Sudan University of Science and Technology

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Studies on Morphological and HistochemicalSeasonal changes on the lacrimal Apparatus of the One-humpedcamel (*Camelusdromedarius*)

دراسات مورفولوجية وكيمياء نسيجية للتغيرات الموسمية للجهاز الدمعى فى الأبل وحيدة السنام

By

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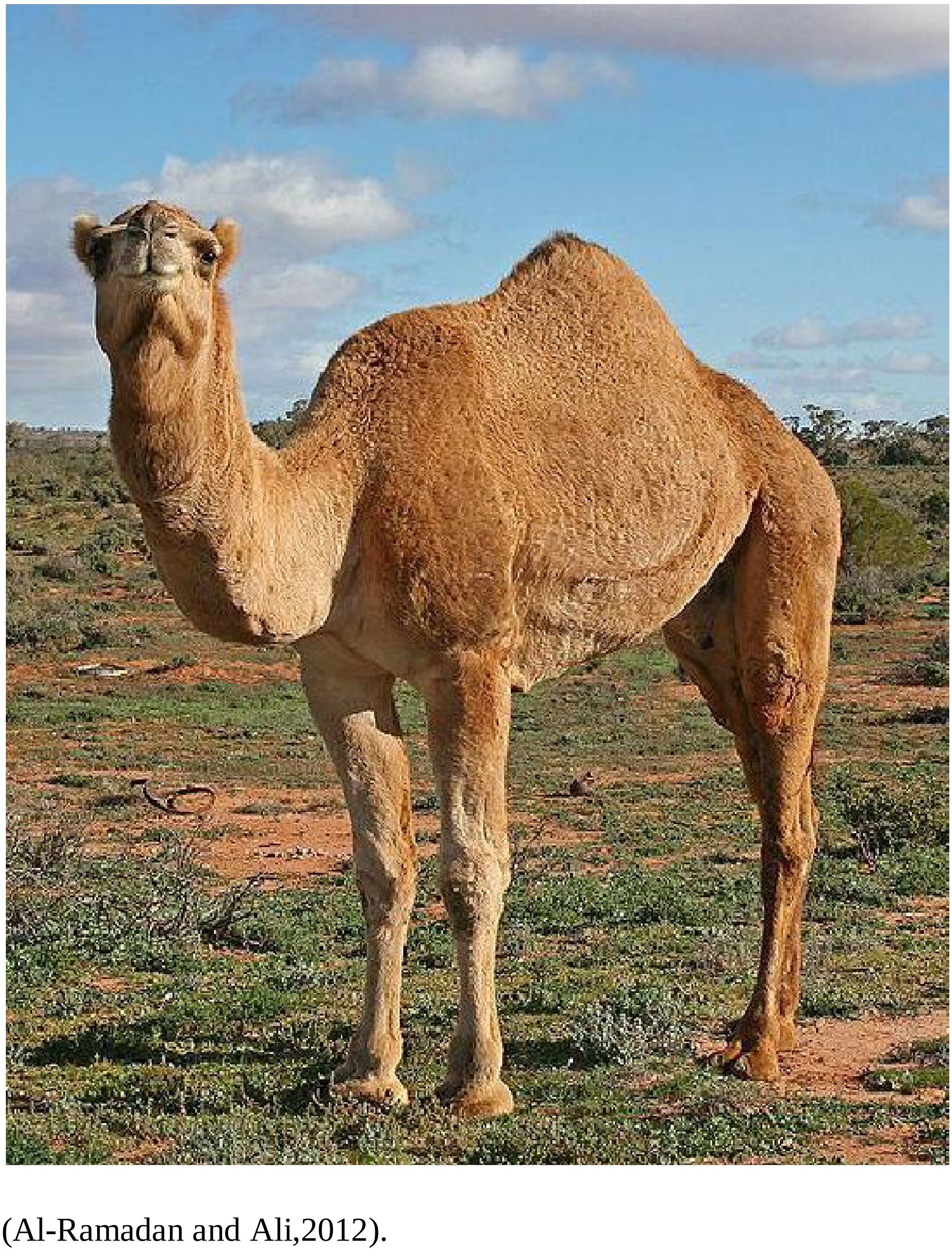

(Al-Ramadan and Ali,2012).

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INTRODUCTION

The scientific classification of the animal species in this issue (*Camelus dromedarius*) Wilson, (1984) is as follows:

Class **:** Mammalia.

SubClass **:** Eutheria.

Superorder **:** Paraxonia.

Order : Artiodactyla.

Suborder: Tylopoda.

Family: Camelidae.

Subfamily: Camelinae

Genus : Camelus.

Species : Dromedarius.

: Bactrianus.

There are two species of camels: the one-humped (*Camelus dromedarius*), and the two-humped camel (*Camelus bactrianus*) (Al-Ramadan and Ali, 2012).

The one-humped camel (*Camelus dromedarius*) is found in Iran, Iraq, Arabia, Egypt, Sudan, NorthAfrica, Somaliland, India, and many other countries (Sadegh *et al*., 2007). This animal is adapted to the hot climate of the desert where it is subject to the high temperature and scorching sun rays.

The lacrimal apparatus system consists of lacrimal gland, excretory ducts, lacrimal ducts, lacrimal sac and nasolacrimal duct. It provides a passage for tear drainage from the eye to the nasal cavity. The system for each eye in most species consists of dorsal and ventral lacrimal puncta (openings) through which the excess lacrimal secretion is drained from the eye into the lacrimal ducts, lacrimal sac, and the nasolacrimal duct (Abdalla *et al*., 1970; Sisson and Grossman, 1975; Ibrahim *et al*., 2006; Alsafy, 2010).

The lacrimal gland is the main contributor to the aqueous layer of the tear film, it secretes proteins, electrolytes and water, which helps to nourish, moisten and protect the ocular surface from dryness, pathogens and harmful particles. The lacrimal puncta have been found to be absent in camels (Abdalla *et al*., 1970; Ibrahim *et al*., 2006) and the main function of the lacrimal fluid in the camel is confined to the washing and moistening of anterior part of the eyeball.

The review of the available literature showed that there has been no work on the seasonal morphological changes in the mammalian lacrimal gland and its duct system. In the dromedary camels the seasonal structural changes of the lacrimal apparatus, if any, could be part of the mechanism that keeps the environment of the anterior surface of the eye in balance under hot and dry habitat. This study aims at investigating the seasonal morphology, histochemistry and histometry of the camel lacrimal apparatus.

General objectives:

- This study aims at investigating the seasonal morphology, histochemistry and histometry of the camel lacrimal apparatus.

Specific objectives:

- To study the gross anatomy of the camel lacrimal apparatus during hot and cold seasons.
- To study the histolology of the camel lacrimal apparatus during hot and cold seasons.
- To study histometry of the camel lacrimal gland during hot and cold seasons.
- To study histochemistry of the camel lacrimal gland during hot and cold seasons.

CHAPTER ONE

LITERATURE REVIEW

1.1. Gross anatomy of the lacrimal apparatus:

1.1.1. Position and relationshipsof the lacrimal gland:

The position and relationship of the lacrimal gland has been studied in the different mammalian species (Sinha and Calhoun, 1966; Sisson and Grossman, 1975; Dellmann and Brown, 1981; Dyce *et al.*, 1996).

In the domestic animals the lacrimal gland lies in the dorso-lateral aspect of orbit on the eyeball in horse (Sisson and Grossman, 1975; Budras *et al.*, 2009), cow (Budras *et al.*, 2011) and dog (Dyce *et al.*, 1996).

According to Bradley (1948) Sisson and Grossman (1975) and Dyce, *et al.* (1996) the gland lies chiefly under the orbital ligament in the dog and under the zygomatic process of the frontal bone (Dursum, 2000; Aslan *et al.*, 2005).The gland is difficult to distinguish from the extraorbital muscles (Bradley, 1948; Sisson and Grossman, 1975; Dyce *et al*., 1996).

In the pig (Sisson and Grossman, 1975), horse (Bradley, 1946; Sisson and Grossman, 1975), ox (Dyce and Wensing, 1971; Sisson and Grossman, 1975) and small ruminants (Sinha and Calhoun, 1966) the gland is separated from the eyeball by the periorbita. In the horse (Sisson and Grossman, 1975) and ox (Sisson and Grossman, 1975; Diesem, 1968) the lacrimal gland is partially covered by fat.

In Philippine water buffalo (Maala *et al.*, 2007), Iranian River Buffalo (Shadkhast and Bigham, 2010) and Lori sheep (Abbasi *et al.*, 2014) the gland is situated along the dorsolateral aspect of the eyeball and it is enclosed by the periorbita (Maala *et al*., 2007).

According to Zwingenberger *et al.* (2014) the gland conforms to the dorsolateral surface of the globe andis located deep to the orbital ligament.

The Roe deer lacrimal gland occupies the dorsolateral angle of the orbit between the tendons of the dorsal rectus and the lateral rectus muscles (Klećkowska-Nawrot *et al.*, 2013).

In small mammalian species the lacrimal gland lies eitherin the posterior aspect of the orbit asin therabbit (Rehorek *et al.*, 2011) or at the rim of the bony orbit between the duct of the exordial gland and the zygomatic arch asin therat (Ross and Pawlina, 2009).

In the Bactrian camels the lacrimal gland is situated dorsolateral to the eyeball (Chengjuan *et al*., 2008).

The lacrimal gland in dromedary camels (Ibrahim *et al.*, 2006) is located between the caudodorsoal aspect of the eyeball and the supraorbital and frontal process of the frontal and zygomatic bones. According to Abdalla *et al.* (1970) the gland lies between the caudodorsolateral part of the eyeball and the bony orbit. It has also been stated that the camel gland lies between the caudolateral part of the eyeball and the bony orbit (Awkati and AL- Bagdadi, 1971). Claims that the lacrimal gland is located in dorsolateral part of the eyeball and it extends caudally beyond the caudal border of the zygomatic process of the frontal bone and it is surrounded by the periorbital tissue and the periosteum on the inner surface of the supraorbital portion of the frontal bone (Mohammadpour, 2011).

1.1.2. Colour and shape of the lacrimal gland:

The colour of the lacrimal gland has been described as light brown in many mammalian species including goat and donkey (Sisson and Grossman, 1975; Alsafy, 2010), Lori sheep (Abbasi *et al*., 2014) and rat (Ross and Pawlina, 2009). It has also been described as pale red in horse (Diesem, 1968) and dog (Bradley, 1948). The glandular colour has been described as pink to red in Iran river buffalo (Maala *et al.*, 2007).In dog it is pink (Sisson and Grossman, 1975) and sheep (Sinha and Calhoun, 1966).In sheep it isred in colour (Sisson and Grossman, 1975).

In Iranian river buffalo it is pale yellow (Shadkhast and Bigham, 2010). In rabbit it is white to pale brown in colour (Al-Murshidi, 2015).

In the Bacterin camels the lacrimal gland is light brown in colour (Chengjuan *et al.,* 2008).

The colour of the lacrimal gland in dromedary camels has been described as light brown (Ibrahim *et al.*, 2006).It is pink in colour (Alsafy, 2010).

The shape of the lacrimal gland is determined by it is position and relationships as it is convex dorsally and concave ventrally because it is included between the eyeball and the bony orbit.

In the Lori sheep (Abbasi *et al.*, 2014), rabbit (Al-Murshidi, 2015) and in different animal species (Menakab and Puri, 2015) the lacrimal gland is lobulated in rabbits and cattle as bilobed.In other mammals including the dog; it has a single lobe (Zwingenberger *et al*., 2014). In cattle it is bipartite (Pinard *et al*., 2003).

In goat and donkey, the lacrimal gland is large in size (Sisson and Grossman, 1975; Alsafy, 2010). It is flattened and oval in shape in goat and donkey (Sisson and Grossman, 1975; Alsafy, 2010), horse (Sisson and Grossman, 1975) and Iranian river buffalo (Shadkhast and Bigham, 2010).

The ox lacrimal gland is thick and distinctly lobulated and more or less clearly divided into a thick upper and a thin lower part (Sisson and Grossman, 1975).

In sheep (Abbasi *et al*., 2014) and rabbit (Al-Murshidi, 2015) it is irregularly rounded to oval.

The dog lacrimal gland is flat (Dyce *et al*., 1996; Sisson and Grossman, 1975).It is oval in shape (Zwingenberger *et al*., 2014).

In the Philippine water buffalo the gland is distinctly lobulated and flattened (Maala *et al*., 2007).

In rat it is small and triangular (Ross and Pawlina, 2009). In Roe deer the gland is triangular in shape (Klećkowska-Nawrot *et al.*, 2013).

In the Bacterin camels the gland is irregulaly triangular in shape (Chengjuan *et al.*, 2008).

