ومجهري، مجهري دقيق وقياسات نسيجية دقيقة) والدراسة الكيميائية النسيجية على الغدد الموجودة في الأكياس الغدية بمعدة الجمال.

أظهرت الدراسة أن معدة الجمال مكونة من أربع غرف؛ الغرفة الأولى هى أكبر الغرف وتمتد مابين الحجاب الحاجز والحافة الذيلية للضلع الإثنى عشر، وتحتوي على كيسين؛ كيس أمامى بطنى وكيس خلفى ظهرى إضافةً الى منطقة غير غدية. الكيس الأمامى البطنى بيضاوى الشكل واحيانا يكون سطحه الخارجى أملس بينما الكيس الخلفى الظهرى غير منتظم وهو الأكبر حجماً وبه عدد من التكيسات؛ الغرفة الثانية أصغر حجماً من الغرفة الأولى وتشبه فى شكلها حبة الفاصوليا؛ الغرفة الثالثة طويلة و أنبوبية الشكل؛ الغرفة الرابعة تشبه فى شكلها حبة الفاصوليا وهى أصغر من الغرفه الثالثة وتقسم الى منطقتين؛ منطقة قاعية وأخرى بوابية.

الغرفة الأولى بها منطقة غير غدية وأخرى غدية تحوى كيساً أمامياً بطنياً وكيساً خلفياً ظهرياً. يحتوي كل من الكيس الأمامى البطنى و الخلفى الظهري على حفر غدية، تحتوي كل حفرة على أربع حواجز (جدر)، حاجزان طوليان وحاجزان عرضيان، وهذه الحواجز تحيط بأرضية الحفرة؛ حواجز وأرضية الحفر تحتوي على أربع طبقات نسيجية؛ طبقة مخاطية، تحت مخاطية، عضلية ومصلية. الحواجز تحتوي على طبقة مخاطية غير غدية تبطن بطلائى حرشفى مصفف متقرن؛ بينما أرضية الحفر بها مخاطية تحتوى على غدد إفرازية مصلية تبطن بطلائى عمودى بسيط.

الغرفه الثانية بها طبقة مخاطية غدية تحتوي على غدد تبطن بطلائى عمودى بسيط وتفتح في حفر سطحية ضحلة. كذلك وجد أن الطبقة المخاطية غدية في الغرفة الثالثة والرابعة.

أظهرت القياسات النسجية في الكيسين الأمامى البطنى والخلفى الظهرى عدم وجود إختلافات بينهما في حجم الغدد وسمك الطبقات.

بينت دراسة المجهر الإلكتروني الماسح أن سطح المنطقة الغدية للكيسين مكون من طيات متعرجة تحتوي على غدد تشبه فى شكلها الكأس والقلنسوة (القبعة) والزهرة. كما أوضحت دراسة المجهر الإلكتروني النافذ أن الخلايا العمودية لغدد الكيسين تتراص مع بعضها البعض وتحتوي على العديد من العضيات كالمتقدرات

وجهاز جولوجى، إضافة إلى عدد من الأجسام الكثيفة و الحبيبات الإفرازية وخصوصاً بالمنطقة القمية للسايتوبلازم.

الخلايا الغدية للكيسين أظهرت تفاعلاً إيجابياً قوياً مع صبغة *PAS* وتم التعرف على الجلايكوجين فى بعض الأنسجة الغدية. لوحظ أن هنالك خلايا غدية زرقاء وحمراء وأرجوانية بعد صبغها بصبغة PAS و AB. إنزيم الألكالاين فوسفاتيز أبدى تفاعلاً إيجابياً فى أنسجة الكيسين خصوصاً فى خلايا تجويف الغدد والطلائى.

خلصت الدراسة إلى عدم وجود إختلافات مورفولوجية أساسية بين الكيسين الأمامى البطنى والخلفى الظهرى غير أن حجم الحفر الغدية أكبر في الكيس الأمامى البطنى. كما أوضحت الدراسة الكيميائية النسيجية أن غدد هذه الأكياس تفرز إفرازاً متعادلاً من عديد السكر المخاطى بالإضافة إلى أن بعض الخلايا تفرز إفرازاً مختلطاً، من عديدات السكر المخاطية الحمضية والمتعادلة مع وجود جلايكوجين فى بعض الأنسجة الغدية.

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Introduction

The habitat of the dromedary Camel is Northern Africa, and the near East and West Central Asia (Wilson, 1984).

Camel population in the world is estimated to be 18 million; about 16.5 million are one-humped camels, or dromedary type (Majied, 2000). Sudan and Somalia contain 55% of the world's camel population and 70% of the African camel population (Wilson, 1984). In Africa Sudan ranks second after Somalia (Madani, 1996; AOAD, 2001).

Sudan is one of the most important countries in Africa regarding rearing and export of livestock. The most recent animal census estimated population in Sudan to be about 3 million (AOAD, 2001).

The dromedary camel (*camelus dromedarius*) is uniquely adapted to hot and arid environment. It produces milk, meat, wool, hair, and hides and is used for riding, as an animal of burden and as a draft animal for agriculture and short distance transport (Schwart and Diolim, 1992).

Camels comprise about 6% of the number of animals used for the production of milk and meat in the Sudan. Its' meat constitutes about 9% of the national annual meat consumption. Trading in camels brings in about 25% of the national revenue of animal international trade (Haroon, 1991).

The camel is an important component of the desert ecosystem. The ability of the camel to withstand adverse conditions is attributed to its' adaptive physiological mechanisms aided by an array of supporting morphological features and behavioral attitudes (CRC News letter, 2002).The camel is also known for its' ability to resist diseases.

Perrault cited by Cummings *et al. (*1972) investigated the glandular sac area of the stomach in the camel. Various studies have since been conducted on the

unusual tolerance of the camel to desert heat and water deprivation. Grossly the stomach of the camel differs from the stomach of ruminants such as bovines, in that it consists of three compartments. The glands of the glandular sac area of the first and second compartments are lined by a simple columnar epithelium (Xie, 1977; Hoshino, 1985), and the third compartment consist of wide cardiac glands, narrow gastric glands and pyloric glands (Eerdunchaolu *et al*., 1999). Previous hypotheses suggested that the glands of the glandular sac area consist of water cells that function as water tanks; however, these hypotheses have since been disproved (Hansen and Schmidt-Nielsen, 1957). It has been confirmed that the glands of the glandular sac area consist of cells similar to the cardiac gland cells of pigs and that the glands secrete a PAS-positive mucus substance (Cummings *et al*., 1972).

The present work is intended to be a further contribution to the morphological and histochemical studies on the functional importance of the stomach glandular sacs of the camel *(Camelus dromedarius)* in an attempt to understand their function.

Moreover the ultrastructure of these glands was not thoroughly investigated.

Objectives:

- To study the gross external and internal structure of camel stomach including the glandular sacs.
- To study the histological structure of the camel stomach.
- To study the ultrastructure of the glandular sacs.
- To study the histometry of the glandular sacs.
- To study the histochemistry of the glandular sacs.
- To elucidate the function of the glandular sacs, according to morphological characterization and histochemistry.

CHAPTER ONE

LITERATURE REVIEW

1. 1. Gross Anatomy

1.1.1. Stomach

Camel stomach is physiologically similar to that of typical ruminants in several aspects, such as regurgitation of ingesta, and active microbial fermentation (Frandson, 1974). The typical ruminant stomach consists of four compartments; rumen, reticulum, omasum and abomasum. In contrast to the compound stomach of typical ruminants, the stomach of the camel 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). Camels are thus considered pseudo-ruminants. (Dougbag and Berg, 1980) subdivided the third compartment according to the external and internal appearance into three parts: an initial dilated part, a middle long narrow part and a terminal dilated part. However many other authors divided the dromedary stomach into four compartments: rumen, reticulum, omasum and abomasum (Hegazi, 1950; Hansen and Schmidt-Nielsen, 1957; Bohken, 1960; Czerkawski, 1985; Smuts and Bezuidenhout, 1987; Langer, 1988). Osman (1999) stated that the dromedary camel stomach was formed of four compartments: 1, 2, 3 and 4. The sacs characterized compartment 1 and 2, compartment 3 corresponded to the omasum and compartment 4 internally resembled the abomasum.

The rumen was the first and largest compartment and presented a glandular region and non-glandular region. The glandular portion had two glandular sacs on its visceral surface. The glandular sac region was lined by a simple columnar epithelium (Hoshino, 1985).

Erden *et al*. (1998) observed that the stomach of the camel was composed of four compartments (rumen, reticulum, omasum and obomasum), as in all ruminants. However, these compartments greatly differed in shape and structure from the typical design encountered in the ruminants. It had a capacity of approximately 80 liters. It extended from the diaphragm to the pelvic inlet and occupied the major portion of the abdominal cavity. The rumen was divided into a relatively small cranioventral and a large caudodorsal sac. The cranioventral sac was composed of so-called (water cell) or (glandular sac) and non-glandular area. Internally the glandular sacs consisted of smaller compartments divided by strong longitudinal bands and most of these compartments were again subdivided by transverse bands, thus giving them a honey comb appearance. The mucous membrane of the rumen was not studded with papillae.

Erden *et al*. (1998) described the reticulum as a pear shaped organ and unlike other ruminants, the mucous membrane of the reticulum formed deep pouches which are separated from each other by muscular bands. Each pouch was again divided and subdivided to form many layers. The mucosae of the pouches were studded with very small rounded papillae. The omasum was a long colon-shaped organ and very different from the omasum of the domestic ruminants. The mucous membrane was thrown into about 50-60 longitudinal folds which gave a leafy appearance to this organ. Internally the abomasum was divided into fundic and pyloric parts.

The (glandular sac) areas of the rumen, once considered to be the water store of the camel, consist of a number of small chambers separated by folds of mucosa. The mucosa is covered by a columnar epithelium which has up to 100 million short tubular glands. Similar areas are found in the reticulum and the omasum. These glands probably act as absorption and fermentation areas, as well as areas of secretion of enzymes. The stomach of true ruminants does not have comparable

mucosa. The rumen essentially performs the same functions as in the ruminantia and its contents are normally equivalent to 11 to 15 per cent of total body weight (Wilson, 1989).

The three compartments of the camelid digestive system are referred to as C1, C2, and C3 and bear little homology to the rumen, reticulum, omasum, and abomasums of true ruminants.

The first chamber, C1, occupies a large portion of the left side of the trunk and holds approximately 83% of the total gastric volume. This structure is the site of a great deal of the primary bacterial breakdown of plant cellulose into absorbable nutrients. C1 is partially divided into a cranial (forward) sac and a caudal (rearward) sac (Vallenas *et al.,* 1971). The ingesta were relatively homogenous throughout, but the material found in the caudal sac and the upper dorsal portion of the cranial sac was somewhat drier, while finer particulate matter lay within the lower ventral portion of the cranial sac. C1 communicated with the much smaller C2 that is located along the right abdominal wall. C2 represented about 6% of the total gastric volume and contained liquid ingesta which enter from C1. It was divided into a dorsal lesser curvature and a ventral greater curvature and itself empties into C3 via a short, thick walled, muscular tube that could constrict to control the rate at which material moves into the third compartment (Vallenas *et al.,* 1971). The third compartment was a more elongated structure that lay below C2 and along the lower right abdominal wall and comprised approximately 11% of the gastric volume. The last 1|5th of this compartment contained the gastric glands that define the true stomach (Vallenas *et al.,* 1971). One of the most unique aspects of the camelid foregut are the saccules that are found in the first and second compartment. These thin-walled invaginations of the gut wall are formed by the intersection of primary, secondary, tertiary, and some times higher order crests and lie in oblong regions along the ventral portions of C1 and C2. According to

Vallenas *et al.*, (1971) the saccules of C1 were deeper than in C2 and gave the appearance of a distinct, regular pattern of mounds when viewed from outside the chamber. In addition they also had partial diaphragm that restricted the size of their opening on the inside of C1. With each contraction cycle, the saccules of C1 will partially, empty their contents into the lumen of the chamber.

The anatomical studies of llama (Lama Glama) showed that the proximal compartment was located totally in the left abdominal wall. The intermediate compartment was kidney -like in shape, with thick walls. The distal compartment was elongated, tubular and located toward the ventral and right aspect of the abdominal cavity (Lazuli *et al*., 2004).