The lacrimal gland in dromedary camels is irregularly flattened, lobulated and elongated in shape.It is composed of three lobes caudal, lateral and cranial and it is smaller in size in relation to body weight (Alsafy, 2010). According to Awkati and Al-Baghdadi (1971) the camel lacrimal gland is comparatively less developed than that in the horse or ox. The gland is described as flat (Awkati and Al-Baghdadi, 1971).The lacrimal gland is elongated and irregular (Mohammadpour, 2008, 2011). It is irregularly triangular (Abdalla *et al.,* 1970; Ibrahim *et al.*, 2006).Occasionally crescent-shaped consisting of two lobes connected by a connective tissue sheath (Ibrahim *et al.*, 2006).It has two surfaces, three margins, and three angles and the dorsal surface is convex in conformity with concavity of the bony orbit. The ventral surface is concave, being adapted to the convex eyeball (Ibrahim *et al.*, 2006; Alsafy, 2010).

1.1.3. Weight and dimensions of the lacrimal gland:

According to available literature the weight and dimensions of the lacrimal gland vary with the animal size, age and species.

In the horse it measures about two inches (5cm) transversely and an inch or more (2.5-3cm) in the sagittal direction (Sisson and Grossman, 1975).

The ox lacrimal gland is 60mm long and 35mm wide (Diesem, 1968; Sisson and Grossman, 1975).

In the goat the gland body dimension is 2.5-2.8cm long, 2cm wide, while the appendage is 1cm long and 0.7cm wide. In donkeys the gland body dimension is 3.2cm in length and 2cm in width (Alsafy, 2010).

In small ruminants the gland which weighs about 1.5gm.is 28mm long, 20 mm wide and 5mm thick (Sinha and Calhoun, 1966; Sisson and Grossman, 1975).

In canines the mean volume of the lacrimal gland is 0.14 cm^3, the mean height is 9.36 mm, width 4.29 mm, and length 9.35mm (Zwingenberger *et al.*, 2014).

In the Lori sheep the mean glandular weight, length, width and thickness of the gland are 1.48 ± 0.3gm , 26.98 ± 0.37 mm , 20.11 ± 0.31 mm and 3.58 ± 0.7 mm , respectively (Abbasi *et al.*,2014).

The weight of the lacrimal gland in camel ranges between 1.95 and 2.49gm and as a single unit.The gland measures 55mm in length, and 20mm in width (Ibrahim *et al.*, 2006). The length of the cranial lobe is 35mm, and its width is 20mm. The caudal lobe is 20mm in length and width. The thickness of the gland varies between 5mm in the middle of the cranial lobe and 2mm in the most lateral aspect of the caudal lobe and the most medial part of the cranial (Ibrahim *et al.*, 2006).The dimensions of the caudal lobe are 3cm in length and width is 1.7-1.9cm, the lateral lobe is 1.7cm in length, and 1.7cm in width, the cranial lobe is 1.5cm in length and 1cm in width (Alsafy, 2010).

1.1.4.The excretory ducts:

In all mammals the lacrimal gland secretion is conveyed to the conjunctiva of the upper eyelid by means of excretory ducts (Sisson and Grossman, 1975).

In the horse they open into the lateral part of the conjunctival sac along a line a little in front of the superior fornix. The size and number of excretory ducts varies within mammalian species. According to Alsafy (2010) it is two in goat and donkey.The excretory ducts very small and twelve to sixteen in horse (Sisson and Grossman, 1975). It is large and six to eight in ox (Bradley, 1946;

Diesem, 1968; Sisson and Grossman, 1975) and five to six in pig (Sisson and Grossman, 1975).

In the camel the excretory ducts are relatively small and each duct is about 12mm long; they leave the gland at the ventral surface of the corresponding part of the gland penetrating the periorbita, and open anterior to the fornix of the conjunctiva of the upper eyelid (Ibrahim *et al.*, 2006). They vary in number between two to four (Abdalla *et al.*, 1970), two (Awkati and Al-Bagdadi, 1971; Zaid and Ghadiri, 1991; Al-Ani, 1997) and three to four (Ibrahim *et al.*, 2006). According to Ibrahim *et al.* (2006) the cranial lobe has 1-2 ducts, the caudal lobe has a single duct and the accessory gland has one duct.

1.1.5. The lacrimal ducts (Canaliculi):

In mammals the lacrimal ducts (lacrimal canaliculi) are two, one dorsal and one ventral, the lacrimal ducts start by an opening (punctum) close to the medial angle of the eyelid, they lead into the lacrimal sac (Sisson and Grossman, 1975).

In horse the puncta lacrimalia are the entrances to the two lacrimal ducts, the opening is about 2mm long, situated close behind the free edge of the lid and about a third of an inch (8mm) from the medial canthus (Sisson and Grossman, 1975). The lacrimal ducts (canaliculi) join at the lacrimal sac (Budras *et al.*, 2011).

In the goat and donkey the dorsal and ventral lacrimal puncta are 0.05cm in diameter and 0.5cm away from the medial angle of the eye, the lacrimal ducts start at the medial part of the upper and lower eyelids (Alsafy, 2010).

In pig there is no lacrimal sac and the two lacrimal ducts pass through separate openings at the infraorbital margin (Sisson and Grossman, 1975).

In dog each lacrimal punctum leads to a short lacrimal duct (Dyce, 1996).

In rabbits, there is only a single medial punctum and a lacrimal duct (Rehorek *et al.*, 2011).

In the Iranian river buffaloes the average total length of lacrimal duct is 260 mm (Bigham and Shadkhast, 2009).

In camel the dorsal and ventral lacrimal puncta are absent and the lacrimal duct starts blindly at the medial part of the upper and lower eyelids (Abdalla *et al*, 1970; Saber and Makady, 1987; Ibrahim *et al.*, 2006; Sadegh *et al.*, 2007; Alsafy, 2010).The lacrimal puncta are slit-like openings, 0.5-1.0 mm in diameter, 4.0-10.0 mm away from the medial canthus located 1.0 mm from the mucocutaneous junction of the palpebral margin (Sadegh *et al.*, 2007). The lacrimal ducts are 10.5±0.5 mm long and the proximal portion of the lacrimal duct is 45.64±0.41 mm long in the osseous lacrimal canal (Sadegh *et al.*, 2007).They are 7 to 9 mm long and converge into a small dilatation and lead to lacrimal sac (Alsafy, 2010). According to Ibrahim *et al.*(2006) there are two lacrimal ducts which are about 10mm long each, and they open into the lacrimal sac after penetrating the periorbital tissue. However, Al-Ani (1997) states that there is a single large duct.

1.1.6. The lacrimal sac:

In the horse and dog (Dyce *et al.*,1996; Budras *et al.*, 2009) the fluid drains to the medial angle where it forms the so-called lacrimal lake that surrounds, moat-like prominentlacrimal caruncle (Budras *et al.*, 2009).

The lacrimal sac (Succus lacrimalis) is regarded as the dilated origin of the nasolacrimal duct in horse (Sisson and Grossman, 1975).

In the dog and horse it occupies a funnel-shaped (Sisson and Grossman, 1975; Dyce *et al.*, 1996).Fossa near the margin of the orbit (Dyce *et al.*, 1996).

In the pig there is no lacrimal sac, the lacrimal sac occupies the fossa of the lacrimal bone in dog and sheep (Sisson and Grossman, 1975);and islocated in the orbit on the fossa of the lacrimal bone (Bigham and Shadkhast, 2009).

The lacrimal sac in the camelis located in the lacrimal fossa of the lacrimal bone (Ibrahim *et al.*, 2006; Alsafy, 2010; Sadegh *et al.*, 2007), outside the periorbita (Sadegh *et al.*, 2007). Abdalla *et al.* (1970) states that the lacrimal sac is situated in a well-developped lacrimal fossa in the lacrimal bone.

According to Ibrahim *et al.* (2006) the lacrimal sac is funnel-shaped and its palpebral part is concave, as it presses against the convex eyeball, the outer surface is convex in adaptation to the concavity of the lacrimal fossa; it measures 15mm transversely and 5mm sagittaly, the sac is blind dorsolaterally and receives medially and laterally the corresponding lacrimal ducts. Rostroventrally it is continuous with the nasolacrimal duct.

1.1.7. The nasolacrimal duct:

The nasolacrimal duct in all mammalian species originates fromthe lacrimal sac and runs along the medial surface of the maxilla under the nasal mucosa to end at the nostrils (Sisson and Grossman, 1975; Dyce *et al.*, 1996).

According to Sisson and Grossman (1975) the duct may open into the ventral meatus immediately after its emergence from the osseous lacrimal canals; it continues forward and finally opens on the lateral wall of the nostril below the ventral turbinate fold.

In the ox the duct is shorter than in the horse and is almost straight, its terminal part is enclosed between two plates of cartilage and it opens near the nostril on the lateral wall of the vestibule of the nasal cavity (Budras *et al.*, 2011).The orifice is placed on the medial side of the alar fold of the ventral turbinate and therefore not easily found (Sisson and Grossman, 1975).

In the horse the length is about 25-30cm which passes forward and a little downward along the outer wall of the frontal sinus and the nasal cavity and opens near the lower commissure of the nostril(Sisson and Grossman, 1975). The orifice of the long nasolacrimal duct of horse is located in the floor of the nostril (Budras *et al.*, 2009).

In the donkey the external opening of the nasolacrimal duct is located on the cutaneous wall of the nostril (Said *et al.*, 1977).

In the dog the nasolacrimal duct is much relatively longer and in some species it ends at the nostril, in others more deeply in the nasal cavity (Dyce *et al.*, 1996).

In the pig it is usually short and opens into the ventral nasal meatus at the posterior end of the ventral turbinate (Sisson and Grossman, 1975).

In the rabbits the nasolacrimal duct begins in the orbital region with an opening in the lower eyelid, it then traverses through the tissues that form the wall of the rostrum and extends along the length of the nasal cavity to end in the lateral wall of the naris (Rehorek *et al.*, 2011).

In the Iranian river buffaloesthe nasolacrimal duct extends from the lacrimal sac to the nostril in the wall of the nasal cavity.The duct is coved only by nasal mucosa and a thin connective tissue membrane. It then traverses the nasal cavity in a curved (descending) fashion. The distal opening of the nasolacrimal duct is 1.5 to 2 mm in diameter; it is located in the medial surface of the lateral nasal wall about 40 mm above the dorsal angle of the nostril (Bigham and Shadkhast, 2009).

The camelnasolacrimal duct which originates from the lacrimal sac is about 200mm long. Its initial part, about 10–15mm, is situated in the osseous canal of lacrimal bone; it parted from the osseous canal at the caudal portion of the ventral nasal meatus, ventral to the maxilloturbinate crest (Ibrahim *et al.*, 2006).The nasolacrimal duct which traverses the nasal cavity in an S- shape fashion is covered only by nasal mucosa and a thin connective tissue membrane (Sadegh *et al.*, 2007). Its opening is on the lateral wall of the dorsal angle of the nostril and it is 2.6-0.41mm in diameter and about 11.5-0.5mm from the dorsal angle of the nostril where it is easily identified. The latter authors states that the camel nasolacrimal duct runs in the osseous lacrimal canal rostrally, with a slight curve at its origin. It passes alongthe lacrimal, zygomatic and maxillary bones, through the maxillary sinus and then traverses the nasal cavity in a curved descending fashion covered only by the nasal mucosa and a thin connective tissue membrane on the lateral surface of ventral nasal concha. The nasolacrimal duct opens at the medial wall of the nasal vestibule at the junction between the mucous membrane and skin by the nasal opening of the nasolacrimal duct that is very minute in camel (Alsafy, 2010). According to Ibrahim *et al*. (2006) the duct has many fenestrae in its wall along its course distal to the osseous canal and opens into the medial wall of the nasal vestibule at the junction between the mucous membrane and skin. The duct, which is10mm medial to the wider opening of the blind sac opening, is oval and difficult to detect.

1.2. Histology of the lacrimal gland:

The histology of the lacrimal apparatus of the different mammalian species has been described by a number of authors including Sinha and Calhoun (1966), KÜhnel (1968), Dellmann and Brown (1981), Banks (1993), Dellmann and Eurell(1998), Burkitt *et al.* (1999),Gargiula *et al*.(1999), Bacha and Bacha (2000), Pinard *et al*. (2003), Maala *et al.* (2007), Ross and Pawlina (2009), Shadkhast and Bigham (2010),Daryous and Ahmed (2012a,b), Klećkowska-Nawrot *et al*. (2013), Abbasi *et al*. (2014), Zwingenberger *et al*. (2014) and Al-Murshidi (2015).