According to Lechner-Doll *et al.* (1995) in camelids, the forestomach consisted of a large compartment 1 (Cl) which was divided by a strong transverse muscular ridge into a cranial and a caudal portion. The relatively small compartment 2 (C2) was not completely separated from Cl. Compartment 3 (C3) which originates from C2, was situated at the right side of C1. C3 was a long, tube-like organ. Hcl was produced only in the comparatively small hind stomach. The ventral regions of C1 and C2 were formed by glandular sac areas, which were particularly prominent between the strong muscular ridges in Cl.

Raji (2011) found that the mucosa of the abomasum was divided into four regions, i.e. cardiac, pseudocardiac, fundic and pyloric. His investigation revealed that the cardiac and pseudocardiac regions occupied a wide part of the abomasum in camel and it reached approximately the third fourth of the abomasum. In addition, gross anatomical observations showed small diverticulae in the fundic region. This part was also covered with thick mucosal folds that were separated by deep branching furrows.

According to Vaughan (2008), the alpaca stomach had three compartments (C-1, C-2 and C-3) and was not analogous to any of the true ruminant stomachs.

Neonates had a large true stomach but a poorly developed C-1. By 8 weeks of age, C-1 reached adult proportions. It took about 12 weeks to reach full adult activity allowing the breakdown of plant fiber. C-1 lay on the left hand side of the abdomen and constituted about 80% of forestomach volume. Compartment 2 constituted 6% of stomach volume and together with C-1 they contained 10-15 liters of digesta. There were also glandular saccules across the ventral surfaces of C-1 and C-2. This glandular area had many functions including absorption of nutrients, addition of mucus secretions, glycoproteins and urea to provide an optimum environment for the microbes and possibly secrete bicarbonate ions to buffer C-1 and C-2 contents. The opening between C-1 and C-2 was large (mineral pellets do not remain in C-1 for any significant period of time) and the pH ranged from 6-7. C-3 (11% of forestomach volume) was tubular and extended next to C-1 on the right side of the abdomen. The last one-fifth ha true gastric glands and it had a pH of 2-3. Solutes and water were rapidly absorbed.

In typical ruminants, it is Known that the first three compartments (rumen, reticulum and omasum) are non-glandular whereas the fourth one (abomasum) is glandular and contains typical cardiac, fundic and pyloric glands (Banks, 1993; Eurell and Dellman, 1998).There seems to be no consensus on categorization of the different parts of the stomach of the camel. Dougbag and Berg (1980) designated the second compartment of the stomach of the dromedary camel as the reticulum and the third as the tubular portion. They reported cardiac and fundic glands in the third compartment. On the other hand, Eerdunchaolu *et al*. (1999), Lechner-Doll *et al.* (1995) regarded the stomach of the bactrian camel as a single compartment formed by multiple differentiations of cardiac glands. Wang *et al*. (2000) considered the stomach of the Bactrian camel to be divided into three ventricles; they regarded the first and second compartments as one stomach that

differed from the typical rumen and reticulum and referred to the third one as the abomasum.

Hegazi (1950) observed 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. However, Hansen and Schmidt-Nielsen, (1957), Shahrasbi and Radmehr (1974) and Langer, (1988) stated that the rumen is divided into two sacs. 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) and 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 greater part of the rumen was lined by smooth mucous membrane, while the remaining part of the rumen was interrupted by muscular bands enclosing between them the water sacs. The mucous membrane of the rumen had no papillae, and was raised in small folds (Hegazi, 1950; Purohit and Rathor, 1962). The reticulum or compartment 2 was small in size and was described as bean or pear-shaped, and its mucous membrane formed deep pouches which were separated from each other by muscular bands (Purohit and Rathor, 1962; Engelhard *et al.*, 1986; Smuts and Bezuidenhout, 1987; Lechner-Doll *et al*., 1995).

The omasum or compartment 3 is elongated or sausage-shaped, and is curved ventrally and caudally under the reticulum (Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962; Engelhardt and Holler, 1987; Smuts and Bezuidenhout, 1987; Lechner-Doll *et al*., 1995). Purohit and Rathor, (1962) stated that the mucous membrane of the omasum was thrown into about 50 longitudinal folds.

However, Vallenas *et al.,* (1971) and Cummings *et al.,* (1972) claimed that this comportment was blended with compartment 4 and they considered, them together as a third compartment.

The abomasum or hind stomach was relatively small. Internally this compartment was divided into two parts: fundic and pyloric (Purohit and Rathor, 1962; Dougbag and Berg, 1981; Engelhardt and Holler, 1987; Smuts and Bezuidenhout, 1987). The mucous membrane of the fundic part had distinct circular laminae or folds, while the pyloric part contained a few folds (Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962).

Wang *et al*. (2000) described a cranioventral glandular sac area which was located in the cranial end of the cranioventral sac of the first ventricle. Its ventral margin was slightly zonular, 65-80cm long, and 10-12cm wide.

The mucous membrane in this area had transverse and longitudinal folds extending from the external muscular layer of the stomach wall. 20-25 transverse mucosal folds were slightly semilunar in shape and were present throughout the glandular sac area (Wang *et al*., 2000).

These folds projected like spokes from the center of the cranioventral sac. The concave free border of the transverse folds contains a smooth muscle bundle of approximately 0.1-0.2cm in diameter. This bundle is formed by muscle fibers from the internal muscular layer in the wall of the stomach. The longitudinal mucosal folds were short, thin and connected with the transverse folds. There were generally four longitudinal folds that connected to two adjacent transverse folds.

According to Wang *et al*. (2000) the glandular sac area was divided into 65-75 glandular sacs by the transverse and longitudinal mucosal folds. The ventral part of the glandular sac was larger than the dorsal part. The orifice of a glandular sac was about 2.5-4×2-3cm in diameter. Glandular sacs in the middle part of the glandular sac area were about 3-5cm in depth, while in other areas; they were about 1-2cm

deep. The glandular sac orifice was covered by an iris-like mucosal fold. There were low mucosal folds in the bottom one-fifth of the glandular sacs that subdivided the bottom of sac into 2-4 zones. The mucous membrane of the upper portion of the glandular sac wall, the sac orifice and the iris-like fold was grey, rough and similar to the mucous membrane of the glandular sac area of the proventriculus. The mucous membrane of the lower portion of the glandular sac wall was lucid, soft, greasy and similar to the mucous membrane of the abomasum.

Wang *et al*. (2000) described a caudal glandular sac area which was located in the caudodorsal sac of the first compartment on the right side of the ridge of the transverse fold. It had an elliptically concave face, 50-70cm long and 25-35cm wide. Its ventral part was caudal to the second compartment, sac-like and extended downward on the right side of the cranioventral sac. The mucous membrane of the caudal glandular sac area had also some transverse and longitudinal folds that were similar to those in the cranial glandular sac area. Ten to twelve semilunar shaped transverse mucosal folds were present throughout the glandular sac area. Their concave border was free and their convex border was attached to the stomach wall. The free border was 0.5-1.0cm in diameter and contained a smooth muscular bundle that originated from the internal muscular layer of the stomach wall. The 5-6 longitudinal mucosal folds were short, thin and connected with adjacent transverse folds. Both the longitudinal and transverse mucosal folds contained smooth muscle that extended from the external muscular layer of the stomach wall to the free border. The glandular sac area was subdivided into 60-70 glandular units by these longitudinal and transverse mucosal folds. The upper part of the glandular unit was smaller than the lower part. The diameter of sac orifice was about 4-5×2-4cm (Wang *et al*., 2000). Glandular sacs in the middle part of the glandular sac area were 5-7cm deep while in other parts they were 1-3cm deep. Glandular sacs near the ridge of the transverse fold were large. The glandular sacs

were also covered by an iris-like mucosal fold. The bottoms of most of the glandular sacs had low mucosal folds which divided this space into 2-4 zones. The mucous membrane of the dorsal part of the glandular sac wall, the glandular sac orifice and the iris-like fold were similar to the glandular sac area of the proventriculus. The mucous membrane of the ventral part of the glandular sac wall was like that of the abomasum.

Wang *et al*. (2000) observed a third glandular area in the second compartment. It was elliptically concave in shape and measured 35-45cm long and 15-20cm wide. Its cranial end was continuous with the cardiac glandular area at the outlet of the proventriculus. Its caudal end was continuous with the caudal glandular sac area at the interventricular orifice. The mucous membrane of third glandular sac area had some longitudinal and transverse folds showing basically the same characteristics as those of the cranial and caudal glandular sac areas. However, the glandular sacs in this area were small and subdivided into many small glandular sacs by many small mucosal folds. The transverse mucosal folds of the cranial half of the glandular sac area branched following blood vessels parallel to each other in the intermediate part but not on either side. The transverse mucosal folds of the caudal half were present throughout the glandular sac area and were parallel to the transverse folds of the intermediate part of the cranial half of the glandular sac area, as well as those of the cranial and caudal glandular sac areas. There were 14-16 parallel transverse mucosal folds in this glandular sac area. They were semilunar in shape and were arranged as spokes arising from the inlet of the second ventricle. The free concave border of the fold contains a large smooth muscle bundle of about 0.4-0.8cm in diameter, which was formed by accumulating muscular fibers from the internal muscular layer in the wall of the stomach. The convex border is attached to the wall of the stomach. Longitudinal mucosal folds were short, thin, and connect with adjacent transverse mucosal folds. There were

14-16 longitudinal mucosal folds with 3-5 folds uniting with adjacent transverse mucosal folds in the intermediate part and at both ends of the glandular sac. The glandular sac area contained 140-160 glandular sacs formed by the crossing of longitudinal and transverse mucosal folds. The ventral part of the glandular sac is larger than the dorsal. The diameter of the glandular sac orifice was about 2-3×1-1.5cm.

According to Wang *et al*. (2000) the glandular sacs in the intermediate part of the glandular sac area were 4-5cm deep and 1-2cm deep in the peripheral part. There was no iris-like mucosal fold at the glandular sac orifice. The rugged mucosal folds at bottom of the glandular sac might be divided into primary, secondary, tertiary and quaternary mucosal folds. These folds connect to each other and with the glandular sac wall so that each glandular sac is subdivided into many small glandular sacs. The glandular sac wall and all levels of the mucosal folds contained smooth muscle from the external muscular layer of the stomach wall. The smooth muscle extended to the free border of the mucosal fold. The mucous membranes of the glandular sac wall and orifice were similar to those of the glandular sac area of the proventriculus. The mucous membranes of the lower part of the glandular sac wall, the bottom and all levels of the mucosal folds were similar to the abomasum.

1. 2. Histology

The Histological, studies by Abdel-Magied and Taha (2003) showed that the lining of the camel stomach was divided into eight grossly identifiable regions. The first region was non-glandular (53.2%) and occupied the body of the first compartment. The other seven regions were lined by a glandular mucosa. Their study had also shown that the glandular mucosa comprised four regions: pseudo cardiac (36.2%), cardiac (3.4%), fundic (4.3%) and pyloric regions (2.9%).

The mucosa of the first and second compartments was non-papillated and lined by squamous epithelium, and glandular within the saccules. In true ruminants, however, the mucosa of the first compartment (rumen) was structurally composed of papillated squamous epithelium. Within the individual saccules of the camellid digestive compartments, the ultastructure of the mucosa was similar to the epithelium of the gallbladder and small intestine. This type of mucosa was correlated with high rates of molecule absorption and might indicate that the saccules had an important absorptive function (Cummings *et al.,* 1972).

Histological study of llama's stomach (Lama Glama) described a proximal and intermediate compartment with and without glands. The non-glandular region was covered by stratified epithelium and without papillae. The glandular area, whose recesses originated from deep pouches, was occupied by simple tubular glands; the lining epithelium was simple cylindrical. The distal compartment was completely glandular (Lazuli *et al*., 2004).

In camelids, unlike ruminants, only the dorsal parts of Cl and C2 were lined with stratified squamous keratinized epithelium. The ventral parts of Cl, C2 and the whole inner surface of C3 were instead, lined by a columnar surface epithelium and deep tubular glands. This regional mucosa appeared to be similar to the cardiac region of the abomasum of ruminants (Cummings *et al.,* 1972; Luciano *et al.,* 1979).