1.2.1. The lacrimal gland:

The lacrimal gland in most domestic mammals is compound tubulo-alveolar in structure with clusters of secretory end-pieces (Dellmann and Brown, 1981; Burkitt *et al.*,1999; Bacha and Bacha, 2000).The septa which divide the gland into lobes and lobules of different shapes and sizes come from a connective tissue capsule that surrounds the gland and is composed mainly of collagen fibres and profiles of interlobular blood vessels are found in the connective tissue septa (Dellmann and Brown,1981; Maala *et al*., 2007).

The thick capsule according to Daryous and Ahmed (2012b) is composed of collagenous fibres, elastic fibres, smooth muscle fibres, adipose tissue, blood vessels and nerve fibres. The septa have thick connective tissue surrounding the blood vessels and interlobular ducts.

The lacrimal glands are compound tubuloacinar in sheep (Gargiula *et al*., 1999), Philippine water buffalo (Maala *et al*., 2007), Klećkowska-Nawrot et al., 2013) and European bison (Klećkowska-Nawrot *et al*.,2015).

It is tubuloalveolar in American bison(Pinard *et al*., 2003) and camel (Shadkhast and Bigham, 2010).

The lobules are surrounded by loose connective tissue. The secretory units are lined by simple cuboidal epithelium (KÜhnel, 1968; Menakab and Puri, 2015).

The acini are surrounded by basal myoepithelial cells and composed of two types of cells: serous cells, and mucous cells (Klećkowska-Nawrot *et al*., 2013).The cells of parenchyma are mixed including serous and mucous cells.

The Philippine water buffalo lacrimal glands are predominantly mucous (Maala *et al*., 2007). The secretory units are surrounding by myoepithelial cells (Daryous and Ahmed, 2012b).

The gland is described as serous in the cattle, horse and rabbit, mucous in the pig and goat, and mixed in dog and sheep (Ross and Pawlina, 2009).

It is serous in the cats and mixed in dogs (Sisson and Grossman, 1975; Ross and Pawlina, 2009).

Dellmann and Eurell(1998) and Sisson and Grossman (1975) described the gland as mucous in pig. The intercalated and secretory ducts of the lacrimal gland are lined with a simple and stratified cuboidal epithelium (Dellmann and Eurell, 1998).

In the Black goat and Awasi sheeps the intercalated ducts are lined with low cuboidal epithelium, then gradually increase in height to become stratified cuboidal to stratified columnar epithelium with goblet cells, the interlobular ducts are lined with two layers of cuboidal to columnar epithelium (Daryous and Ahmed, 2012b).

In Lori sheep (Abbasi *et al.*, 2014) the intralobular and interlobular ducts of the gland are lined with cuboidal, stratified cuboidal and pseudostratified columnar epithelium. In some ducts goblet cells are present among epithelial cells (Sinha and Calhoun, 1966; Abbasi *et al.*, 2014).

In rabbit intralobular and interlobular ducts are lined with cuboidal, stratified cuboidal epithelium (Al-Murshidi, 2015).

According to Sinha and Calhoun (1966) the interlobular ducts are lined withstratified cuboidal epithelium in small ruminants.

In the Bactrian camels the gland is tubuloacinar and the acini have large lumina and lined with cuboidal cells (Chengjuan *et al.*, 2008).

In the dromedary camel the lacrimal gland is serous and tubuloalveolar; it is covered by a dense connective tissue capsule it was divided by dense septa of connective tissue into numerous small and large lobules (Mohammadpour, 2011). It has also been described as lobulated (Abdala *et al.*, 1970). It was compound alveolar (Awkati and Al-Bagdadi, 1971).The secretory endpieces are lined with pyramidal cells (Abdalla *et al.*, 1970; Awkati and Al-Bagdadi, 1971). The camel intralobular ducts are lined by simple columnar epithelium and opened into the interlobular ducts (Ibrahim and Abdalla, 2015). The interlobular ducts are found in the connective tissue septum and lined by tall simple to stratified columnar epithelium (Sadegh *et al.*, 2007). According to Ibrahim and Abdalla (2015) interlobular ducts are lined by stratified cuboidal or stratified columnar epithelium and some large ones are lined by pseudo-stratified columnar epithelium that contains goblet cells andissurrounded by loose connective tissue, containing blood vessels, reticular and elastic fibres.

1.2.2. The excretory ducts:

According to Daryous and Ahmed (2012b) the Awasi sheep and black goat excretory ducts are lined with stratified columnar epithelium with goblet cells.

In Roe Deer they are lined with a basal layer of cuboidal cells (Klećkowska-Nawrot *et al.*, 2013).

The excretory ducts are lined with stratified cuboidal and pseudostratified columnar epithelium with some goblet cells in Lori sheep (Abbasi *et al.*, 2014).

In the small ruminants, pig and rabbit (Sinha and Calhoun, 1966; Kuehnel and Scheele, 1979; Al-Murshidi, 2015) the excretoryducts are lined with pseudostratified columnar epithelium with goblet cells and the lamina propria composeof dense collagensous tissue (Sinha and Calhoun, 1966).

In the camel the excretory ducts are lined by stratified or pseudostratified columnar epithelium rich in goblet cells, lymphocytes and melanin granules and the lamina propria is made of dense irregular connective tissue containing mainly collagenous fibres, adipose tissue, some smooth muscle fibres and blood vessels (Ibrahim and Abdalla, 2015). The excretory ducts are also found to be lined by stratified columnar epithelium rich in melanin granules especially the superficial layers and the subepithelial layer is vascular and infiltrated with lymphocytes (Awkati and Al-Bagdadi, 1971). The latter authors also state that the conjunctival end of the main duct had less goblet cell, and its lining epithelium and the epithelium of its two main branches was heavily laden with melanin and chormatophore pigment, giving the duct its black colour.

1.2.3. The lacrimal ducts (Canaliculi):

In the goat and sheep the lacrimal puncta which lead to the lacrimal ducts are lined by stratified squamous epithelium surrounded by fibrous tissue (Sinha and Calhoun, 1966).

The mammalian lacrimal ducts (lacrimal canaculi) are lined by stratified columnar epithelium (Dellmann and Eurell, 1998).

In the black goat and Awasi sheep the lacrimal ducts are also lined by stratified columnar epithelium with goblet cells (Daryous and Ahmed, 2012b).In the horse squamous or columnar epithelium (Banks, 1993).In small ruminants squamous or cuboidal near the puncta and stratified columnar elsewhere with a few goblet cells (Sinha and Calhoun, 1966).

In camels the lacrimal duct epithelium is stratified columnar rich in melanin and goblet cells (Abdalla *et al.*, 1970; Ibrahim, 2003).

1.2.4. The lacrimal sac:

In the horsethe lining epithelium of the lacrimal sac is columnar (Sisson and Grossman, 1975), squamous or columnar epithelium (Banks, 1993).

In small ruminants the epithelium is stratified columnar with goblet cells (Sinha and Calhoun, 1966).

According to Dellmann and Brown (1981) the lamina propria is well-developed and highly vascular with cavernous plexues in the horse and small ruminants (Sinha and Calhoun, 1966).

In the black goat and Awasi sheep the lacrimal sac is lined by stratified columnar epithelium with goblet cells (Daryous and Ahmed, 2012b).

In the pig, however, the sac is lined with transitional epithelium (Sisson and Grossman, 1975).

In camel the lacrimal sac is lined by stratified columnar cells rich in melanin and goblet cells and the lamina proporia contains irregular venous plexuses; the outermost layer is formed of a dense sheath of collagenous fibres parallel to each other and interposed with fibroblasts, whereas the superficial one contains irregular venous plexues (Abdalla *et al.*, 1970).

1.2.5. The nasolacrimal ducts:

The epithelium of the nasolacrimal duct in the domestic mammals is stratified columnar, except in the pig in which the epithelium is transitional orsimple columnar and the lamina propria contains lymphatic tissue towards the nasal end of the duct (Dellmann and Brown, 1981), simplebranched tubuloacinar mucous glands (Dellmann and Eurell, 1998). The latter authors describe the ductal glands as seromucous in sheep and goats.

In the black goat and Awasi sheepthe nasolacrimal ducts are also lined with stratified columnar epithelium cells with goblet cells (Daryous and Ahmed, 2012b). In the sheep and goat a few areas of pseudostratified columnar epithelium are presentin the distal portion with numerous goblet cells; seromucous glands and venous plexuses in lamina proporia has also been observed (Sinha and Calhoun, 1966).

In camel the nasolacrimal duct is lined by stratified columnar cells and the lamina proporia contains irregular venous plexuses and mucigenous granules (Abdalla *et al.*, 1970). According to Badawi and Fateh El-Bab (1974) the nasolacrimal duct has two layers of cuboidal cells which change into stratified squamous near the external orifice of the duct.

1.3. Histometry:

Little work is doneon mammalian lacrimal gland histometry in the available literature**.** The percentage of glandular acini of the right and left lacrimal glands is greater than that of the tubules in Awasi sheep and black goat, while the mucous acini are comparatively greater in lacrimal glands of Awasi sheep than those of black goat (Daryuos and Ahmed, 2012a).They also state that there are no significant differences in the measurements of glandular diameter, luminal diameter and epithelial height of the secretory units in the Awasi sheep and black goat. The left and right lacrimal glands of Awasi sheep are significant wider than that of the black goat whereas the length and thickness show no significant differences (Daryuos and Ahmed, 2012b).

In canine the lacrimal gland positively correlates with body weight (Zwingenberger *et al.*, 2014).

According to Klećkowska-Nawrot *et al.* (2013) the mean size of thelacrimal gland of Roe Deer is 27.6 (±4.6) x 13.0 (±2.0) x 2.2 (±0.7) mm in females and 26.4 (±4.4) x 12.6 (±2.2) x 1.8 (±0.4) mm in males; the differences are not statistically significant for the three dimensions and no correlation is observed between the body size and the size of the lacrimal gland.

In the Iranian River Buffalo no significant differences are seen in the length and width between both sexes (Shadkhast and Bigham, 2010).

Ibrahim and Abdalla (2007) studied the morphometry of the camel lacrimal gland noting that the glandular tissue occupies about 64% of the total volume of the gland, whereas the connective tissue occupies about 29% of the volume of the gland. They concluded that there is no significant difference between the right and left glands in the relative volumes occupied by the above mentioned components, the mean volume of the right gland is 2.26±0.24cm^3 and the mean volume of the left gland is 2.26±0.20 cm^3.

The mean length of the left dorsal lacrimal gland in camel is 53.7±2.58 and that of the right is 49.4±2.63 mm; the mean width is 20.1±1.37 and 18.2±1.2 mm in the left and right side, respectively. These results confirm that the left lacrimal gland is significantly greaterin its dimensions than the right one (Mohammadpour, 2008).

1.4. Histochemistry:

The literature review shows that the mammalian lacrimal gland is predominantly serous (Dellmann and Brown, 1981). However, in the pig the mucous cells predominate (Kuehnel and Scheele, 1979),in the dog gland is reported to be purely mucous (Kühnel, 1968). The latter authors added that the dog lacrimal gland contains PAS and Alcian blue positive granules in the secretory units of the gland. Martin *et al*. (1988) claim that the tubular epithelium in the dog is PAS positive and Alcian blue (PH2.5) negative, whereas the predominant acinar cells are PAS and Alcian blue (PH2.5) positive.

In the ox the glandular cells contain PAS positive granules and some are rich in Alcian blue negative material (Kühnel, 1968).

In cattel and American bison lacrimal gland histochemistry of mucosubstances reveals acidic and neutral glycoproteins with similar staining patterns (Pinard *et al*., 2003).

The secretion of the lacrimal gland in the European bison is serous (Klećkowska-Nawrot *et al*., 2015). Menakab and Puri(2015) state that in swine, the secretion is mucous and the cells show mucin reaction in sheep, goat and dog.

In the sheep the lacrimal gland is mixed and the secretory portions consist of three cell types mucous, serous and seromuocus (Gargiula *et al*., 1999).

The lacrimal gland of the Philippine water buffalo is a mixed but predominantly mucous compound tubulo-acinar gland (Maala *et al*., 2007).

Lori Sheep secretory portions of the gland reveal that it is a mixed gland but in some areas serous acini are dominant while in other places the mucous cell contents are more abundant; mucous cells show high affinity to PAS and Alcian blue staining (Abbasi *et al*., 2014).

In Roe Deer the lacrimal gland is serous gland and the secretory cells are generally PAS-negative and alcian blue (pH2.5) negative; the apical parts of the excretory ducts also demonstrated a slight positive PAS reaction and Alcian blue (pH2.5) staining demonstrates the presence of moderate negative granules in apical parts of the secretory cells and the epithelial cells in the interlobular ducts (Klećkowska-Nawrot *et al*., 2013). These authors also observed the presence of single cells fully filled with Alcian blue (pH2.5) positive granules.