1.3. Histometry:

Little work has been done on histometric measurements of the glandular sacs in camelidae.

The mucosa of dorsal surface of cranioventral sac was about 200μm thick. It comprised a stratified squamous keratinized epithelium and a connective tissue lamina propria devoid of glands. There was no muscularis mucosa. Small mucosal

folds and deep submucosal aggregates of adipocytes were frequently encountered (Abdel-Magied and Taha, 2003).

According to Abdel-Magied and Taha, (2003) the mucosa of the cranioventral sac was about 250 µm thick, showed shallow gastric pits, about 95µm deep and was bounded basally by a muscularis mucosa. Surface and gastric pit epithelium was simple columnar containing relatively pale cells. The proprial connective tissue was clearly visible and contained widely separated short (120µm long) simple tubular branching glands. The reticulum branching mucosal crypts were frequently seen in this region. The mucosa was about 260µm thick, the pits were about 100µm deep and mucosal glands were about 130µm long.

1. 4. Ultrastructure:

In camelids, the epithelium lining the surface areas of the mucosa consisted of about 40 µm high columnar cells having prominent oval nuclei located in the basal third (Lechner-Doll *et al.,* 1995). The fine structure was comparable to that found in the corresponding regions in llama and guanaco (Luciano *et al.,* 1979). The main characteristics of these cells were; a brush border membrane formed by tiny microvilli, a well-developed Golgi apparatus and numerous secretory granules (mainly packed together between the Golgi and the apical plasma membrane). The mitochondria were elongated, slender and with a dense matrix. They filled wide cytoplasmic areas in the upper region in the cell where several dense bodies could also be seen. The lateral plasma membrane was extremely infolded; the intracellular space was very variable in width. These characteristics indicated that the cells had absorptive functions and furthermore, those of the llama and guanaco, probably secreted mucosubstances (Cummings *et al.,* 1972; Luciano *et al.,* 1979).

The epithelial cells of the glands are cuboidal and produce two morphologically different types of granules. One type is of variable diameter (from 300 to 800 nm) and pale, the other type was small (from 160 to 300 nm) and

electron –dense. These two types of granules were present either separately in different cells or together in the same cell. Endocrine cells occurred mainly at the glands. Moving cells, especially eosinophilic granulocytes, are often observed intraepithelially by Lechner-Doll *et al.,* (1995).

Transmission electron microscopy showed that gland cells in the glandular sac area contained granules of low and high density in the supranuclear region. The granules of low density were about 720 nm in diameter and granules of high density were about 240 nm in diameter (Eerdunchaolu *et al.*, 1999).

Raji (2011) studied SEM of abomasum of one-humped camel. He observed that after complete removal of mucin from the surface of the mucosa, simple columnar epithelial cells with a mean length of 20 µm had been observed together with some epithelial cells arranged as flower body (FB). Also, hexagonal structures were reported on the surface of abomasal mucosa that resembled honeycomb structure (HC). The mean diameter of these HC structures was 30-40 µm. The average length of epithelial cells was 20µm. The epithelial surface was covered with small invaginations called gastric pits that were connected to the surface of lumen by a foramen. Many epithelial cells together created continuous crest structure like flower. According to Saber and Weyrauch (1998) the one-humped camel cranial glandular sac area showed rosette-like structures which were more numerous in the first, rather than in the second compartment of the stomach and the connective tissue core (CTC) was arranged in a network-like in the cranial glandular sac area. On the other hand, the epithelial underside was furnished with highly wrinkled ridges of different heights, corresponding to the grooves between the CTCs. In addition, the epithelial underside was also studded with rounded openings, corresponding to the connective tissue rosettes; these rounded openings were highly plicated.

1. 5. Histochemistry:

Carbohydrate histochemistry had shown that the surface epithelial cells were either negative to both AB and PAS or partially PAS positive (±). Gastric pit cells were strongly positive (+++) to AB and/or PAS. Gland bodies were negative to both AB and PAS but their luminar parts were often weakly PAS positive (±). The gland bases were often moderately positive (++) to alcian blue at pH 1 and to wheat germ agglutinin (WGA) (Abdel-Magied and Taha, 2003).

Histochemical reactions of regions 2 and 3 were similar. The Surface epithelial cells were either negative to AB/PAS or partially positive to PAS (±). Gastric pit cells were strongly positive (+++) to AB and/or PAS. Mucosal gland bodies were negative to both AB and PAS, but their luminar margins were often weakly PAS positive. The gland bases were often moderately positive (++) to alcian blue at pH 1 and to WGA, (Abdel-Magied and Taha, 2003).

Eerdunchaolu, *et al.*, (1999) in carbohydrate histochemical experiments observed that the surface mucous cells of both the glands of the glandular sac area in the first and second compartments and the cardiac glands showed a strong positive reaction to PAS.

In camel Raji (2011observed that the surface epithelium in abomasum was negative to AB and positive to PAS staining, whereas in the gastric pit cells it was positive to AB and PAS staining, but gastric gland cells were negative to PAS and positive to AB staining.

In the available literature, there was no report on alkaline phosphatase enzyme.

CHAPTER TWO

MATERIALS AND METHODS

Stomach specimens of 35 apparently healthy adult camels and ten foeti of both sexes were used in this study. They were collected from Tamboul slaughterhouse, Sudan during the period 2|2013 – 2|2014.

2.1. Gross Anatomy:

Ten fresh specimens of adult animals of both sexes and different 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 cranioventral and caudodorsal sacs were also measured. Ten foetal samples of different developmental stages were used to study the topography of stomach.

2.2. Histology:

Tissue samples were collected from each of the grossly identifiable regions of the glandular sacs of 10 adult healthy animals of both sexes and different ages. Samples (about 1cm) were taken from each region immediately after slaughtering and were fixed by immersion in buffered neutral formalin, 10% formalin or Bouin's solution about 4-18 hours. They were then dehydrated, cleared and embedded in paraffin wax. Sections (3–5 µm) thick were stained by haematoxylin and eosin (Culling, 1974) for the general structure of stomach, Masson's trichrome stain for collagen fibres, Verhoff's for elastic fibers, and silver nitrite for reticular fibers (Culling, 1974).

2.3. Histometry:

Tissue samples from five adult animals were used for the histometric measurements. The tissues were fixed in either 10% formaldehyde or Bouin's fluid. Dehydration, clearing and embedding were carried out as for general

histology. Sections 5 μm thick were cut in a rotary microtome and stained conventionally with hematoxylin and eosin.

Measurements were performed on transversally cut glandular tissue of cranioventral and caudodorsal sacs. Olympus microscope (CH20-Japan) with ocular micrometer lens X6 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, gastric pit depth, glandular length, mucosal thickness, submucosal thickness, tunica muscularis thickness and serosa thickness were taken from each animal. The measurements of each animal were recorded and the averages were calculated.

2. 4. Ultrastructure

Samples of glandular sacs from five adult camels were used for ultrastructural studies and were processed according to the procedures described by Bancroft and Stevens (1990, 1996).

2.4.1. Transmission electron microscopy

Small pieces of tissue (1x1mm in diameter) were taken immediately and fixed rapidly in 5% glutaraldehyde in phosphate buffer at a pH of 7.4 for 2-4 hours at 4°C. The blocks were then washed every 10 minutes for 30-60 minutes in phosphate buffer using shaker machine. The tissues were post fixed in 1% osmic acid for 2 hours, and then washed in phosphate buffer every 10 minutes for 30-60 minutes, using a shaker machine.

Dehydration was carried out in ascending grades of ethanol, 50% and 70% alcohol for 30 minutes using shaker machine or 70% alcohol for several days without shaking, 90% alcohol for 30 minutes and two changes of absolute alcohol for 30 minutes. Then the blocks were immersed in propylene oxide for 30 minutes, and transferred to a solution containing propylene oxide (a) plus mixture (b) composed

of EPON 15ml, ARALDITE 15ml and DDSA 36ml for 30 minutes. The ratio of a: b was 1:1. The blocks were finally left in mixture (b) for 2 hours. Then Dimethylaminomethyl phenol (DMP30 1. 5%) was added to the mixture to make it hard for blocking. The blocks were kept in an oven at 60°C for 48 hours. Semi thin sections (0.5 μ) were cut on a LKB or a Reichert-ultra microtome, using glass knifes, and were then stained with toluidine blue and examined with the light microscope. The desired regions for electron microscopy were then selected and ultrathin sections were cut with glass knifes or diamond knifes. The sections were mounted on uncoated copper grids, treated with 2% uranyl acetate for 20 minutes, washed in distilled water and then treated with lead citrate for 15 minutes. They were then washed, dried and examined in a Zeiss EM 109 electron microscope.

2. 4. 2. Scanning electron microscopy

Small pieces of tissue (1cm³) were taken immediately and fixed rapidly in 5% glutaraldehyde in phosphate buffer at a pH of 7.4 for 48 hours at 4°C. The blocks were washed in 3 or 5 changes in the same buffer and post-fixed in osmic acid for 2 hours. The blocks were washed in 3 changes in the buffer for 4 hours and dehydrated in ascending grades of alcohol 30%, 50%, 70%, and 90% each for 2 hours and in 100% for 2 days. The blocks were immersed in amylacetate for 1-2 days and then drying using critical point drying process. Finally the blocks were coated by a very thin layer of gold and examined by JEOL JSM-6390LA Analytical Scanning Electron Microscope.

2.5. Histochemistory

Materials for histochemical investigation were obtained from 5 adult animals. Tissues were taken from craniovetral sac and caudodorsal sac, fixed in Bouin`s fluid and 10% formaldehyde and processed for paraffin sections according to (Culling, 1974) to investigate:

2. 5. 1. Carbohydrates

The sections were stained by periodic acid Schiff`s (PAS) technique for neutral mucopolysacharides; glycogen detection was done by treatment of control sections with 1% malt diastase for 30 minutes at 37 ºC before being stained by PAS. PAS|alcian blue (AB) 1% sequence was also applied for acid, mixed and neutral mucopolysacharides.

2. 5. 2. Alkaline phosphatase reactivity

The detection of alkaline phosphatase was carried out following the methods described by Culling (1974) and Durary and Wallington (1980). The sections were incubated in the substrate for half to three hours, washed in distilled water, placed in aqueous solution of cobalt nitrate for 5 minutes, washed in distilled water, transferred to a fresh 1% solution of yellow ammonium sulphide for one minute, washed in running tap water, counterstained by neutral red for 1 minute, dehydrated, cleared and mounted in D.P.X.

2.6. The results were analyzed using Students T-test.

CHAPTER THREE
RESULTS

3.1. Gross anatomy

The camel stomach extended between the diaphragm and cranial border of the 7th rib to the caudal border of the 12th rib caudally on the left side (Fig. 1). It was located ventral to the costal arch at the level between the 6th and 11th rib on the right side (Fig. 2). The stomach was divided into four compartments: compartment 1, compartment 2, compartment 3 and compartment 4 (Figs.3 and 4). Externally, while compartment 1 was separated from compartment 2 by a coronary groove, compartment 2 was separated from compartment 3 by a constriction. The tubular compartment 3 ended as an enlarged part to form compartment 4.

3.1.1. Compartment 1

This was the largest part of stomach about 80-100cm in length in adult animals) extending 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 in the cranioventral and caudodorsal portions which form the cranioventral and caudodorsal glandular sacs (Figs.3 and 4). Ventrally there was an oblique transverse groove separating the cranioventral sac from the caudodorsal sac. Compartment 1 had six surfaces: the cranial surface was related to the diaphragm opposite to the caudal lobe of the left lung; the dorsal surface was related to the bodies of 10th to 12th thoracic vertebrae; the ventral surface was related to the visceral surface of the left lobe of liver. Compartment 3 and spiral loop of ascending colon. The caudal surface was related to the spleen, jejunum and spiral loop of ascending colon. The left surface was covered by the peritoneum

while the right surface was related to the liver, lesser omentum, compartments 2, 3 and 4 (Figs. 5 and 6).

Internally compartment 1 was divided into a dorsal part and a ventral part (Fig. 7).The dorsal part was larger and subdivided into 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.

The gastric (esophageal) groove extended from the esophageal opening at the dorsal part of compartment 1 along the lesser curvature of compartment 2 and ended at the junction of compartment 2 with compartment 3. It consisted of two smooth thick folds (Fig. 7).

The crescent-shaped pillar corresponding to the transverse groove separated the cranioventral sac from the caudodorsal sac. From this pillar originated smaller pillars which divided 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 (Fig. 7).

3.1.1.1. Glandular sacs

The measurements of the different structures of cranioventral and caudodorsal sacs are shown in Tables 1and 2.

Cranioventral sac

The cranioventral sac was small and oval in shape with more or less smooth external surface (Figs. 3 and 4). A caudally directed blind sac was present in its caudal part (Fig. 4). The cranioventral sac was situated between the 7^{th} rib cranially and 9^{th} rib caudally and related to the diaphragm, left lobe of liver, caudal lobe of

left lung, compartment 2, compartment 3, compartment 4, spiral loop of ascending colon and and lesser omentum(Figs. 5 and 6).

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 (Fig. 8 and 9).

Caudodorsal sac

The caudodorsal sac was irregular in shape (Figs. 3 and 4), relatively larger and more sacculated than the cranioventral sac (Tables 1 and 2). About 10 small sacs; 7 horizontal and 3 ventral sacs could be observed externally (Fig. 6).The sac was related dorsally to longus coli muscle at the level of bodies of 8^{th} -12^{th} thoracic vertebrae. Caudodorsally it was attached to the visceral surface of 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 (Fig. 7).

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 1, Text-Fig. 1 and Fig. 9).

3.1.2. Compartment 2

It was bean-shaped and smaller than compartment 1 and located in the right side of abdominal cavity (Figs. 2, 3 and 4). It had two surfaces; a visceral surface and parietal surface. The visceral surface was related to the visceral surface of compartment 1. The parietal surface was related to the visceral surface of the liver.

It consisted of a greater curvature which was related to the cranioventral sac and compartment 3 and a lesser curvature which was related to the visceral surface of the liver.

The internal surface of compartment 2 showed several longitudinal muscular bands which sent smaller transverse bands to divide the surface into large chambers which were furtherly subdivided into 3 to 4 smaller chambers by smaller folds (Fig. 10).

3.1.3. Compartment 3

Compartment 3 was long and tubular in shape and situated in the right side of the abdominal cavity (Fig. 2). It was related to the diaphragm cranially, the cranioventral sac ventrally and the small intestine caudally. It presented greater and lesser curvatures. The greater curvature was related to the diaphragm and floor of abdominal cavity, the lesser one was related to the visceral surface of compartment 1 and compartment 2. Compartment 3 was connected to the craniodorsal part of compartment 2.

Internally the mucous membrane of compartment 3 was composed of thin longitudinal folds which increased in the middle part and decreased craniocaudally (Fig. 11).

3.1.4. Compartment 4

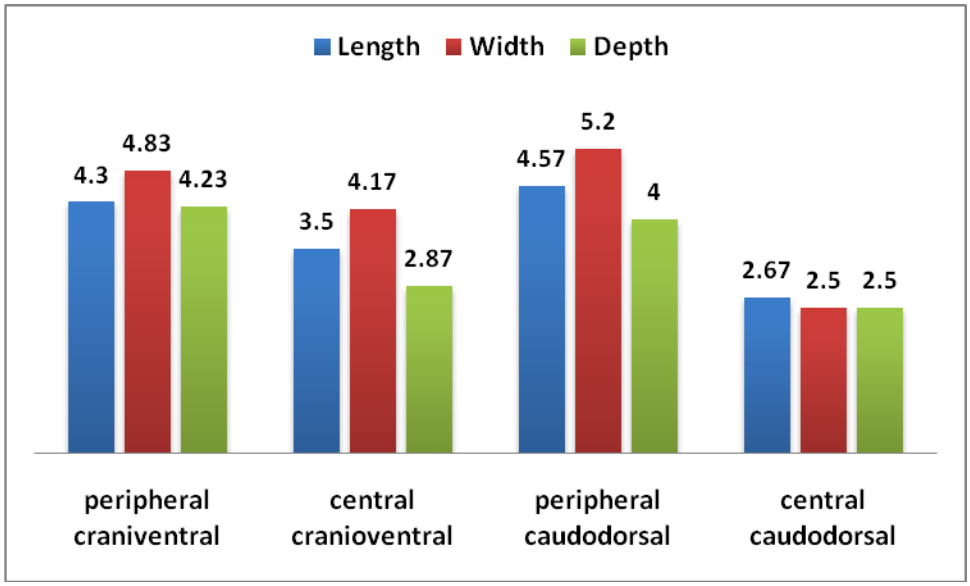
Compartment 4 was also bean-shaped and smaller than compartment 3. It showed two curvatures; the lesser curvature was in contact with the lesser omentum, the greater curvature was related to duodenum and jejunum (Fig. 2).
Internally, compartment 4 consisted of two regions; fundic and pyloric regions. The fundic region was formed of about 20-23 thick longitudinal and corrugated folds; the pyloric region consisted of low and thin folds (Fig. 12).

Table 1: Mean linear measurements of glandular pits of cranioventral and caudodorsal sacs of adult camel.

Parameter	Sites				
	peripheral cranioventral	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



Text-Fig. 1: Linear measurements of glandular pits in cranioventral and caudodorsal sacs of adult camel.

3.3. Histology

Histologically the wall of the different compartments of camel stomach consisted of four tunics: tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa.

3.3.1. Compartment 1

The interior of this compartment was divided into a sacculated part and a non-sacculated part. The sacculated part was represented by the internal surfaces of the cranioventral and caudodorsal sacs; the non-sacculated part included the remaining part of compartment 1. The glandular part of this compartment was located in the floor of central region of the glandular pits of sacculated part, whereas the non-glandular part was found in the pit walls of sacculated part and pit walls and floors of the peripheral region of sacculated part in addition to the non-sacculated part of this compartment.

Sacculated Glandular part

Floor of glandular pits

The tunica mucosa was folded forming shallow gastric pits and consisted of simple columnar epithelium. The lamina propria was formed of loose connective tissue containing mainly reticular fibres and elastic fibres together with collagenous fibres, blood vessels, lymphatic tissue and adipose cells (Figs. 13, 14 and 15). The propria was highly occupied by simple branched tubular glands which opened in the gastric pits and were surrounded by reticular fibres. The glands were of different shapes and sizes. They were lined by simple columnar or tall cuboidal epithelial cells which had oval or vertically elongated nuclei. The glands were characterized by narrow lumina and serous secretion.

The muscularis mucosa was a thin layer which consisted of circular smooth muscle fibres with some reticular fibres, separating the lamina propria from submucosa (Fig. 15).

The submucosa was thick and folded and consisted of loose connective tissue which was rich in collagenous fibres and blood vessels, reticular fibres and a few elastic fibres (Figs. 15, 16 and17).

The tunica muscularis was very thick and formed of smooth muscle fibres arranged in inner circular layer and outer longitudinal one. In some sections an oblique layer was observed between the inner circular and outer longitudinal layers. In other sections the inner layer was longitudinal and the outer one was circular. Between these layers and among the muscle bundles there were groups of adipose cells and blood vessels in addition to collagenous and reticular fibres (Figs.15 and 16).

The tunica serosa was a thin layer of loose connective tissue (sub-mesothelium) which was covered by simple squamous epithelium (mesothelium) (Fig. 13). It was connected to the muscular layer by connective tissue fibres rich in collagenous and reticular fibres.

Wall of glandular pits

The walls of the glandular pits were covered on either side by tunica mucosa which was slightly folded and lined by keratinized stratified squamous epithelium (Fig. 18). There was no muscularis mucosa and the lamina propria consisted of loose connective tissue which blended with that of submucosa forming a thick layer containing mainly collagenous, reticular fibres, blood vessels, lymphatic tissue, nerve endings and adipose cells (Fig. 19).

The tunica muscularis was very thin and it consisted of smooth muscle fibres arranged in scattered longitudinal bands in the centre forming the core of the wall. The muscle fibres were supported by collagenous and reticular fibres. The smooth muscle bands showed gradual increase in number and thickness from the apex towards the base (Fig. 19).

Sacculated non-glandular part

Floor of non-glandular pits

The floor of the non-glandular region was covered by a folded tunica mucosa which was lined by keratinized stratified squamous epithelium. The muscularis mucosa was absent and the lamina propria blended with submucosa forming a thin loose connective tissue layer which was rich in reticular and collagenous fibres, blood vessels, lymphatic tissue and adipose cells (Fig. 20; I and II).

The tunica muscularis was thick and consisted of two smooth muscle layers; inner circular and outer longitudinal. The layers were separated from each other by loose connective tissue which contained collagenous, reticular fibres and blood vessels. In a few sections the inner layer was longitudinal and the outer one was circular.

The tunica serosa was formed of a sub-mesothelium of loose connective tissue and covered by a mesothelium of simple squamous epithelium. It was connected to the muscular layer by connective tissue fibres (Fig. 20; I and II).

Wall of non-glandular pits

The walls of the non-glandular pits were covered in either side by tunica mucosa which was more or less straight and lined by keratinized stratified squamous epithelium (Fig. 21). The muscularis mucosa was absent and the lamina propria and submucosa formed a thick loose connective tissue layer which was rich in reticular and collageous fibres, blood vessels and adipose cells.

The tunica muscularis was in the form of a few smooth muscle fibres scattered longitudinaly among a vascular connective which was also rich in adipose tissue. The muscle fibres and blood vessels decreased from the apex towards the base (Fig. 21).

Non-sacculated part:

The non-sacculated part was non-glandular and it formed the floor. Its mucosa was folded and lined by keratinized stratified squamous epithelium. The muscularis mucosa was absent and the lamina propria blended with submucosa forming a thin loose connective tissue layer which contained blood vessels, lymphatic tissue and adipose cells (Fig. 22).

The tunica muscularis was comparatively thick and consisted of two smooth muscle layers; inner circular and outer longitudinal. The layers were separated from each other by loose connective tissue which contained blood vessels.

The tunica serosa was formed of a sub-mesothelium of loose connective tissue and covered by a mesothelium of simple squamous epithelium. It was connected to the muscular layer by connective tissue fibres (Fig. 22).

3.3.2. Compartment 2

The interior of compartment 2 was in the form of a glandular region which occupied the walls and floors of small chambers and a non-glandular region which was found in the longitudinal bands. The layers forming this compartment consisted of a tunica mucosa, a tunica submucosa, a tunica muscularis and a tunica serosa.

Glandular region

The mucosa of the glandular region of compartment 2 was folded forming shallow pits and lined by simple columnar epithelium (Fig. 23). The lamina propria was formed of loose connective tissue rich in simple branched tubular glands of different shapes and sizes and opened in gastric pits. The glands were lined by simple columnar epithelial cells which had oval or vertical nuclei. The muscularis mucosa was thin and consisted of circular smooth muscle fibres which separated the lamina propria from submucosa (Fig. 24; I and II).

The submucosa was thick and consisted of loose connective tissue rich in blood vessels and adipose cells.

The tunica muscularis was thick and was formed of smooth muscle fibres in the form of inner circular and outer longitudinal layers. Some sections showed inner longitudinal and circular layers. The muscle layers were separated by connective tissue containing adipose cells.

The tunica serosa was thin and formed of loose connective tissue (sub-mesothelium) covered by simple squamous epithelium (mesothelium) (Fig. 24; I and II).

Non-glandular region

The mucosa of either surface in longitudinal bands was folded and covered by thin keratinized stratified squamous epithelium. There was no muscularis mucosa and the lamina propria formed one layer of loose connective tissue with submucosa. The connective tissue was rich in blood vessels and adipose tissue which decreased towards the base (Fig. 25).

The tunica muscularis was thick forming the core of the band and consisted of an outer longitudinal and an inner circular muscle layers which decreased in thickness towards the base of the band.

3.3.3. Compartment 3

The mucosa of compartment 3 was highly folded and contained numerous gastric pits. The epithelial lining was simple columnar and the lamina propria was formed of loose connective tissue which contained simple tubular branched glands which opened in gastric pits. The glands were lined by simple columnar epithelium with oval or vertical nuclei (Fig. 26). A thin muscularis mucosa separated the lamina propria from submucosa and consisted of circular smooth muscle fibres.

The submucosa consisted of loose connective tissue and contained blood vessels and adipose cells.