In the Philippine water buffaloes the secretory acini react strongly to the mucicarmine, periodic acid Schiff and alcian blue (pH 2.5) stains; only a weak reaction is observed with alcian blue (pH1.0) stain but the ducts reaction is negative (Maala *et al.*, 2007).

In the Bactrian camels the lacrimal gland has mucoserous secretions and the cells of tubuloacinar units show a positive PAS and alcian blue reactions (Chengjuan *et al.*, 2008).

In the dromedary camel the lacrimal gland is formed of seromucous compound tubuloalveolar secretory units(Ibrahim and Abdalla, 2015), these secretory units are predominantly serous (Ibrahim, 2003). The secretory units contain acidic and neutral glycoproteins with different staining pattern (Mohammadpour, 2011; Ibrahim and Abdalla, 2015). However, some author considered the lacrimal gland as serous (Abdalla *et al.*, 1970; Awkati and Al-Bagdadi, 1971).

CHAPTER TWO

MATERIALANDMETHODS

A total number of One hundred and twenty five headsofadult (ranging between four- thirteen year in age)camels (*Camelus dromedarius*), have been collected from Omdurman and Tambul slaughterhouses, Central Sudan (Table: 1). Specimenshave been taken from both sexes of healthy adult camels during cold Winter (between October and March) and hot Summer (between April and July), 2014 and 2015.

2.1. Gross anatomy:

For anatomical study 48 fresh camel heads (20 during hot season and 28 during cold season) were used. The heads were immediately separated after the animals have been slaughtered. They were first cleaned and then carefully dissected to expose the gland and its duct system. For studying the glandular position, relationship, shape and colour the superior orbital skin together with the zygomatic process of the frontal bone and frontal processes of zygomatic bone were cut. The periorbital tissues were carefully dissected. The glands were then carefully removed and weighed using a sensitive balance. Measurements of the dimensions during Summer and Winter were taken including the glandular length, glandular width and glandular thickness. The position and relationship of the duct system including the lacrimal duct, lacrimal sac, and nasolacrimal duct were performed using injection of Bouin‘s solution, %10 vinlylite and Hero Ink Shanghai, (China)through the external opening of the nasolacrimal duct. The injected heads were then put in freeze chest before being studied and photographed.

2.2. Histology:

In this study 32 animals were used (14 during hot season and 18 during cold season). Histological specimens from the different parts of the lacrimal apparatus were collected shortly after the animals had been slaughtered. Fixatives of Bouin‘s solution, 10% formal saline, buffered 10% formalin and neutral buffered formalin (N.B.F) were tried. Bouin‘s solution and neutral buffered formalin (N.B.F) were found the best fixatives.

Specimens for histological processing of the different parts of the duct system were taken from Bouin‘s perfused specimens.

Small pieces of the different parts of the lacrimal apparatus were processed using routine histological technique by dehydrating in ascending grades of ethyl alcohol, overnight clearing in cholorophorm, embedding in paraffin wax and cutting of thin (3µ) sections by a rotary microtome as describedby Drury and Wallington (1980).

General and some special stains were used as follows:

1. Hematoxlyin and eosin for general histological observations (Culling, 1974).
2. Elastic fibers: Gomori‘s Aldehyde Fuchsin (Culling, 1974).
3. Reticular Fibers: (Gordon and Sweet) (Bancroft and Stevens, 1990).
4. Collagen fibers: Van Giesson‘s Stain (Culling, 1974).

2.3. Histometry:

Twenty specimens of lacrimal glands (ten during hot season and ten during cold season) were used for histometric measurements.

Histological samples from the apex, middle and base of each gland and routinely processed (Culling, 1974).Paraffin sections (3µ thick) were cut and stained with haematoxylin and eosin (Culling, 1974). One section from each block was selected on the basis of technical quality. Histometric measurements of glandular epithelial thickness, luminal diameter and interstitial tissue thickness were carried out on the rounded secretary units of each section using Olympus software BX51WH10X/22. The data were statistically analyzed by Statistical Package for the Social Sciences (SPSS) 20 and graphs by Excel 2010. The data were found to be significant at ($P < 0.05$).

2.4. Histochemistry:

The histochemical study was performed on 24 animals (ten during hot season and 14 during cold season).The routinely processed paraffin sections of the lacrimal glands were prepared according to Culling (1974) for determination of the seasonal histochemical changes of the lacrimal gland using the following techniques:

1- Periodic acid Schiff (PAS) (Culling, 1974) for detection of neutral mucopolysacharides.
2- Periodic acid Schiff (PAS) after diastase treatment (Culling, 1974) for detection of glycogen.
3- Alcian blue for detection of acidic mucopolysacharides (pH 2.5) (Culling, 1974).
4- Alcian Blue/ PAS sequence (Culling, 1974) for specification of acidic, neutral and mixed mucopolysacharide.
5- Alcian Blue/ Aldehyde fuchsin sequence (Culling, 1974) for specification of carboxylic and sulphated mucins.

Table 1: The number of animals and types of studies conducted.

Study	Number of animals in Winter	Number of animals in Summer
Position and relationships	14	11
Weight and dimensions	14	10
Histology	18	14
Histochemistry	14	10
Histometry	10	10
Total number of animals	70	55

CHAPTER THREE

RESULTS

3.1. Gross anatomy of the lacrimal apparatus:

3.1.1. Position and relationships:

No seasonal change was observed regarding position, relationship, shape and colour in the camel lacrimal gland in all the specimens studied.

The lacrimal gland was located at the dorsolateral part of the eyeball extending caudally between the frontal process of zygomatic bone and zygomatic process of the frontal bone (Figs.1, 2). The gland rested on the eyeball and it was separated from the orbit by the periorbita. It was related craniodorsally to the orbital muscles. The gland was lobulated but in some specimens a ventral accessory lobe was observed which was totally separated from the main lacrimal gland by thick connective tissue. The accessory lobe had its own single excretory duct (Fig. 3).

3.1.2. Shape and colour:

The camel lacrimal gland was lobulated and was irregularly triangular in shape (Figs.2, 3). Its dorsal surface was convex following the concavity of the orbit and the ventral surface was concave following the convexity of the eyeball. The gland had three irregular borders, ventral, cranioventral and caudodorsal; the caudodorsal border was the longest.

In both Winter and Summer seasons the lacrimal gland was light red in colour and was very difficult to distinguish from the underlying muscles (Figs.1, 2, 3).

3.1.3. Weight and dimensions:

3.1.3.1. Weight and dimensions in Winter:

The weight and dimensions in Winterwere summarized in Table 2, Table 3, Text-fig. 1and Appendix.

The mean weight of the right lacrimal gland during the Winter season was 3.70 ± 0.88g. The maximum value was 4.7g, the minimum value was 1.9g, the standard error was 0.29 and the variance was 0.77. The mean glandular length was 4.90 ± 0.72cm; the maximum value was 6.00cm, the minimum value was 3.8cm, the standard error was 0.24 and the variance was 0.52. The mean glandular width was 2.14 ± 0.29cm; the maximum value was 2.6cm, the minimum value was 1.6cm, the standard error was 0.09 and the variance was 0.08. The mean glandular thickness was 0.38± 0.06cm; the maximum value was 0.50cm, the minimum value was 0.30cm, the standard error was 0.02 and the variance was 0.004.

The mean glandular weight of the left lacrimal glands during the Winter season was 3.82 ± 0.97g. The maximum value was 6.1g, the minimum value was 2.9g, the standard error was 0.32 and the variance was 0.95. The mean glandular length was 5.00 ± 0.93cm; the maximum value was 6.3cm, and the minimum value was 3.8cm, the standard error was 0.31 and the variance was 0.86. The mean glandular width was 2.13 ± 0.20cm; the maximum value was 2.5cm, the minimum value was 1.9cm,the standard error was0.06 and the variance was 0.04. The mean glandular thickness was 0.40 ± 0.11cm; the maximum value was 0.65cm, the minimum value was 0.25cm, the standard error was0.03 and the variance was 0.01.

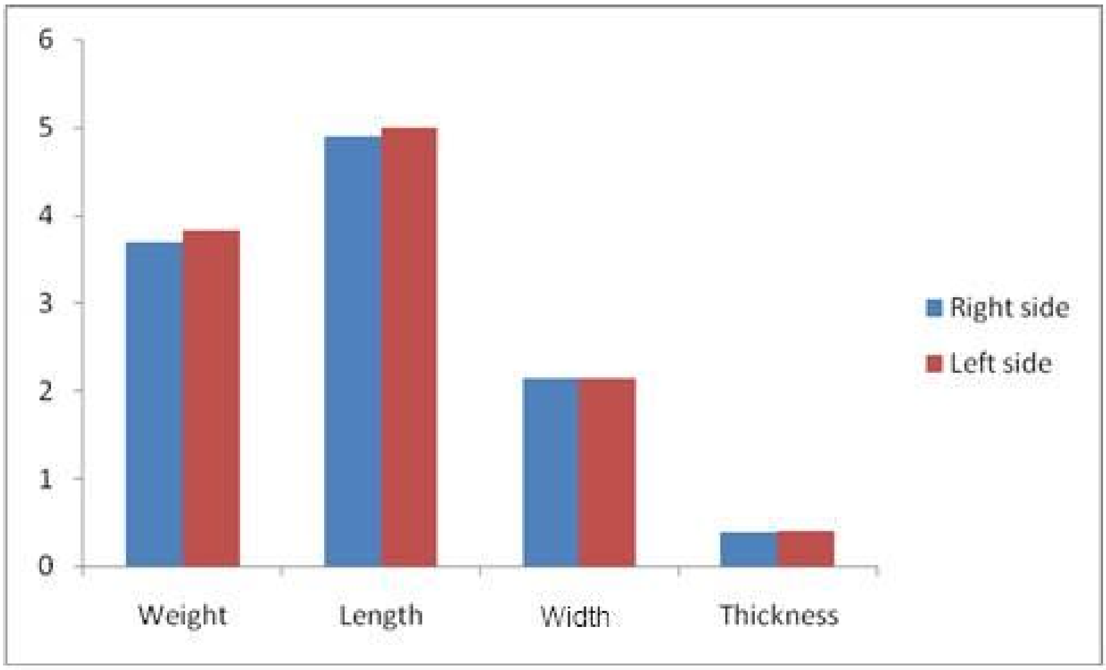
The statistical analysis showed insignificant differences in the weight, length and thickness of right and left glands in Winter; the width of the right and left glands also showed insignificant difference in Winter ($P > 0.05$).

Table 2: The weight and dimensions of the right lacrimal gland of camel in Winter:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Weight(g)	10	1.9	4.7	3.700	0.2939	0.8818	0.777
Length(cm)	10	3.8	6.0	4.900	0.2409	0.7228	0.523
Width(cm)	10	1.6	2.6	2.144	0.0973	0.2920	0.085
Thickness (cm)	10	0.30	0.50	0.3822	0.02184	0.06553	0.004
Valid Number	10						

Table 3: The weight and dimensions of the left lacrimal gland of camel in Winter:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Weight(g)	10	2.9	6.1	3.822	0.3252	0.9757	0.952
Length(cm)	10	3.8	6.3	5.000	0.3100	0.9301	0.865
Width(cm)	10	1.9	2.5	2.133	0.0667	0.2000	0.040
Thickness (cm)	10	0.25	0.65	0.4067	0.03951	0.11853	0.014
Valid Number	10						



Text-Fig. 1: Theglandular weight and dimensions of the right and left lacrimal glands of camel in Winter.

3.1.3.2. Weight and dimensions in Summer:

The weight and dimensions in Summerwere summarized in Table 4, Table 5, Text-fig. 2 and Appendix.

The mean glandular weight of the right lacrimal glands during the Summer season was 3.91 ± 0.98g (Table 4 and Appendix). The maximum value was 5.00g, the minimum value was 2.3g, the standard error was 0.40 and the variance was 0.97. The mean glandular length was 4.56 ± 0.85cm; the maximum value was 6.2cm, the minimum value was 3.2cm, the standard error was 0.28 and the variance was 0.73. The mean glandular width was 2.08 ± 0.41cm; the maximum value was 2.9cm, the minimum value was 1.5cm, the standard error was 0.13 and the variance was 0.17. The mean glandular thickness was 0.36± 0.07cm; the maximum value was 0.50cm, the minimum value was 0.30cm, the standard error was 0.02 and the variance was 0.006.

The mean glandular weight of the left lacrimal glands during the Summer season was 3.38 ± 0.73g. The maximum value was 4.4g, the minimum value was 2.3g, the standard error was 0.30 and the variance was 0.54. The mean glandular length was 4.18 ± 0.57cm; the maximum value was 5.1cm, the minimum value was 3.2cm, the standard error was0.19 and the variance was 0.33. The mean glandular width was 2.05 ± 0.42cm; the maximum value was 2.5cm, the minimum value was 1.3cm, the standard error was 0.14 and the variance was 0.18. The mean glandular thickness was 0.31 ± 0.04cm; the maximum value was 0.40cm, the minimum value was 0.25cm, the standard error was 0.01 and the variance was 0.002.