The tunica muscularis was thick and formed of inner circular and outer longitudinal smooth muscle fibres.

The serosa was thin and formed of loose connective tissue (sub-mesothelium) covered by simple squamous epithelium (mesothelium) (Fig. 27; I and II).

3.3.4. Compartment 4

This compartment was histologically divided into three regions:

Cardiac region

The tunica mucosa was folded forming shallow gastric pits and lined by simple columnar epithelium. The lamina propria was formed of loose connective tissue containing blood vessels, lymphatic tissue and adipose cells. Simple tubular branched glands were found in lamina propria which opened in the gastric pits (Fig. 28). The glandular secretory units were lined by tall cells with oval nuclei and were characterized by narrow lumina and mucous secretion.

The muscularis mucosa was a thin layer of circular smooth muscle fibres which separated the lamina propria from submucosa (Fig. 29). The submucosa was thick and consisted of loose connective tissue rich in collagenous fibres, blood vessels and adipose cells. The tunica muscularis was thick and was formed of smooth muscle fibres arranged in an inner circular layer and an outer longitudinal one. The serosa was a thin layer of loose connective tissue which was covered by mesothelium.

Fundic region

The tunica mucosa was folded forming deep gastric pits and consisted of simple columnar epithelium. The lamina propria was thick and was formed of loose connective tissue containing blood vessels, lymphatic tissue and adipose cells. The propria was highly occupied by simple branched tubular glands which opened in the gastric pits (Fig. 30). Three types of cells were observed in the

glandular units which were mucous cells, chief cells and parietal cells (Fig. 31). The mucous cells were found in the neck region of the glands. They were tall and characterized by oval or elongated nuclei occupying the basal parts of the cells. The chief cells were mainly found in the basal part of secretory units. They were tall and basophilic with basal elongated nuclei. The parietal cells were more numerous than the chief cells located in the basal and parietal part of glands and they were round in shape with one or two rounded central nuclei.

The muscularis mucosa was a thin layer consisting of circular smooth muscle fibres separating the lamina propria from submucosa.

The submucosa was thick and consisted of loose connective tissue rich in collagenous fibres, blood vessels, adipose cells and diffuse and nodular lymphatic tissue.

The tunica muscularis was very thick and was formed of smooth muscle fibres arranged in an inner circular layer and an outer longitudinal one.

The serosa was thin consisting of loose connective tissue which was covered by mesothelium.

Pyloric region

The mucosa of pyloric region was highly folded forming very deep gastric pits. The epithelial lining was simple columnar. The lamina propria was thin and it contained tall simple branched tubular glands which opened in the gastric pits. The glandular cells were mainly mucous secreting cells with a few parietal cells scattered in the basal part of the glands (Fig. 32).

The muscularis mucosa was comparatively thick consisting of circular smooth muscle fibres between the lamina propria and submucosa (Fig. 33).

The submucosa was thick and consisted of loose connective tissue which was rich in connective tissue fibres, blood vessels and diffuse lymphatic tissue.

The tunica muscularis was thick and was formed of smooth muscle fibres arranged in an inner circular layer and an outer longitudinal one.

The serosa was thin consisting of loose connective tissue and mesothelium.

3. 4. Histometry:

The general histometric measurements of cranioventral and caudodorsal sacs are shown in Table 3 and Text Figure 3.

3. 4. 1. Glandular size

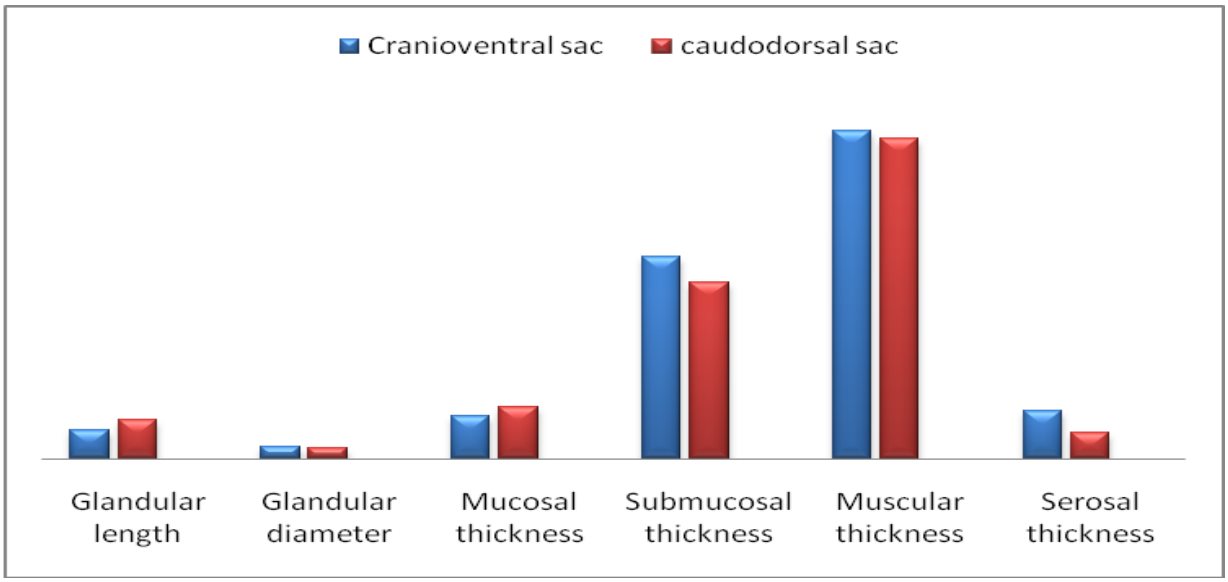
The histometric analysis of data in the glandular regions of adult camels revealed that the glandular length of cranioventral sac was (158.34±61.83μm), and that of caudodorsal sac was (217.50±33.83μm). The glandular diameter of cranioventral sac was (69.60±15.13μm), and that of caudodorsal sac was (62.14±14.64μm). There were no significant differences between the different measurements of the cranioventral and caudodorsal sacs.

3. 4. 2. Glandular sac layers

The mucosal thickness was (235.60±28.10μm) in the cranioventral sac, whereas in the caudodorsal sac was (285.70±42.72μm). The submucosal thickness in cranioventral sac was (1124.16±521.41μm), and in caudodorsal sac was (982.75±490.20μm). The muscular thickness in cranioventral sac was (1826.02±349.91μm), and in caudodorsal sac it was (1788.90±817.44μm). Serosal thickness in cranioventral sac was (263.60±142.75μm), and in caudodorsal sac was (143.90±67.92μm). The glandular floor was generally insignificantly thicker in caudodorsal sacs in comparison to cranioventral sacs.

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

Parameter	Cranioventral 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



Text-fig. 2: Histometric measurements of structures in the glandular regions of Cranioventral and Caudodorsal sacs.

3.5. Ultrastructure

3.5.1. Scanning electron microscopy

3.5.1.1. Cranioventral sac

The surface of the glandular region of cranioventral sac was formed of corrugated folds of different shapes and sizes (Fig. 34). The folds were separated by deep irregular grooves. The surface of the folds was studded by numerous glands with different shapes and sizes (average diameter of glands was about 40.56 um). The glands were lined by tall simple columnar cells and opened in glandular pits through small foramina (Fig. 35). Small areas in the folds were covered by simple columnar cells.

The cranioventral sac consisted of three types of glands depending on the glandular shape: cup-shaped glands, cap-shaped glands and flower-shaped glands (Fig. 36). The cup-shaped and cap-shaped glands projected on the surface of fold, whereas the flower-shaped glands were situated under the surface. The cup-shaped glands were characterized by irregularly rounded and wide shallow cavities which were surrounded by tall simple columnar cells (Fig. 37). The cap-shaped glands were rounded in shape and were lacking central cavities. The flower-shaped glands were surrounded by surface epithelial cells which were arranged in six crests giving a hexagonal appearance (Fig. 35).

3.5.1.2. Caudodorsal sac

The glands in this sac were distributed in a few irregular folds; these folds were larger than those found in the cranioventral sac and they were separated from each other by large and deep grooves (Figs. 38 and 39). Each large fold was divided by small grooves into smaller folds. Similar types of glands were also observed in these sacs which were the cap-shaped, cup-shaped and flower-shaped glands. The main gland type found in this sac was the cap-shaped glands (Fig. 39).

The surface epithelium surrounding the flower-shaped glands was tall simple columnar (Fig. 40).

3.5.2 Transmission electron microscopy

The transmission electron microscopy revealed that the glands of cranioventral and caudodorsal sacs were lined by columnar or pyramidal epithelial cells. The basal parts of the epithelial cells were wide and generally rounded, whereas the apical parts were narrow and pointed. The glandular cells were situated between the basal lamina and lumen and were closely packed together (Fig. 41).

The basal lamina on which the glandular cells rested was concave and was associated with smooth muscle and connective tissue fibers (Figs. 41and 42). The basal plasma membrane was more or less rounded corresponding to the rounded basal lamina (Fig. 41). The lateral membranes were straight in most cells and connected to the neighboring membranes by gap junctions in some places. In some cells, however, the lateral plasma membrane showed infoldings and interdigitations (Fig. 43). The apical membranes were mainly triangular corresponding to the pointed appearance of the apical cellular parts which resulted in increased intercellular space in the apical parts in comparison to that in the basal and lateral parts.

The nuclei were situated in the basal part of the cytoplasm. They were oval or round in shape and surrounded by a double nuclear envelope; their nucleoli were peripheral and their chromatin was diffuse (euchromatin) centrally and condensed (heterochromatin) laterally (Fig. 42).

The cytoplasm contained a number of organelles including mitochondria, cytoplasmic granules, lipid droplets, rough endoplasmic reticulum, Golgi apparatus, cytoplasmic vacuoles and electron-dense bodies.

Mitochondria were observed in large numbers mainly in the supra-nuclear part of cytoplasm in many cells; they were oval, elongated or rod-shaped and they showed internal folds (cristae) (Fig. 42).

Clusters of small electron dense were located mainly in the supra-nuclear cytoplasm in most cells (Fig. 42). Round and oval lipid droplets were also observed distributed throughout the cytoplasm of some cells (Fig. 42). In some cells the nuclei were irregularly shaped containing many folds in the nuclear envelope. Some cells were characterized by the presence of large vacuoles of irregular shapes and filled with small vesicles (Fig. 43). A few tubules of smooth endoplasmic reticulum and Golgi apparatus were observed in the supranuclear cytoplasm.

The rough endoplasmic reticulum was found around the nucleus and in the apical nuclear part of cytoplasm; it was arranged in communicating tubules connected with the outer nuclear membrane and was studded with small dark granules (Fig. 44).

The cytoplasm was characterized by the presence of vacuoles of different shapes and sizes especially in its apical parts; some of these vacuoles were empty and the others contained vesicles (Fig. 45). Large and small electron-dense bodies were also observed in a few cells. In one section these bodies appeared to accumulate together with the cytoplasmic granules in a condensed round shape surrounded by empty cytoplasmic vacuoles (Fig. 46).

3.6. Histochemistry

The histochemical reactions of periodic acid Schiff, alcian blue and alkaline phosphatase enzyme were carried out on the glandular region of cranioventral and caudodorsal sacs.

Periodic Acid Schiff (PAS)

There was no difference in PAS reactivity between the glandular regions of cranioventral and caudodorsal sacs.

A strong PAS positive reaction was observed in the surface epithelial cells. A positive reaction was observed in the glandular cells. The reaction was stronger in the glandular body and neck regions compared to that in the basal region (Fig. 47). The reaction was strong in the basal cellular cytoplasm, whereas the reaction was moderate to weak in the apical cytoplasm and lumina. A moderate reaction was observed in the muscular tissue and blood vessels. The reaction in the glandular intertubular tissue and connective tissue of submucosa and serosa was weak (Fig. 48).

PAS reaction after diastase application showed a few areas of PAS negative reaction in the glandular cells, glandular lumina, interglandular connective tissue, gastric pits and surface epithelium (Figs. 49 and 50).

Alcian blue (AB)/PAS sequence

The AB/PAS sequence stain in the epithelial and glandular parts showed three types of cells; alcian blue positive (blue cells), PAS positive (red cells) and AB and PAS positive (purple cells) (Fig. 51). The purple cells were concentrated in the basal glandular parts, whereas the blue ones were concentrated in the apical parts. The glandular lumina showed purple stain. The glandular interlobular and vascular connective tissues were only PAS positive.

Alkaline phosphatase

The glandular tissue and associated structures of cranioventral and caudodorsal sacs were alkaline phosphatase positive. The reaction was strong in the epithelial cells especially in their luminal portions. The glands showed strong to moderate reaction which was concentrated in the intercellular, apical and basal

parts of the glandular cells (Fig. 52). The interglandular connective tissue, blood vessels, intermuscular connective tissue and serosa showed a strong reaction. The submucosa exhibited a moderate alkaline phosphatase reaction (Fig. 53).

FIGURES

Figure 1: Left view of the abdominal cavity showing the fetal camel stomach (S) between 7^{th} and 12^{th} ribs.

Figure 2: Right view of the abdominal cavity showing the fetal camel stomach between 7^{th} and 11^{th} ribs. Note compartments 2, 3 and 4.

Figure 3: 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 4: 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).

Figure 5: Left view of the fetal 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 10^{th} to 12^{th} thoracic vertebrae (10, 12).

Figure 6: : 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).

Figure 7: Showing the interior of compartment 1 of adult camel, cranioventral sac (CVs), caudodorsal sac (CDs), crescent-shaped pillar (P),vertical pillar (VP), gastric (esophageal) groove (arrow), esophageal opening (arrowhead),compartment 2 and compartment 3.

Figure 8: Showing the interior of cranioventral sac of adult camel; Note that the glandular pits (Pi) consisting of pillars (P), and folds (arrow).

Figure 9: Showing the interior of caudodorsal sac of adult camel with smaller and numerous pits (Pi), larger pillars (P) compared to the cranioventral sac in Fig. 8.

Figure 10: Showing the interior of compartment 2 of adult camel with muscular band (arrow) and small chamber (saccules) (Sa).

Figure 11: Showing the interior of compartment 3 of adult camel with longitudinal folds (arrow).

Figure 12: Showing the interior of compartment 4 of adult camel with the fundic region (Fn) formed of thick longitudinal and corrugated folds. The pyloric region (Pr) consisted of low and thin folds.

Fig. 13: The floor of the glandular pits in sacculated glandular part showing mucosa with gastric pits (Arrow), glandular lamina propria (L) and muscularis mucosa (Arrowheads); submucosa (Sm) with blood vessels (B); tunica muscularis (Ms) with inner longitudinal, middle circular and outer longitudinal layers and serosa (S). H&E stain. X4.

Fig. 14: The floor of the glandular pits in sacculated glandular part showing simple columnar epithelium (E), glands (G) and gastric pits (Arrow). H&E stain. X40.

Fig. 15: The floor of the glandular pits in sacculated glandular part. The glands are supported by reticular fibres (Arrows). Reticular fibers are also present in muscularis mucosa, submucosa and tunica muscularis. Silver nitrate stain. X10.

Fig. 16: The floor of the glandular pits in sacculated glandular part showing simple branched tubular glands (G). Collagenous fibres (Arrows) are shown in the musclaris mucosa, submucosa and tunica muscularis. Note the smooth muscles fibres (Arrowheads) in muscularis mucosa, tunica muscularis and blood vessels. Massons' trichrome stain. X10.

Fig. 17: The floor of the glandular pits in sacculated glandular part showing: simple branched tubular glands (G). Elastic fibres (Arrows) are shown in the lamina propria, musclaris mucosa, submucosa and blood vessels. Verhoffs' stain. X10.

Fig. 18: The wall of the glandular pits in the sacculated glandular part. Mucosa is folded and is lined by keratinized stratified squamous epithelium (E). Note the subepithelial connective tissue (C), smooth muscle bundles (Ms) and blood vessels (B). H&E stain. X4.

Fig. 19: The wall of the glandular pits in the sacculated glandular part showing collagenous fibres (arrows) in the muscularis mucosa, submucosa, and muscular layer. Note the blood vessels (B) in submucosa. Massons' trichrome stain. X10.

Fig. 20 (I and II): The floor of the non-glandular pits in the sacculated non-glandular part. Mucosa is folded and lined by keratinized stratified squamous epithelium (E) which followed by subepithelial connective tissue (C), tunica muscularis (Ms) and serosa (S). Note the collagenous fibres (Arrows) in the subethelial connective tissue, tunica muscularis and serosa. Massons' trichrome stain. X10.

Fig. 21: The wall of the non-glandular pits showing two mucosae of keratinized stratified squamous epithelium (E), subepithelial connective (C) with adipose cells (A) and blood vessels (B), smooth muscle (Ms). H&E stain. X10.

Fig. 22: Non-sacculated part showing the folded mucosa lined by keratinized stratified squamous epithelium (E), subepithelial connective tissue (C), tunica muscularis (Ms) and serosa (S). H&E stain. X10.

Fig. 23: The glandular region in compartment 2 with simple columnar Epithelium (E), gastric pits (Arrow) and simple tubular branched glands (G). H&E stain. X40.

Figs. 24 (I and II): The glandular region in compartment 2 showing mucosa with a shallow gastric pit (Arrow), simple tubular branched glands (G) and muscularis mucosa (Arrowheads), submucosa with blood vessels (B), tunica muscularis (Ms) adipose cells (A), and serosa (S). H&E stain. X10.

Fig. 25: The non-glandular region in compartment 2 showing two folded mucosae covered by keratinized stratified squamous epithelium (E) followed by subepithelial connective tissue (C) with blood vessels (B) and muscle bands (Ms). Massons' trichrome stain. X10.

Fig. 26: Compartment 3 with simple columnar epithelium (E), gastric pits (Arrow) and simple tubular branched glands (G). H&E stain. X40.

Figs. 27 (I and II): Compartment 3 showing mucosa with gastric pits (Arrows), simple tubular branched glands (G) and muscularis mucosa (Arrowheads), submucosa (Sm), tunica muscularis (Ms) with adipose tissue (A) and serosa (S). H&E stain. X10.

Fig. 28: The cardiac region of compartment 4 with simple columnar epithelium (E), a shallow gastric pit (Arrow), Simple tubular branched glands (G) and mucous cells (Mc). H&E stain. X40.

Fig. 29: The cardiac region of compartment 4 with mucosa containing a shallow gastric pit (Arrow), simple tubular branched glands (G) and muscularis mucosa (Arrowheads). Note the connective tissue in the submucosa with blood vessels (B) and adipose cells (A). H&E stain. X10.

Fig. 30: The fundic region of compartment 4 showing simple columnar epithelium (E), deep gastric pits (Arrows) and simple tubular branched glands (G). H&E stain. X40.

Fig. 31: Glands of fundic region in compartment 4 with three types of glandular cells; mucous cells (Mc) chief cells (Ch) and parietal cells (Pc). H&E stain. X40.

Fig. 32: The gastric glands of the pyloric region in compartment 4 showing: simple columnar epithelium (E) and tall simple branched tubular glands (G). H&E stain. X40.

Fig: 33. The pyloric region of compartment 4 with simple columnar epithelium, deep gastric pits (Arrows), simple tubular branched glands (G) and thick muscularis mucosa (Arrowheads). Submucosa (Sm) is formed of loose connective tissue (C). H&E stain. X10.

Fig. 34. Scanning electron microphotograph of a glandular pit in the cranioventral sac showing numerous glands (Arrowheads) with folds (F) and grooves (Arrows). X60.

Fig. 35. Scanning electron microphotograph of a glandular pit in the cranioventral sac showing flower-shaped glands (Fs) and surface epithelium (Arrows), glandular simple tall columnar cells (Cc) and pit-foramina (Arrowheads). X400.

Fig. 36. Scanning electron microphotograph of a glandular pit in the cranioventral sac: Note the cup-shaped glands (Cu), the cap-shaped glands (Ca) and the flower-shaped glands (Fs). X600.

Fig. 37. Scanning electron microphotograph of a glandular pit in the cranioventral sac: Note the simple tall columnar cells (Cc) and wide shallow cavities (Sc). X1000.

Fig. 38. Scanning electron microphotograph of a glandular pit in the caudodorsal sac showing irregular folds (F), a large and deep groove (Arrow) and small grooves (Arrowheads). X200.

Fig. 39. Scanning electron microphotograph of a glandular pit in the caudodorsal sac filled with cap-shaped glands (Ca) and a large groove (Arrow). X350.

Fig. 40. Scanning electron microphotograph of a glandular pit in the caudodorsal sac. Note the surface epithelium (Arrows) surrounding the flower-shaped glands (Fs) and a pit foramen (Arrowhead). X1500.

Fig. 41. Transmission electron microphotograph of the floor of the glandular sac showing columnar or pyramidal epithelial cells with rounded bases and straight lateral plasma membranes (Arrows). Note a sub-epithelial fibroblast (F), basement membrane (Bm) and lumen (L). X3600.

Fig. 42. Transmission electron microphotograph of the floor of the glandular sac showing basal oval or rounded nuclei with lateral nucleoli, peripheral heterochromatin and central euchromatin. Mitochondria (M), lipid droplets (L) and clusters of secretory granules (Gr) are mainly shown in the supra-nuclear cytoplasm. Note a sub-epithelial smooth muscle cell (S). X5800.

Fig. 43. Transmission electron microphotograph of the floor of the glandular sac showing folded lateral plasma membrane (Arrows) and irregular nuclei (N). Note a large vacuole (V). X3600.

Fig. 44. Transmission electron microphotograph of the floor of the glandular sac showing rough endoplasmic reticulum (Re), smooth endoplasmic reticulum (Se) and Golgi apparatus (G). X1100.

Fig. 45. Transmission electron microphotograph of the floor of the glandular sac showing empty and vesicle-filled cytoplasmic vacuoles (V). X1400.

Fig. 46. Transmission electron microphotograph of the floor of the glandular sac showing mitochondria (M), electron-dense bodies (D) and vacuoles (V). X7100.

Fig. 47. Floor of the glandular pits in the sacculated glandular part. A strong PAS positive reaction is shown in the surface epithelial cells, glandular cells of body and neck regions (Arrows). Note moderate reaction in the glandular basal region and interglandular connective tissue (Arrowheads). PAS stain. X40.

Fig. 48. The floor of the glandular pits in the sacculated glandular part with a strong PAS positive reaction in the glandular cells, muscular tissue and blood vessels. The reaction was weak in the submucosa and serosa (Arrowheads). PAS stain. X10.

Figs. 49 and 50. The floor of the glandular pits in sacculated glandular part showing negative areas for PAS reaction (Arrows) in the surface epithelium, glandular cells and lumina and connective tissue after diastase application (A) compared to positive reaction (Arrowheads) before diastase application (B). PAS stain. X40.

Fig. 51. The floor of the glandular pits in sacculated glandular part with three types of glandular cells; alcian blue positive (B), PAS positive (P) and AB and PAS positive (M). Note the PAS positive interglandular connective tissues (Arrowheads). AB/PAS sequence. X40.

Fig. 52. The floor of the glandular pits in sacculated glandular part showing alkaline phosphatase positive reaction in the epithelial cells, lumina of glands and interglandular tissue (Arrows). Alkaline phosphatase stain. X40.

Fig. 53. The floor of the glandular pits in sacculated glandular part. The intermuscular connective tissue and serosa show moderate alkaline phosphatase reaction (Arrows). The submucosa also exhibited moderate reaction (Arrowheads). Alkaline phosphatase stain. X10.

CHAPTER FOUR

DISCUSSION

4.1. Gross anatomy

The gross anatomy of the dromedary stomach has been studied by a number of authors. Some authors agreed that it consisted of four compartments as in ruminants stomach; rumen, reticulum, omasum and abomasum (Hegazi, 1950; Hansen and Schmidt-Nielsen, 1957; Bohken, 1960; Frandson , 1974; Czerkawski, 1985; Smuts and Bezuidenhout, 1987 Erden *et al.*, 1998). However, in the present study the external the constriction between the omasum and abomasum as described by Hegazi (1950) was not observed.