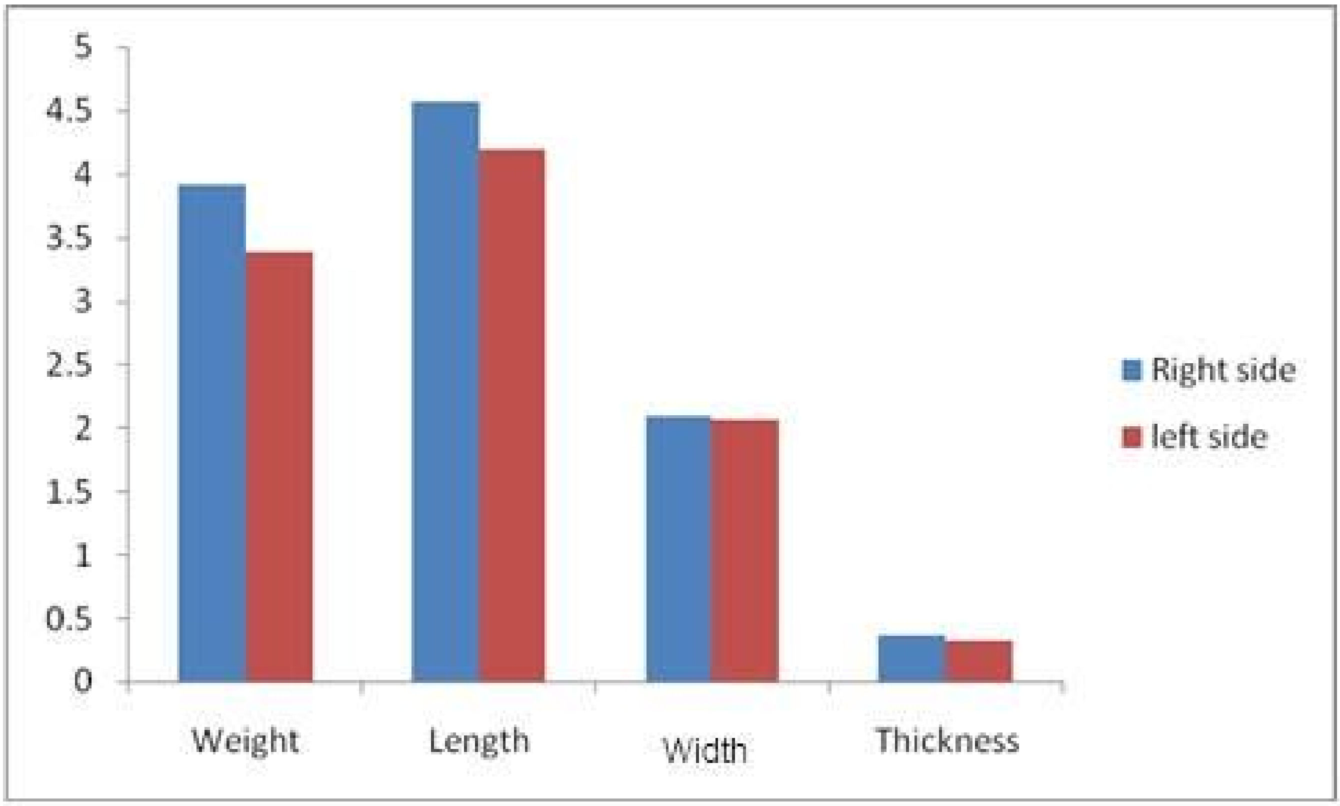
Insignificant difference was observed in the glandular weight and length of the right and left glands in Summer; the width of the right and left glands in Summer also appeared with insignificant difference ($P > 0.05$). On the other hand there was significant difference between the thickness of the right and left glands in Summer ($P < 0.05$).

Table 4: The weight and dimensions of the right lacrimal gland of camel in Summer:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Weight(g)	10	2.3	5.0	3.917	0.4028	0.9867	0.974
Length(cm)	10	3.2	6.2	4.567	0.2863	0.8588	0.738
width(cm)	10	1.5	2.9	2.089	0.1389	0.4167	0.174
Thickness (cm)	10	0.30	0.50	0.3667	0.02500	0.07500	0.006
Valid Number	10						

Table 5: The weight and dimensions of the left lacrimal gland of camel in Summer:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Weight(g)	10	2.3	4.4	3.383	0.3005	0.7360	0.542
Length(cm)	10	3.2	5.1	4.189	0.1933	0.5798	0.336
Width(cm)	10	1.3	2.5	2.056	0.1425	0.4275	0.183
Thickness (cm)	10	0.250	0.400	0.31389	0.01388	0.041667	0.002
Valid Number	10						



Text- Fig. 2: The glandular weight and dimensions of right and left lacrimal glands of camel in Summer.

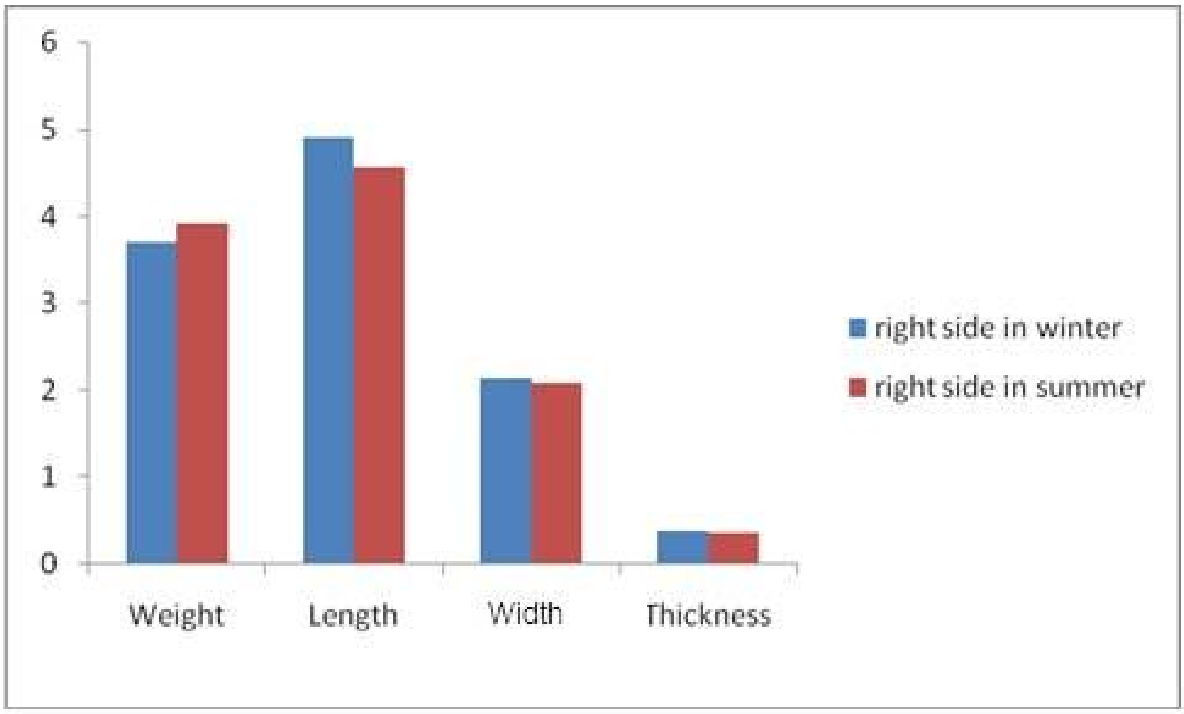
The comparative observations of the weight and dimensions of the right and left glands in Winter and Summer were shown in Text-figs. 3,4 and 5.

There was insignificant difference between the weight of the right glands in Winter and Summer and the weight of the left glands in Winter and Summer ($P > 0.05$).Insignificant difference was also observedbetween the length of the right glands in Winter and Summer and the length of the left glands in Winter and Summer ($P > 0.05$).

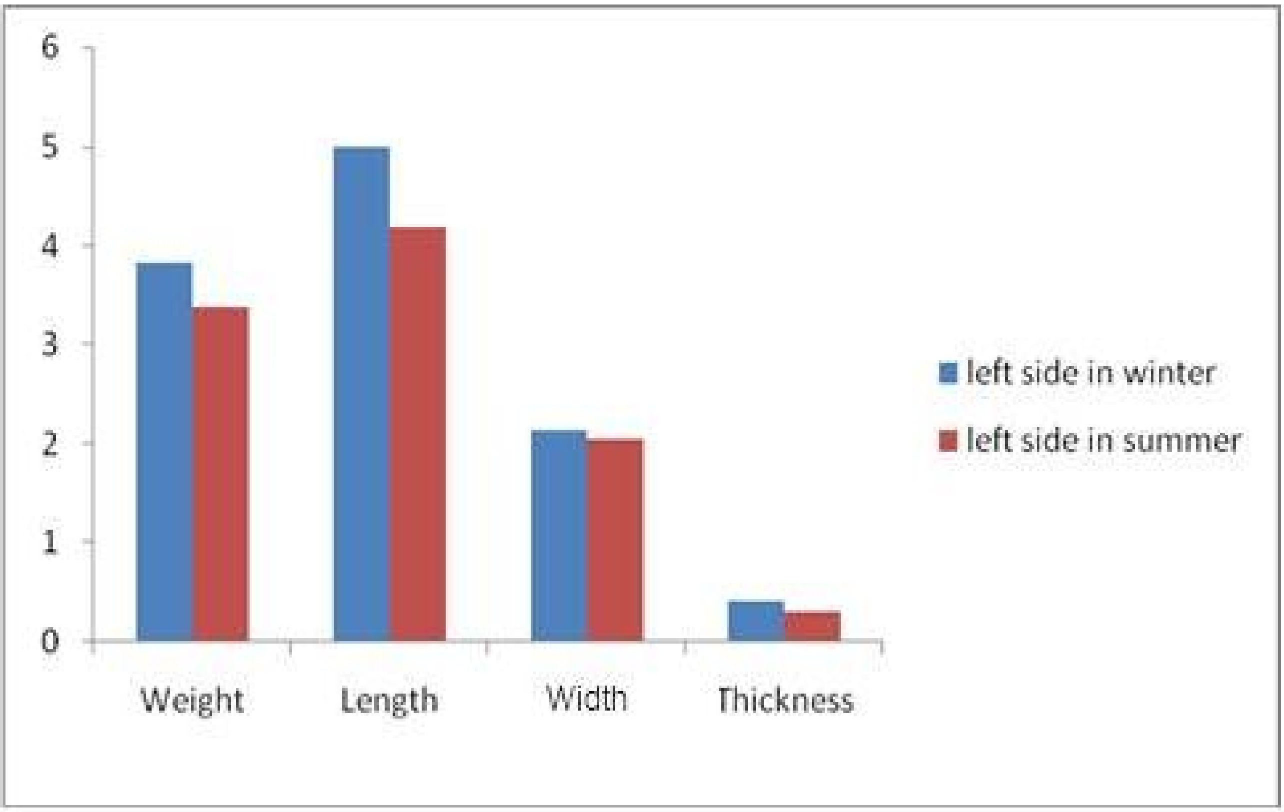
The statistical analysis showed insignificant differences between width of the right glands in Winter and Summer and the length of the base of the left glands in Winter and Summer ($P > 0.05$).

The thickness of the right glands in Winter and Summer was insignificantly different ($P > 0.05$). There was a significant difference in the thickness of the left glands in Winter and Summer ($P < 0.05$).

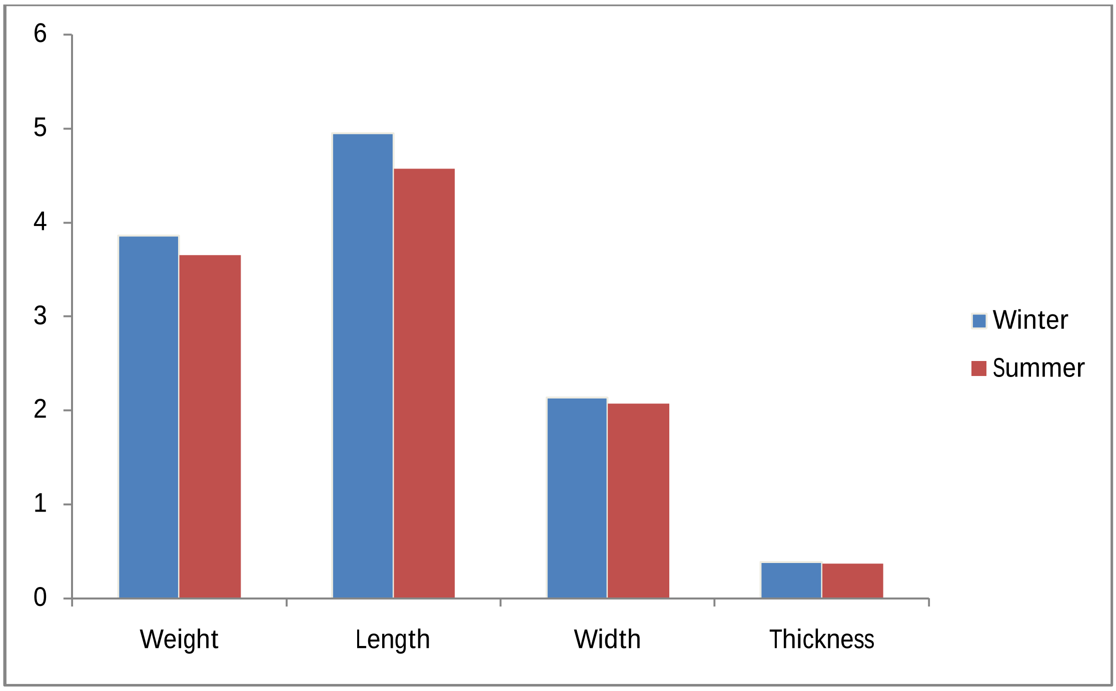
Text-fig 5 shows that there was aninsignificant increase in the glandular weight, length, width and thickness in Winter as compared to Summer.



Text- Fig. 3: The glandular weight and dimensions of the right lacrimal gland of camel in Winter and Summer.



Text- Fig. 4: The glandular weight and dimensions of the left lacrimal gland of camel in Winter and Summer.



Text-Fig. 5: The glandular weight and dimensions in Winter and Summer seasons.

3.1.4. The excretory ducts:

The main lacrimal gland contained two excretory ducts. The accessory lobe had its own duct. The ducts were black in colour; they leftthe main gland and accessory lobe at the ventral surface penetrating the periorbita to open into the superior conjunctiva (Figs. 2, 3).

3.1.5. The lacrimal ducts (Canaliculi):

No puncta lacrimalia were observed in the specimens investigated; there were two lacrimal ducts, superior and inferior, which started blindly near the medial borders of the upper and lower eyelids and opened into the lacrimal sac (Figs.4, 5).

3.1.6. The lacrimal sac:

The lacrimal sac 1.1-2cm long, was located in the lacrimal fossa of the lacrimal bone, it was rounded or funnel-shaped and large in the bottom (Fig. 5). The end of the sac was continuous with the beginning of the nasolacrimal duct.

3.1.7. The nasolacrimal ducts:

The nasolacrimalduct extended from the end of the lacrimal sac to the external opening (Figs. 5, 6). The duct was fenestrated and its length was 21-23cm. Its distal part was large and short and located in the osseous lacrimal canal of the lacrimal bone. After leaving the canal it was located in a groove on the medial surface of the maxilla, lateral to the ventral, dorsal, and middle nasal concha and medial to the nasal diverticulum.The external opening, 2-3cm long and 1-2cm in diameter, was in the form of a fissure or slit located ventral to the opening of the nasal diverticulum and dorsal to the Vomer bone (Fig. 7).

3.2. Histological observations:

There was no obvious seasonal difference in the histology of the lacrimal gland and its duct system.

3.2.1. The lacrimal gland:

The camel lacrimal gland was surrounded by a thick connective tissue capsule from which originated thin connective tissue septa (trabeculae) that penetrated the glandular parenchyma dividing the gland into lobes and lobules of different sizes and shapes (Fig.8).

The connective tissue capsule and septa consisted mainly of collagenous fibres with some reticular and elastic fibres (Figs.9, 10, 11). They were rich in adipose tissue, blood vessels (Fig.8) and nerve fibres (Fig.12). In the septa interlobular ducts and diffuse lymphocytes were also observed (Fig.15).

The parenchyma of the lacrimal gland consisted of serous secretary units (end pieces) in the form of alveoli and tubules (Figs.13, 14). Alveoli and tubules were lined by simple cuboidal cells arranged in one layer around a narrow lumen; their nuclei were spherical and mostly basal. The acini epithelium was relatively tall (pyramidal cells). The acini emptied in the tubules which were characterized by wide lumina and low cuboidal cells with central nuclei (Fig.13). Between the base of the epithelial cells and basal lamina of secretory units basket cells (myoepithelial cells) were found. They were few (2 or 3 around each secretory unit) and spindle shaped, with dark and flat nuclei. In some sections only their nuclei were visible around the secretory units (Fig.13).The tubules ended in sinuses that were irregular in shape with one layer of cuboidal cells and spherical nuclei (Fig.14).Common sinuses opened into the intralobular ducts that were lined by low simple columnar epithelium characterized by oval or spherical nuclei and wide lumina. Some sinuses were foundclustered between the lobules (Fig.14).

The interstitial connective tissue (interstitium) was loose containing diffuse lymphocytes around the acini, tubules and intralobular ducts (Figs.13, 14). The secretory units and intralobular ducts were also surrounded by a thin layer of reticular fibres (Fig.10).

The interlobular ducts were found outside the lobules in the connective tissue septa. Each duct started small, and then increased in size and lead to excretory ducts (Figs.14, 15, 16). Each interlobular duct was lined by stratified columnar epithelium rich in large goblet cells and surrounded by loose connective tissue containing diffuse lymphocytes, blood vessels and nerve fibres (Fig.15). Interlobular ducts which were drained into interlobal ducts that lead to excretory ducts.

3.2.2.Theexcretory ducts:

The excretory ducts were formed by the union of the interlobal ducts and emptied in the conjunctiva of the upper eyelid; they were lined by stratified columnar epithelium with many large goblet cells (Figs.16, 17). In the sub-epithelial layer lymphocytes and groups of mucous glands were observed. The surrounding connective tissue contained blood vessels, nerve fibres and adipose tissue.

3.2.3. The lacrimal ducts (Canaliculi):

The lacrimal duct was characterized by irregular mucosa and lined by stratified columnar epithelium with many large goblet cells (Figs.18, 19). It was surrounded by a lamina propria of thick and dense connective tissue with smooth muscles, irregular blood vessels and lymphocytes.

3.2.4. The lacrimal sac:

The lacrimal sac mucosa was somewhat irregular and was lined by two layers of columnar epithelium with a few goblet cells followed by a thin lamina propria of loose connective tissue rich in blood vessels (venous plexuses) (Figs.20, 21).

3.2.5. The nasolacrimal ducts:

The nasolacrimal ductswere divided into distal and proximal parts. The distal part was lined with stratified columnar epithelium with a few or without goblet cells and contained a sub-epithelial connective tissue rich in blood vessels (Fig.22). In its proximal part the duct was lined by stratified columnar epithelium with large and numerous goblet cells; the sub-epithelial layer was made up connective tissue consisting of rows of blood vessels, nerve fibre and mixed glands (Figs.24,25,26).Hyaline cartilage around the wall of the proximal part could also be observed in some sections(Fig.23).

3.3. Histometry:

3.3.1. Glandular tissue:

3.3.1.1. Glandular tissue in Winter:

The Winter histometric measurements of glandular epithelial height, secretory units diameter and interstitial tissue thickness are shown intable 6, Text-fig. 6.

The mean glandular epithelial height during the Winter season was 130.65 ± 12.06µm. The maximum value was 153.15µm, the minimum value was 104.71µm, the standard error was 3.81 and the variance was 145.45.

The mean glandular secretory units diameter was 276.83 ± 31.31µm; the maximum value was 335.66µm, the minimum value was 214.13µm, the standard error was 9.90 and the variance was 980.77.

The mean glandular interstitial tissue thickness was 230.31 ± 82.84µm; the maximum value was 427.88µm and the minimum value was 136.87µm, the standard error was 26.19 and the variance was 6863.67.

Table 6: The glandular epithelial height, secretory unitdiameter and interstitial tissue of thickness in Winter:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Height (µm)	10	104.7166	153.1592	130.6504	3.8137	12.06027	145.450
Diameter (µm)	10	214.1377	335.6666	276.8390	9.9034	31.3173	980.777
Thickness (µm)	10	136.8730	427.8880	230.3154	26.1986	82.8473	6863.678
Valid Number	10						

3.3.1.2 Glandular tissue in Summer:

The Summer histometric measurements of glandular epithelial height, secretory unit diameter and interstitial tissue thickness are shown in table 7 and Appendix.

The mean glandular epithelial height during the Summer season was 136.31 ± 9.38µm. The maximum value was 154.55µm, the minimum value was 119.69µm, the standard error was 2.96 and the variance was 88.12.

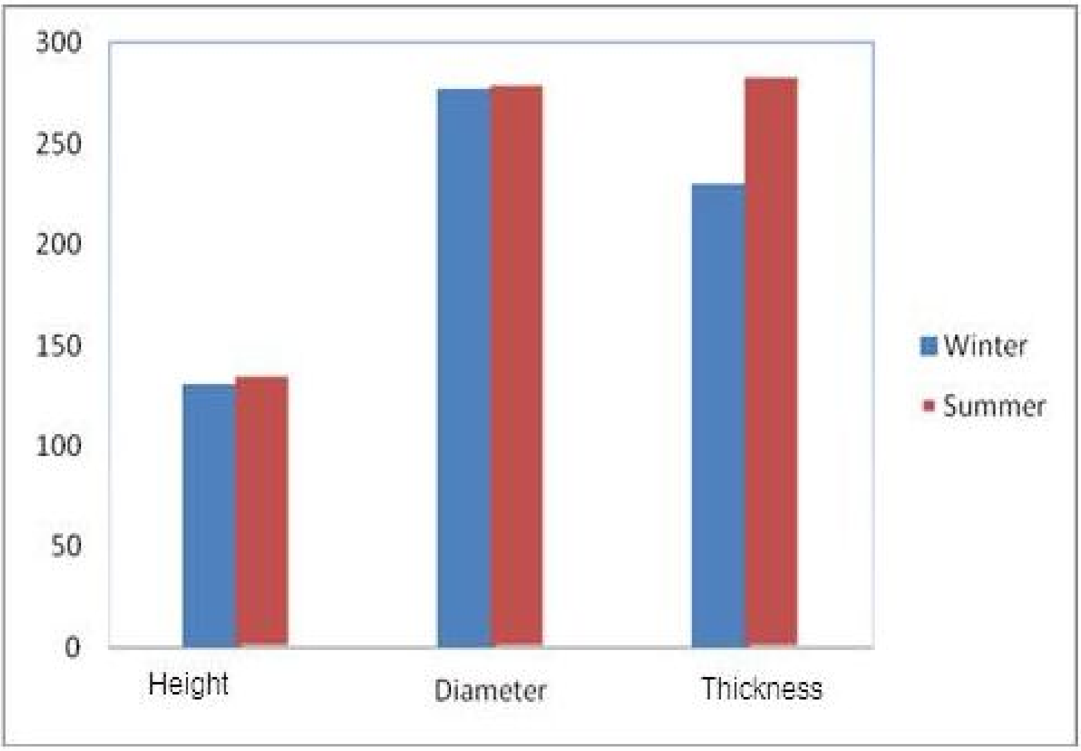
The meansecretory unit diameter was 280.02 ± 22.38µm; the maximum value was 315.25µm, the minimum value was 243.66µm, the standard error was 7.07 and variance was 501.23.

The mean glandular interstitial tissue thickness was 284.11 ± 25.04µm; the maximum value was 317.97µm, the minimum value was 235.45µm, the standard error was 7.91 and variance was 627.15.

No significant difference was observed in the glandular epithelial height, secretory unit diameter and interstitial tissue thickness between Winter and Summer (Text-fig. 6).

Table 7: The glandular epithelial height, secretory unit diameter and interstitial tissue thickness in Summer:

Descriptive Statistics							
	Sample Number	Minimum	Maximum	Mean		Standard Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Standard Error	Statistic	Statistic
Height(μm)	10	119.6910	154.5554	136.3114	2.9686	9.38755	88.126
Diameter (μm)	10	243.6666	315.2521	280.0289	7.0798	22.38835	501.239
Thickness (μm)	10	235.4577	317.9755	284.1155	7.9193	25.04306	627.155
Valid Number	10						


300
250
200
150
100
50
0
Height
Diameter
Thickness
Winter
Summer

Text- Fig. 6: The glandular epithelial height, secretory unit diameter and interstitial tissue thickness in Winter and Summer seasons.

3.4. Histochemistry:

3.4.1. Alcian blue-pH2.5 (AB-pH2.5) reaction:

In Winter the lacrimal gland showed negative or weak reaction in the acini and positive reaction in many tubules, intralobular and interlobular ducts (Fig.27). The excretory ducts appeared with a strongly positive reaction especially in the lumen, goblet cells and mucous glands (Fig.28).