The present study also showed that 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. This is in agreement with the findings of Osman (1999) who described four compartments in the camel. In contrast to this, some authors claimed that the stomach of the dromedary camel had only three compartments; compartment 1, compartment 2 and compartment 3 (Dougbag and Berg, 1980; Singh, *et al*., 1996). Unlike the dromedary camel, the stomach of the Bactrian camel is divided into three compartments (Eerdunchaolu *et al*., 1999; Wang *et al*., 2000). Wang *et al*., (2000) referred to these compartments as ventricles. On the other hand the stomach of the alpaca (Vaughan, 2008) and Lama Glama (Vallenas *et al*., 1971; Lazuli *et al*., 2004). Lazuli *et al*. (2004) stated that the llamas' stomach (Lama Glama) showed three compartments, proximal, intermediate and distal; the proximal compartment was located totally in the left abdominal wall; the intermediate compartment was kidney in shape, with thick walls and the distal compartment was elongated and tubular, and located towards the ventral and right aspect of the abdominal cavity.

Vaughan (2008) noted that compartment 1 of alpaca lied on the left side of the abdomen and it made up about 80% of forestomach volume; compartment 2 made up about 6% and compartment 3 was tubular and ran next to compartment 1 on the right side of the abdomen and it made about 11% of forestomach volume. He added that the opening between compartment 1 and compartment 2 was large (mineral pellets didn't, remain in compartment 1 for any significant period of time).

The present study in foeti showed that the camel stomach extended between the diaphragm and cranial border of the 7^{th} rib to the caudal border of the 12^{th} rib caudally on the left side. However, 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 difference in topography could be explained as a result of gradual growth of stomach.

4.1.1. Compartment 1

The present 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. In present study also a coronary groove separates compartment 1 from compartment 2. In contrast Lechner-Doll *et al.,* (1995) stated that in camelids, compartment 1was divided by a strong transverse muscular ridge into a cranial and a caudal portion and the relatively small compartment 2 (C2) is not completely separated from compartment 1 (Cl).

Moreover, Engelhardt and Holler (1987) and Engelhardt *et al.* (1992) observed a strong ventral and transverse muscular ridge which divided compartment 1 into cranial and caudal portions in camelids. In llama and guanaco

compartment 1 was partially divided into a cranial (forward) sac and a caudal (rearward) sac. The saccules of compartment 1 were deeper than in compartment 2 which gave the appearance of a distinct and regular pattern of mounds when viewed from outside the chamber (Vallenas, 1971).

In present study compartment 1 extends from the diaphragm at the level of 7^{th} rib to the level of the caudal border of the 12^{th} rib and it has six surfaces; the cranial, dorsal, ventral, caudal, left and right surface. However, Osman (1999) stated that compartment 1 extended from the diaphragm or the 7^{th} rib cranially to the 5^{th} lumbar vertebra caudally and it had four surfaces; parietal or left, visceral, right dorsal and ventral.

According to Hegazi (1950) the interior of 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 which was smallest one was 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 8^{th} and the 12^{th} thoracic vertebrae and a cranioventral sac which extends between the 7^{th} rib cranially and the 9^{th} rib, externally.

Internally they are separated by a crescent-shaped pillar corresponding to the external transverse groove. The presence of two ruminal sacs conforms to the observations of Hansen and Schmidt-Nielsen (1957); Shahrasbi and Radmehr (1974) and Langer (1988). 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 lay on the floor of the abdominal cavity (Purohit and Rathor, 1962; Schmidt-Nielsen, 1964; Ramadan, 1994). Wilson, (1989), believed that the glandular sacs were considered to be the water store of the camel and they consisted of a number of small chambers separated by folds of mucosa.

In the present study it has been observed that the gastric (esophageal) groove extends from the esophageal opening at the dorsal part of compartment 1 along the lesser curvature of compartment 2 and ends at the junction of compartment 2 with compartment 3.This is in agreement with the findings of Osman (1999).

The internal surface of cranioventral sac 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 the columns of the sac, and a glandular mucosa which covers the central rows and the 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 similar to the findings of Wilson, (1989) and Erden *et al.* (1998) in the dromedary camel, and Wang *et al*. (2000) in the Bactrian camel.

4.1.2. Compartment 2

In the present study compartment 2 is bean-shaped and it is smaller than compartment 1; it is located on the right aspect of abdominal cavity. These findings are in agreement with those mentioned in the same species (Purohit and Rathor, 1962; Engelhardt *et al.,* 1986; Smuts and Bezuidenhout 1987; Lechner-Doll *et al*., 1995 Osman, 1999) and in llama and guanaco (Vallenas *et al.*, 1971). Furthermore, in the dromedary camel Erden, *et al* (1998) named compartment 2 as reticulum and unlike other ruminants it was pear-shaped. Lechner-Doll *et al.* (1995) stated that compartment 2 was relatively small and it was not completely separated from Cl. In Bactrian camel, however, Wang *et al*. (2000) observed that compartment 2 was elliptically concave in shape with convex and concave borders and it was continuous with the proventriculus cranially and with the caudal glandular sac area at the interventricular orifice.

In the present study it has been found that compartment 2 consists of greater and lesser curvatures and two surfaces; visceral surface and parietal surface. The visceral surface is related to compartment 1 and the parietal surface is related to the liver. Similar findings were reported by Osman (1999) in dromedary camel. In llama guanaco this compartment was divided by a dorsal lesser curvature and a ventral greater curvature and it emptied into C3 via a short, thick walled, muscular tube that could constrict to control the rate at which material move into the third compartment (Vallenas *et al.* (1971).

In this study the internal surface of compartment 2 shows several longitudinal muscular bands which send smaller transverse bands to divide the surface into large chambers which are furtherly subdivided into 3 to 4 smaller chambers by smaller folds. However, Osman (1999) claimed that the structure of the internal surface of compartment 2 resembled that of the sacs of compartment 1, except that the bands and folds were numerous and all chambers were subdivided by small longitudinal folds to form small deep chambers. The mucous membrane of compartment 2 observed in the present study is similar to that mentioned by Erden *et al.* (1998) in the dromedary reticulum forming deep pouches which are separated from each other by muscular bands.

4.1.3. Compartment 3

In the current investigation and that of Osman (1999) in dromedary camels compartment 3 was long and tubular in shape and it was situated on the right aspect of the abdominal cavity. However, in other investigations this compartment was referred to as omasum and described as elongated or sausage-shaped, and was curved ventrally and caudally under the reticulum (Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962; Engelhardt and Holler, 1986; Smuts and Bezuidenhout, 1987; Lechner- Doll *et al*., 1995). In the present study compartment 3 is separated from compartment 2 by a constriction and ends as an enlarged part to

form compartment 4. However, in llama and guanaco (Vallenas *et al.*, 1971; Cummings *et al.*, 1972) and Bactrian camel (Wang, *et al*. (2000) comportment 3 was considered to be blended with compartment 4 forming one compartment which was called the third compartment. While the greater curvature in the present study is related to the diaphragm and floor of abdominal cavity and the lesser one is related to the visceral surface of compartment 1 and compartment 2, Osman (1999) stated that the greater curvature relates to the diaphragm and the lesser one faces the greater curvature of compartment 2.

In this study the mucous membrane of compartment 3 is composed of thin longitudinal folds which increase in the middle part and decrease craniocaudally. Similar findings were reported by Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962; Engelhardt and Holler, 1987; Smuts and Bezuidenhout, 1987 and Lechner- Doll *et al*., 1995 in the one humped camel. According to Osman (1999) the mucous membrane of compartment 3 in dromedary camel is thrown into about 50 longitudinal folds. However, Wang *et al*. (2000) stated that the mucous membrane of third glandular sac area had some longitudinal and transverse folds showing basically the same characteristics as those of the cranial and caudal glandular sac areas.

The present study shows that the mucous membrane of the omasum is thrown into longitudinal folds. This is in agreement with a number of authors (Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962; Engelhardt and Holler, 1986; Smuts and Bezuidenhout, 1987; Lechner-Doll *et al*., 1995). Osman (1999) showed that the mucous membrane of compartment 3 was composed of thin longitudinal folds which increased in the middle part and decreased craniocaudally.

4.1.4. Compartment 4

Compartment 4 in the current study is found to be bean-shaped and smaller than compartment 3. According to Osman (1999) it was kidney-shaped and it was

relatively short. The present study and that of Osman (1999) describe two curvatures. In this study the lesser curvature is in contact with the lesser omentum and the greater curvature is related to duodenum and jejunum. However, Osman (1999) claimed that the greater curvature was curved from ventral to dorsal aspects and faced the ventral abdominal wall.

In the current study compartment 4 consists of two regions; fundic and pyloric regions. Similar findings were also reported by a number of authors (Purohit and Rathor, 1962; Dougbag and Berg, 1980; Smuts and Bezuidenhout, 1987 Erden *et al*, 1998; Raji, 2011). Moreover, Raji (2011) had observed small diverticulae in the fundic region and this part was also covered with thick mucosal folds that were separated by deep branching furrows.

While the fundic region in this study is formed of about 20-23 thick longitudinal and corrugated folds; the pyloric region consists of low and thin folds. However, the mucous membrane of the fundic part had been described to have distinct circular laminae or folds and the pyloric part contained a few folds (Hansen and Schmidt-Nielsen, 1957; Purohit and Rathor, 1962; Osman, 1999).

4.2. Histology

In the present study the camel stomach consists of four compartments; compartment 2, 3 and 4 are glandular and compartment 1 contains sacculated and non-sacculated regions. Each saccule (pit) of the sacculated region is formed of a non-glandular wall (fold) and a floor which is glandular centrally and non-glandular peripherally. The non-sacculated part is non-glandular. Abdel-Magied and Taha (2003), however, divided the stomach of camel into eight histological regions; the first region was non-glandular (53.2%) and occupied the body of the first compartment. The other seven regions were lined by a glandular mucosa. In contrast, Cummings *et al.* (1972) had reported three histological

regions. The mucosa of the first and second compartments were non-papillated squamous epithelium, and glandular within the saccules.

The histological structure of the different compartments of the camel stomach in the present study consists of four tunics: tunica mucosa, tunica submucosa, tunica muscularis and tunica serosa.

4.2.1. Compartment 1

The present study is in agreement with Lechner-Doll *et al.* (1995) and Osman (1999) that the nonsacculated region which forms the dorsal part of compartment 1 is lined by keratinzed stratified squamous epithelium and the glandular sac areas which consist of a number of small chambers separated by folds of mucosa are lined by a simple columnar epithelium. In contrast to this, Shahrasbi and Radmehr (1974) claimed that the water sacs were lined by keratinized stratified squamous epithelium. Cummings *et al.*, (1972) and Luciano *et al.*, *(*1979) stated that in camelids unlike ruminants the dorsal parts of C l was lined with keratinized stratified squamous epithelium and the ventral part was instead, lined by a columnar surface epithelium. The columnar lining epithelium of the saccules described in the present study may agree with the suggestions of Englehardt and Holler (1987) who reported that absorption within the saccules of compartment 1 was significantly increased by absorptive surface area.

The present study confirms the findings of Osman (1999), Wilson, (1989) Purohit and Rathor (1962) and Engelhardt and Holler (1987) that compartment 1 contained simple branched glands in the lamina propria. These glands were also described as deep tubular glands (Cummings *et al.*, 1972; Luciano *et al.*, 1979) and they probably acted as absorption and fermentation areas, as well as areas of secretion of enzymes (Wilson, 1989).

The present study shows that the muscularis mucosa is found as a thin layer of circular smooth muscle fibres in the glandular region and is absent in the

nonglandular region of compartment 1. Schmidt-Nielsen (1964) and Osman (1999) noted that the muscularis mucosa in the dorsal part of compartment 1 (non-glandular) occurred as scattered smooth muscle bundles, while it was present as a thin circular smooth muscle layer in the glandular chambers. However, Shahrasbi and Radmehr (1974) stated that the muscularis mucosa was absent in the rumen water sacs.

The present investigation confirms the findings of Osman (1999) that the tunica muscularis which followed the submucosa was very thick in compartment 1 and it was formed of smooth muscle fibres. In the present study the muscularis layer is mainly arranged in inner circular layer and outer longitudinal one; in some sections the inner layer is longitudinal and the outer one is circular. However, Osman (1999) stated that the muscular coat in compartment 1 consisted of thick inner longitudinal and thin outer circular smooth muscle layers; in the other parts of compartment 1 the muscular coat was arranged into thick inner circular and thin outer longitudinal layers of smooth muscle. These observations are in contrast with those of Shahrasbi and Radmehr (1974) who reported that the muscular coat consisted of inner circular and outer longitudinal smooth muscle layers throughout compartment 1.