In Summer the glandular acini showed Alcian blue (pH2.5) negative reaction (Fig.29). The reactions in tubules, intralobular and interlobular ducts were strongly positive.

The connective tissue capsule and connective tissue septa were alcian blue negative in Winter and weakly positive in Summer (Figs.27, 28, 29).

3.4.2. Periodic acid schiff's (PAS) reaction:

The secretary units in Winter contained strongly PAS positive granules in the acini, tubules, intralobular ducts and connective tissue septa(Fig.30). The interlobular and excretory ducts were very strongly PAS positive in their goblet cells and lumen (Fig.31). The surrounding connective tissue of the ducts was weakly PAS positive.

In Summer the PAS reaction was comparatively stronger, especially in the acini, tubules, intralobular ducts, interlobular ducts, excretory ducts and connective tissue septa (Figs.32, 33).

3.4.3 Alcian blue/ PAS sequence:

In Winter the glandular tubules and intralobular ducts were mainly PAS positive. A few cells were alcian blue positive. The acini were only PAS positive (Fig.34).

The interlobular and excretory ducts were only alcian blue positive in many goblet cells (Fig.35). A few cells were alcian blue and PAS positive. Their epithelial cells were mainly PAS positive (Fig.35).

While the acini were strongly PAS positive in Summer, the tubules and intralobular ducts were alcian blue and PAS positive and the reaction was generally slightly stronger (Figs. 36, 37). The interlobular ducts and excretory ducts showed strong alcian blue and PAS positive goblet cells (Figs.37, 38).

3.4.4. Alcian Blue/ Aldehyde fuchsin sequence:

In Winter the lacrimal gland showed strong aldehyde fuchsin positive reaction in the acini (Fig.39). The tubules, intralobular ducts, interlobular ducts and excretory ducts were strongly alcian blue positive (Figs.39, 40).

In Summer the secretory units contained mainly aldehyde fuchsin positive materials in the secretory units and duct system of the lacrimal gland (Fig.41).

3.4.5. Periodic acid Schiff's (PAS) before and after Diastase treatment:

Periodic acid Schiff's reagent staining in the different parts of the lacrimal gland showed no difference before and after diastase treatment in Winter and Summer seasons. This indicated the absence of glycogen.

FIGURES

Fig. 1: A photograph of fresh camel skull showing the left lacrimal gland (G), supraorbital and frontal processes (Z), cut supraorbital and frontal processes (ZC), eyelid (EL) and eyeball (E).

Fig. 2: A photograph of the fresh camel skull showing the supraorbital and frontal processes (Z), the lobulated gland (Arrowhead), excretory ducts (EX) and eyeball (E).

Fig. 3: A photograph of fresh right lacrimal gland with clear lobulation (Arrow), accessory lobe (AL) and excretory ducts (EX).

Fig. 4: A photograph of fresh camel skull with displaced eyeball (E) showing the lacrimal duct (LD) entering the lacrimal fossa (Arrow).

Fig. 5: A photograph showing the lacrimal ducts (LD), lacrimal sac (LS) and nasolacrimal duct (D) after being removed from the skull.

Fig 6: A photograph of the fresh left half of camel skull showing the course of the nasolacrimal duct (Arrows) along the medial surface of the maxillary bone (MB).

Fig 7: A photograph of fresh camel skull showing the opening of the nasolacrimal duct(Arrow) and opening of the nasaldiverticulum(DI).

Fig. 8: A section of the lacrimal gland showing the capsule (C), septa (S) lobes and lobules (LB), adipose cells (AC), excretory duct (EX). Note blood vessels (BV) in capsule and septa. H&E Stain (X100).

Fig. 9: A section of the lacrimal gland showing the connective tissue septa with collagenous fibres (Arrows), secretory units (U) and interlobular duct (IE).Van Giesson‘s Stain(X100).

Fig. 10: A section of the lacrimal gland showing reticular fibres (Arrows) in the capsule, septa and around the secretory units (U). Gordon and Sweet Silver Stain (X200).

Fig. 11: The glandular capsule and septa containing elastic fibres (Arrows).Van Giesson‘s Stain (X100).

Fig. 12: A section of the lacrimal gland showing the nerve fibre (N) in the capsule (C). H&E Stain (X200).

Fig. 13: A section of the lacrimal gland showing the acini (A), tubules (T), interstitium (Arrow), intralobular duct (IA), basket cells (B) and lymphocytes (L). H&E Stain (X1000).

Fig. 14: The parenchyma of the lacrimal gland with acini (A), tubules (T), interstitium (Arrows), septa (S), sinuses (SI), intralobular duct (IA) and interlobular duct (IE). H&E Stain (X400).

Fig. 15: Interlobular duct (IE) lined by stratified columnar epithelium with goblet cells (GC) and surrounded by loose connective tissue (CT) with lymphocytes (L) and blood vessels (BV). H&E Stain (X400).

Fig. 16: Excretory duct (EX) and interlobular duct (IE) lined by stratified columnar epithelium with goblet cells (GC); the surrounding connective tissue (CT) is rich in adipose cells (AC). H&E Stain (X100).

Fig. 17: A section of the excretory duct (EX)showing the connective tissue (CT) with mucous gland (MG), goblet cells (GC) and lymphocytes (L). H&E Stain (X1000).

Fig. 18: A section of the lacrimal duct (LD) lined by stratified columnar epithelium with goblet cells (GC) surrounded by dense connective tissue (CT) rich in blood vessels (BV). H&E Stain (X400).

Fig. 19: Higher magnification of (Fig.18) showing the lacrimal duct (LD) lined by stratified columnar epithelium with goblet cells (GC) surrounded by connective tissue (CT) rich in blood vessels (BV) and smooth muscle (M). H&E Stain (X400).

Fig. 20: A section of the lacrimal sac (LS) lined by two layerof columnar epithelium with goblet cells (GC) surrounded by vascular connective tissue (CT) rich in venous plexuses (VP). H&E Stain (X200).

Fig. 21: Higher magnification of (Fig.20) showing the lacrimal sac (LS) lined by stratified columnar epithelium surrounded by connective tissue (CT) and venous plexus (VP). H&E Stain (X1000).

Fig. 22: The distal part of the nasolacrimal duct (DD) lined by stratified columnar epithelium. Note the lymphocytes (L) in the surrounding connective tissue (CT). H&E Stain (X1000).

Fig. 23: The proximal part of the nasolacrimal duct (PD) showing hyaline cartilage (H) and blood vessels (BV) in the surrounding connective tissue. H&E Stain (X200).

Fig. 24: The proximal part of the nasolacrimal duct (PD) with many goblet cells (GC), blood vessels (BV) and nerve fibres (N). H&E Stain (X100).

Fig. 25: Higher magnification of (Fig.24) showing the proximal part of the nasolacrimal duct (PD) and goblet cells (GC). H&E Stain (X400).

Figure 26: The proximal part of the nasolacrimal duct (PD) with mixed glands (MI) in the surrounding connective tissue. H&E Stain (X100).

Fig. 27: The lacrimal gland in Winter showing negative or weak alcian blue reaction in the acini (A). The tubules (T), intralobular (IA) and interlobular (IE) ducts are alcian blue positive. Alcian Blue Stain (X200).

Fig. 28: A section of the lacrimal gland in Winter, showing strong alcian blue positive reaction in mucous gland (MG) and goblet cells (GC) of excretory ducts (EX) and large interlobular ducts (IE). Alcian Blue Stain (X100).

Fig. 29: The lacrimal gland in Summer showing the acini (A) with negative alcian blue reaction; tubules (T) and intralobular ducts (IA) and interlobular ducts (IE) are alcian blue positive. Alcian Blue Stain (X200).

Fig. 30: A section of the lacrimal gland in Winter showing strong PAS positive reaction in the acini (A), tubules (T), intralobular ducts (IA) and septa (S). PAS Stain (X200).

Fig. 31: The excretory ducts (EX) in Winter with strong PAS positive reaction in Goblet cells (GC) and lumen. PAS Stain (X400).

Fig. 32: The lacrimal gland in Summer showing strong PAS positive reaction in acini (A) and tubules (T). PAS Stain(X400).

Fig. 33: The lacrimal gland in Summer with strong PAS positive reaction in intralobular ducts (IA), interlobular duct (IE) and septa (S). PAS stain (X200).

Fig. 34: The lacrimal gland in Winter showing the tubules (T) and intralobular ducts (IA) with alcian blue positive (blue colour) and PAS positive (pink colour) reactions. The acini (A) are only PAS positive (pink colour). Alcian blue / PAS sequence Stain (X400).

Fig. 35: The interlobular duct (IE) in Winter showing alcian blue positive in many goblet cells (GC). Some other cells are both alcian blue and PAS positive (GC1). Alcian blue / PAS sequence Stain. (X100).

Fig. 36: The lacrimal gland in Summer with strongly PAS positive reaction in acini (A); the tubules (T) and intralobular ducts (IA) are strongly alcian blue and PAS positive. Alcian blue / PAS sequence Stain. (X400).

Fig. 37: The lacrimal gland in Summer showing strong PAS positive reaction in acini (A), the tubules (T) and intralobular ducts (IA) are strongly alcian blue and PAS positive. Septa (S). Alcian blue / PAS sequence Stain (X400).

Fig. 38: The excretory ducts (EX) in Summer showing strong Alcian blue positive goblet cells (GC). A few cells were PAS positive (GC1). Alcian blue / PAS sequence Stain (X200).

Fig. 39: The lacrimal gland in Winter showing the acini (A) with mainly aldehyde fuchsin reaction (purple colour); the tubules (T) and intralobular ducts (IA) are alcian blue positive (blue colour). Some secretory units are alcian blue and aldehyde fuchsin positive. Alcian blue /Aldehyde fuchsin sequence Stain (X200).

Fig. 40: The lacrimal gland in Winter showing intralobular ducts (IA), interlobular ducts (IE) and septa (S) with alcian blue (blue colour) and Aldehyde fuchsin (purple colour) positive reactions. Alcian blue /Aldehyde fuchsin sequence Stain (X200).

Fig. 41: The lacrimal gland in Summer showing acini (A),tubules (T) and excretory ducts (EX) with mainly strong Aldehyde fuchsin positive reactions (purple colour). Alcian blue /Aldehyde fuchsin sequence Stain (X200).

CHAPTER FOUR

DISCUSSION

4.1. Gross anatomy of the lacrimal apparatus:

4.1.1. Position and relationships of the lacrimal gland:

The present study shows that the camel lacrimal gland is located at the dorsolateral part of the eyeball. The same findings have also been stated by Abdalla *et al.* (1970), Ibrahim *et al.* (2006) and Mohammadpour (2011) in the same species and Chengjuan *et al*. (2008) in Bactrian camel. Awkati and AL-

Bagdadi (1971) claimed that the camel gland was located between the caudolateral part of the eyeball and the bony orbit. The lacrimal gland is also reported to be located at the dorsolateral part of the eyeball in other mammalian species including horse (Sisson and Grossman, 1975; Budras *et al*., 2009), cow (Budras *et al*., 2011), dog (Dyce *et al.,* 1996), Lori sheep (Abbasi *et al*., 2014), Philippine water buffalo (Maala *et al.,* 2007) and Iranian River Buffalo (Shadkhast and Bigham, 2010). According to the current study, the gland extends caudally between the supraorbital and frontal process of zygomatic bone and zygomatic process of the frontal bone; it rests on the eyeball and it is separated from the orbit by the periorbita. It has been mentioned that the dog gland lies chiefly under the orbital ligament (Bradley, 1948; Sisson and Grossman, 1975; Dyce, *et a*l., 1996) and under the zygomatic process of the frontal bone (Dursum *et al*., 2000; Aslan *et al*., 2005). Moreover, in the pig (Sisson and Grossman, 1975), horse (Bradley, 1946; Sisson and Grossman, 1975), ox (Dyce and Wensing, 1971; Sisson and Grossman, 1975) and small ruminants (Sinha and Calhoun, 1966) the gland is separated from the eyeball by the periorbita. Furthermore, in the horse (Sisson and Grossman, 1975) and ox (Sisson and Grossman, 1975; Diesem, 1968) the lacrimal gland is partially covered by fat. The gland has also been reported to be enclosed by the periorbita (Maala *et al*., 2007) in Philippine river buffalo, found deep to the orbital ligament (Zwingenberger *et al.,* 2014) in canines and between the tendons of the dorsal rectus and the lateral rectus muscles in Roe deer (Klećkowska-Nawrot *et al*., 2013).

4.1.2. Colour and shape:

In this study, the lacrimal gland is lobulated and it is very difficult to distinguish from the underlying orbital muscles. Similarly,(Bradley,1948; Sisson and Grossman, 1975; Dyce *et al*. 1996) in different mammalian species.