4.2.2. Compartment 2

The walls (folds) and floors (chambers) of compartment 2 were glandular and they were lined by simple columnar epithelium. The longitudinal bands were non-glandular and are lined by keratinized stratified squamous epithelium. This is in accord with the findings mentioned by Osman (1999) and Lechner-Doll *et al.* (1995) that compartment 2 had two types of epithelia; stratified squamous and simple columnar epithelium. According to Osman (1999) the stratified squamous is not keratinized. In contrast, Purohit and Rathor (1962) and Wilson, (1989) stated

that the whole mucous membrane of the reticulum (compartment 2) was lined with simple columnar epithelium.

In the present study the muscularis mucosa is absent in the non-glandular region; in the glandular region it is thin and consists of circular smooth muscle fibres which separate the lamina propria from submucosa. However, Osman (1999) claimed that the muscularis mucosa of the bands consisted of longitudinally arranged smooth muscle fibres, while in the folds and chambers the muscularis mucosa was in the form of a bundle of smooth muscle fibres located in the upper parts of the primary folds.

4.2.3. Compartment 3

The mucosa of compartment 3 is highly folded and lined by simple columnar epithelium. These results confirm the observations of Osman (1999), Engelhardt and Holler (1987) and Lechner-Doll *et al.* (1995) that compartment 3 was entirely lined with a simple columnar epithelium. Similar results were also noted by Cummings *et al.* (1972) and Luciano *et al., (*1979) that the inner surface of C3 was lined by a columnar surface epithelium and contained deep tubular glands and this regional mucosa appeared to be similar to the cardiac region of the abomasum of ruminants. However, Hansen and Schmidt-Nielsen (1957) and Osman (1999) mentioned that the cardiac region was a narrow strand located between compartment 3 and fundic region of compartment 4. On the other hand, Wilson, (1989) stated that the mucosa in the reticulum and omasum is covered by a columnar epithelium which has up to 100 million short tubular glands.

The lamina propria is formed of loose connective tissue which contains simple branched tubular glands and the muscularis mucosa is composed of a thin circular smooth muscle layer. Similar findings are reported by Osman (1999) who also claimed that the circular layer of the muscular coat didn’t, enter in the folds or laminae of this compartment as in ruminants.

4.2.4. Compartment 4

This study divides compartment 4 into three histological regions: cardiac, fundic and pyloric. These results contradict the findings of Hansen and Schmidt-Nielsen (1957) and Osman (1999) who mentioned that compartment 4 is divided into two regions; fundic and pyloric regions and the cardiac region is a narrow strand located between compartment 3 and fundic region of compartment 4.

The present observations indicate that the mucosa in the cardiac region of compartment 4 is folded and the epithelial lining is simple columnar; the lamina propria contains simple branched tubular glands with mucous secreting cells. Similar findings concerning the epithelial lining of the pyloric region were stated by Osman (1999), Hansen and Schmidt-Nielsen (1957) and Purohit Rathor (1962). The simple columnar epithelium which lined compartment 4 was found to be similar to that of fundic and pyloric regions in the stomach of non-ruminants (Purohit and Rathor, 1962).

According to the present investigation the tunica mucosa of the fundic region of compartment 4 formed deep gastric pits and lined by simple columnar epithelium. The lamina propria was thick and was occupied by simple branched tubular glands which were lined with three types of cells: mucous cells, chief cells and parietal cells. These types of cells in the fundic region were also reported earlier by Hansen and Schmidt-Nielsen (1957) and Osman (1999). According to Vallenas *et al.* (1971) the tunica mucosa in the terminal dilated part (compartment 4) in llama and (guanaco) contained the proper gastric glands (fundic glands) which differed somewhat from those in the advanced ruminants, especially in the arrangement of the parietal cells and the behaviour of the chief cells which could store mucosubstance during fastening or diminishing of the food in the camel.

The present investigation reports that the mucous cells are found in the neck region of the glands and they are tall and characterized by oval or elongated nuclei

occupying the basal parts of the cells. Osman (1999) also mentioned that the mucous neck cells were large and they were found in the neck of the glands of the camel.

The present study confirms the findings of Osman (1999) that the chief cells are basophilic and they are mainly found in the basal part of secretory units.

The parietal cells in the current study and in that of Osman (1999) are more numerous than the chief cells and they are rounded in shape, acidophilic and located in the basal and parietal part of the glands.

The pyloric region mucosa in the present study is highly folded forming very deep gastric pits; the epithelial lining is simlple columnar and the lamina propria contains tall simple branched tubular glands which are mainly lined by mucous secreting cells with a few parietal cells scattered in the basal part of the glands. It has also been mentioned earlier that the pyloric glands in camel were simple branched (Dougbag and Berg, 1980; Osman, 1999). However, Osman (1999) report that the pyloric glands in camel had only mucous cells which contained spherical or flattened nuclei located in the basal part of the cell.

4.3. 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 study reveals that there is no significant difference between the glandular length of cranioventral sac (158.34±61.83 μm) and that of caudodorsal sac

(217.50±33.83 µm). 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) was (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 structures which included submucosal, muscular and serosal thickness.

4.4. Ultrastructure

4.4.1. Scanning electron microscopy

In the current study the glands of cranioventral and caudodorsal sacs in camels are located in corrugated folds of different shapes and sizes separated by deep irregular grooves and the average transverse diameter of glands was about 40.56 µm; the glands were lined by tall simple columnar cells and opened in glandular pits through small foramina. Raji (2011) studied the scanning electron microscopy in the abomasum of dromedary camel. He stated that the abomasal mucous membrane was lined by simple columnar epithelial cells with a mean length of 20 µm. He also mentioned that the epithelial surface was characterized by small invaginations called gastric pits which were related to the surface of lumen by foramina.

The present study reports for the first time three types of glands depending on their shapes; cup-shaped glands, cap-shaped glands and flower-shaped glands; the flower-shaped glands are surrounded by surface epithelial cells arranged in six crests giving a hexagonal appearance. The surface epithelium surrounding the flower-shaped glands is tall simple columnar. According to Raji (2011) some of the abomasal glands of dromedary camel are arranged as flower bodies (FB) and hexagonal structures are observed on the surface of the abomasum that resemble a honeycomb (HC) structure. However, Saber and Weyrauch (1998) noted that the

cranial glandular sac area of one-humped camel showed rosette-like structures which were more numerous in the first, rather than in the second compartment of the stomach and the connective tissue core which was arranged in a network in the cranial glandular sac area.

4.4.2. Transmission electron microscopy

The current transmission electron microscopy studies reveal that the glands of cranioventral and caudodorsal sacs of camel stomach are lined by columnar or pyramidal epithelial cells. The basal parts of the epithelial cells are wide and generally rounded, whereas the apical parts are narrow and pointed with the closely packed glandular cells situated between the basal lamina and lumen. In camelids the epithelium lining the surface areas of the glandular sac mucosa consisted of high columnar cells (Lechner-Doll *et al.,* 1995). In llama guanaco the main characteristics of the epithelial cells is a brush border membrane formed by tiny microvilli (Luciano *et al*., 1979). However, Lechner-Doll *et al.* (1995) mentioned that the epithelial cells of the glands were cuboidal.

In the present study the lateral plasma membrane showed prominent infoldings and interdigitations in some epithelial cells of the glands. Similar findings were observed by (Cummings *et al.,* 1972; Luciano *et al.,* 1979). These characteristics indicate that the cells have an absorptive function.

The nuclei of glandular cells in the present study are situated in the basal part of cytoplasm. They are oval or round in shape and surrounded by a double nuclear envelope. This is in agreement with Lechner-Doll *et al.* (1995) in camelids, who also added that the columnar epithelial cells were characterized by having prominent oval nuclei located in the basal third.

The present investigation shows that the mitochondria in camel epithelial cells of cranioventral and caudodorsal sacs are oval, elongated or rod-shaped with cristae and they are present in large numbers mainly in the supra-nuclear

cytoplasmic region of many cells. In Llama, however, mitochondria were elongated or slender in shape containing a dense matrix and filling wide cytoplasmic areas in the upper region of the cell (Luciano *et al*., 1979).

The present observations are in agreement with those of Luciano *et al*. (1979) in Llama guanaco that the Golgi apparatus and numerous secretory granules were found in the apical cytoplasm of glandular cells in cranioventral and caudodorsal sacs, where several dense bodies could also be seen. It has also been mentioned that glandular cells in the glandular sac area contained granules of low and high density in the supranuclear region of Bactrian camel (Eerdunchaolu *et al.,* 1999). Numerous secretory granules and electron dense bodies in the apical cytoplasm observed in this study are suggestive of increased secretory activity of glandular cells in cranioventral and caudodorsal sacs.

4. 5. Histochemistry

In the present study there is no difference in PAS reactivity between the glandular regions of cranioventral and caudodorsal sacs.

The surface epithelial and glandular cells regions of cranioventral and caudodorsal sacs show strong positive reaction; the reaction is stronger in the glandular body and neck regions in comparison to that in the basal region are strong in the basal cellular cytoplasm, whereas the reaction was moderate to weak in the apical cytoplasm and glandular lumina. Eerdunchaolu *et al.* (1999) stated that the surface mucous cells of both glands in the glandular sac area of the first and second compartments and the cardiac glands showed a strong positive reaction to PAS.

The histochemical observations of periodic Acid Schiff (PAS) after diastase reaction in the present study indicate, for the first time, the presence of glycogen in the glandular cells, glandular lumina, interglandular connective tissue, gastric pits and surface epithelium of cranioventral and caudodorsal sacs.

In the current study, the AB/PAS sequence staining in the epithelial and glandular parts shows three types of cells; alcian blue positive (blue cells), PAS positive (red cells) and AB and PAS positive (purple cells). The purple cells are concentrated in the basal glandular parts, whereas the blue ones are concentrated in the apical parts. According to Abdel-Magied and Taha (2003) the surface epithelial cells were either negative to both AB and PAS or partially PAS positive, gastric pit cells were strongly positive to AB and/or PAS and gland bodies were negative to both AB and PAS but their luminal parts were often weakly PAS positive; the gland bases are often moderately positive to alcian blue at pH 1. In camel, Raji (2011) observed that the in abomasum the surface epithelium is negative to AB and positive to PAS staining, whereas in the gastric pit cells it is positive to AB and PAS staining, but gastric gland cells are negative to PAS and positive to AB staining.

It is mentioned that strong PAS positive reaction indicates presence of neutral mucopolysacharides, whereas alcian blue positive, PAS negative or PAS weak reactions indicate presence of acid mucopolysacharides (Drury and Wallington, 1980). Thus, the present results suggest that the surface epithelial and glandular cells regions of cranioventral and caudodorsal sacs secrete neutral mucopolysacharides, especially in their apical regions. It can also be noted that some cells secrete both neutral and acid mucopolysacharides as indicated by the purple stain concentrated in the basal parts of glandular cells. Other cells are suggested to secrete acid mucopolysacharides as shown by blue stain especially in the apical parts of glandular cells.

The present study shows that the glandular tissue and associated structures of cranioventral and caudodorsal sacs are alkaline phosphatase positive and the reaction is moderate in the epithelial cells especially in their luminal portions. The phosphatases are lysosomal hydrolytic enzymes which are involved in active

transport between the cell and the extracellular structures (Moog and Wenger, 1952; Novikoff *et al.*, 1962). Therefore, in the present study, the alkaline phosphatase reaction recorded in the glandular and connective tissue indicates transport of secretions from the glandular cells.

CONCLUSSION AND RECOMMONDATIONS

Conclusion

The stomach of dromedary camel consists of four compartments (compartment1, compartment 2, compartment 3 and compartment 4).

Compartment 1and 2 are partially glandular and non-glandular, whereas compartment 3 and 4 are entirely glandular.

The results revealed no significant differences between the morphology of cranioventral and caudodorsal sacs except that the pits in the cranioventral sac were larger than that in the caudodorsal sac. Histochemically, these sacs were suggested to secrete neutral mucopolysacharides. In addition, some cells secreted both neutral and acid mucopolysacharides. Moreover, other glandular cells showed glycogen.

Recommendations

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

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