In the current study, the colour of the lacrimal gland is light red in dromedary camels. Sisson and Grossman (1975); Chengjuan *et al*. (2008); Ibrahim *et al*. (2006) and Alsafy (2010); Ross and Pawlina (2009); Abbasi *et al*. (2014) showed that the colour of the gland is light brown in the goat and donkey, Bactrian camels, dromedary camel, ratand Lori sheep consecutive. In dog the colour of the gland has been described as pale red (Bradley, 1948).Diesem (1968) and Maala *et al*.(2007) pink to red.Moreover, Sisson and Grossman (1975) pink colour in dog.Shadkhast and Bigham (2010) pale yellow in Iranian river buffalo and white to pale brown in rabbit (Al-Murshidi, 2015).

The findings of this study are in agreement with those of Ibrahim *et al*. (2006) and Alsafy (2010) that the shape of the camel lacrimal gland is determined by its position and relationships as it is convex dorsally and concave ventrally. In this study, the camel lacrimal gland is irregularly triangular. Similar findings have been observed in dromedary (Abdalla *et al.*, 1970; Ibrahim *et al*., 2006) and Bactrian camels (Chengjuan *et al*., 2008). According to Alsafy (2010), the shape of the lacrimal gland in dromedary camels is irregularly flattened, lobulated and elongated. On the other hand, Mohammadpour (2008, 2011) describes the dromedary camel gland as elongated and irregular.Whereas Awkati and Al-Baghdadi1 (971) claimed that it was flat. In the other domestic mammals the lacrimal gland is large in size, flattened and oval in goat and donkey (Sisson and Grossman, 1975; Alsafy, 2010), horse (Sisson and Grossman, 1975) and Iranian river buffalo (Shadkhast and Bigham, 2010). It has also been described as bipartite in cattle (Pinard *et al*., 2003).It was irregularly rounded to oval in sheep (Abbasi *et al*., 2014) and rabbit (Al-Murshidi, 2015). Furthermore, the gland is reported as flat in dog (Dyce *et al*., 1996; Sisson and Grossman, 1975), oval in canine (Zwingenberger *et al*., 2014). However,Maala *et al*. (2007) observed that lobulated and flattened in Philippine water buffalo and triangular in Roe deer (Klećkowska-Nawrot *et al.*, 2013).

In this study, the camel lacrimal gland is lobulated and has three irregular borders. On the other hand, the lacrimal gland in dromedary camels composed of three lobes, it is smaller in relation to the animal body weight and occasionally it consists of two lobes connected by a connective tissue sheath (Alsafy, 2010). Ibrahim *et al.*(2006) stated that the gland had two surfaces, three margins, and three angles.

4.1.3. Weight and dimensions:

According to the present study, the weight of the right lacrimal gland in the cold season is 3.70gm and that of the left lacrimal gland is 3.82g; in the hot season, the right lacrimal gland weights 3.9g and the left one weights 3.38gm. Ibrahim *et al.* (2006) reported that the weight of the right lacimal gland in camels ranged between 1.95and2.49gm. In small ruminants the gland weighs about 1.5gm (Sinha and Calhoun, 1966; Sisson and Grossman, 1975) and the mean volume incanines is 0.14 cm^3 (Zwingenberger *et al.*, 2014).

In the cold season, the current study shows that the right lacrimal gland of the camel is 4.90cm long, 2.14cm wide and 0.38cm thick, whereas the mean length of theleft lacrimal gland is 5.00cm, 2.13cm wide and 0.40cm thick. In the hot season the means right length is 4.56cm, the width is 2.08cm, the thickness is 0.36cm, the means of left lacrimal gland is 4.cm the length, is 2.05cm width and the thickness is 0.31cm, in the same animal is 55mm length, 20mm width. According to Ibrahim *et al.* (2006) variation of the lacrimal gland dimensions is associated with the animal size, age and species. In horse the gland is about 5cm transversely and 2.5-3cm sagittaly.Sisson and Grossman (1975), stated that the horse gland was 60mm long and 35mm wide.Diesem (1968) and Sisson and

Grossman (1975) reported that the ox gland is 2.5-2.8cm long. In small ruminants the gland measures 28mm long, 20mm wide and 5mm thick (Sinha and Calhoun, 1966; Sisson and Grossman, 1975). In canines the mean thickness of the gland is 9.36mm, the width is 4.29mm, and the length is 9.35mm (Zwingenberger *et al.*, 2014). In the Lori sheep the mean glandular weight, length, width and thickness are 1.48 ± 0.3 gm, 26.98 ± 0.37 mm, 20.11 ± 0.31mm and 3.58 ± 0.7mm, respectively(Abbasi *et al.*,2014).

Ibrahim and Abdalla (2007) found that there were insignificant differences between the right and left lacrimal glands of camel in the relative volumes occupied by the glandular and connective tissue. However, in camelthe left lacrimal gland of the same species is significantly greater than the right one (Mohammadpour, 2008). The left and right lacrimal glands of Awasi sheep are significantly wider than that of the black goat whereas the length and thickness show no significant differences (Daryuos and Ahmed, 2012b).In canine the lacrimal gland positively correlates with body weight (Zwingenberger *et al.*, 2014). According to Klećkowska-Nawrot *et al.* (2013) there is no correlation between the body size and the size of the lacrimal gland between the females and males in Roe deer. Shadkhast and Bigham (2010) stated that there were insignificant differences in the glandular length and width between both sexes in the Iranian river buffalo.Nevertheless, the literature reviewed revealed no seasonal work on the measurements of the weight and dimensions of the lacrimal gland in camels or any other mammalian species. The present study shows that there are insignificant differences in the weight, length width and thickness of the right and left glands in Winter as compared to Summer. In Summer; insignificant difference is also observed in the glandular weight and length of the right and left glands. The width of the right and left glands in Summer also appears with insignificant difference. On the other hand there is significant difference ($P < 0.05$) between the thickness of the right and left glands in Summer.Generally, the present study shows that the lacrimal gland in Winter season shows slight increase in weight and dimensions as compared to those in Summer.

4.1.4. The excretory ducts:

In this study the camel main lacrimal gland has two excretory ducts and the accessory lobe has its own duct; these ducts are small and black in colour and open into the superior conjunctiva. The number of camel excretory ducts has also been mentioned as two to four (Abdalla *et al.*, 1970), two (Awkati and Al-Bagdadi, 1971; Zaid and Ghadiri, 1991; Al-Ani, 1997) and three to four (Ibrahim *et al.*, 2006).The excretory ducts are two in goat and donkey (Alsafy, 2010), twelve to sixteen in horse (Sisson and Grossman, 1975), six to eight in ox (Bradley, 1946; Diesem, 1968; Sisson and Grossman, 1975) and five to six in pig (Sisson and Grossman, 1975).

The present study is in accordance with Sisson and Grossman (1975) in that the excretory ducts open into the superior conjunctiva. According to Ibrahim *et al.* (2006) the excretory ducts open anterior to the conjunctival fornix of the upper eyelid.

4.1.5. The lacrimal ducts(Canaliculi):

This study shows that there are no puncta lacrimalia in the camel and the two lacrimal ducts start blindly. Similar findings have been mentioned in the same species by Abdalla *et al* (1970), Saber and Makady (1987), Ibrahim *et al.*(2006) Sadegh *et al.*(2007), Alsafy (2010) and Al-Ani (1997). In other domestic animals the lacrimal ducts are two; one dorsal and one ventral and the lacrimal duct starts by an opening (punctum) close to the medial angle of the eyelid (Sisson and

Grossman, 1975). In rabbits there is a single large lacrimal duct and a single medial punctum (Rehorek *et al.* 2011).

4.1. 6. The lacrimal sac:

In this study, the camel lacrimal sac is round or funnel-shaped and it is located in the lacrimal fossa of the lacrimal bone. The lacrimal sac has also been described to be enclosed in the lacrimal fossa in the same species (Ibrahim *et al*., 2006; Alsafy, 2010; Sadegh *et al.*, 2007). According to Abdalla *et al*. (1970) the camel lacrimal sac is situated in the well-developed lacrimal fossa, which is located near the margin of the orbit (Dyce *et al.*, 1996). In the dog and horse, the sac occupies a funnel-shaped lacrimal fossa (Sisson and Grossman, 1975; Dyce *et al.*, 1996; Ibrahim *et al.*, 2006). The fossa is reported to be located outside the periorbita (Sisson and Grossman, 1975; Sadegh *et al.*, 2007; Bigham and Shadkhast, 2009). In the present study, the adult camel lacrimal sac is 1.1-2cm long. According to Ibrahim *et al*. (2006) it is 15mm transversely and 5mm sagitally. In the pig however, there is no lacrimal sac (Sisson and Grossman, 1975).

4.1.7. The nasoacrimal ducts:

In the present study, the camel nasolacrimal duct (21-23cm) is fenestrated and it extends from the end of the lacrimal sac to the external opening. In the same species the nasolacrimal duct is about 200mm long (Ibrahim *et al.,* 2006). The duct is about 25-30cm in horse (Sisson and Grossman, 1975). Budras *et al*. (2011) stated that the ox nasolacrimal duct was shorter than in the horse and it was almost straight. While Dyce *et al*.(1996) mentioned that the nasolacrimal duct was much relatively longer in dog, Sisson and Grossman (1975) reported that the duct was usually short in pig. Ibrahim *et al.*(2006) and Alsafy (2010) agree with the current study that the lacrimal duct in camels has many fenestrae in its wall distal to the osseous canal.

As stated in this study, the distal part of the nasolacrimal duct waslarge, short and located in the osseous lacrimal canal of the lacrimal bone; it leaves the canal and runs along the medial surface of the maxilla, lateral to the ventral, dorsal, and middle nasal concha and medial to the nasal diverticulum. According to Alsafy (2010) the duct was situated in the osseous lacrimal canal and thenleaves the osseous canal at the caudal portion of the ventral nasal meatus, ventral to the maxilloturbinate crest. The nasolacrimal duct runs in the osseous lacrimal canal rostrally, with a slight curve at its origin. It passes along the lacrimal, zygomatic and maxillary bones, through the maxillary sinus and then traverses the nasal cavity in a curved descending and S-shape fashion (Sadegh *et al.*, 2007). According to Budras *et al.* (2011) in the ox the duct opens near the nostril on the lateral wall of the vestibule of the nasal cavity and the orifice was placed on the medial side of the alar fold of the ventral turbinate and therefore not easily found (Sisson and Grossman, 1975). The long nasolacrimal duct orifice was located in the floor of the nostril in horse (Budras *et al.*, 2009). In the donkey the external opening of the nasolacrimal duct was located on the cutaneous wall of the nostril (Said *et al.*, 1977). In the pig it opens into the ventral nasal meatus at the posterior end of the ventral turbinate (Sisson and Grossman, 1975). However, the nasolacrimal duct was covered only by nasal mucosa and a thin connective tissue membrane on the lateral surface of ventral nasal concha in camel (Sadegh *et al.*, 2007) and Iranian river buffaloes (Bigham and Shadkhast, 2009).

The present study shows that, the external openingwas 2-3cm long and 1-2cm in diameter and was located ventral to the opening of the nasal diverticulum and dorsal to the Vomer bone. The location of the external openingof duct was similar to that stated by Ibrahim *et al.* (2006) who also state that the duct was10mm medial to the wider opening of the blind sac and it was difficult to detect. Sadegh *et al*. (2007) mentioned that the nasolacrimal duct opens on the lateral wall of the dorsal angle of the nostril and it was 2.6-0.41mm in diameter and about 11.5-0.5mm from the dorsal angle of the nostril where it was easily identified. In Iranian river buffaloes the distal opening of the nasolacrimal duct was 1.5 to 2 mm in diameter; it was located in the medial surface of the lateral nasal wall about 40 mm above the dorsal angle of the nostril (Bigham and Shadkhast, 2009).

4.2. Histology of the lacrimal apparatus:

4.2.1. The lacrimal gland:

The camel lacrimal gland in this study is surrounded by a thick connective tissue capsule, which penetrates the glandular parenchyma to form thin connective tissue septa, the septa divide the gland into lobes and lobules of different sizes and shapes. Similar findings have also been observed earlier in the same species (Mohammadpour, 2011; Ibrahim, 2015; Ibrahim and Abdalla, 2015). The present study shows that the connective tissue capsule and septa consist mainly of collagenous fibres with some reticular and elastic fibres, they were rich in adipose tissue, blood vessels and nerve fibres. This was in accordance with Dellmann and Brown (1981), Maala *et al*. (2007), Daryous and Ahmed (2012b) andIbrahim and Abdalla, (2015).

The present study shows that the lacrimal gland secretion is seromucous. The literature review also reveals that the mammalian lacrimal gland contains serous and mucous cells in Lori sheep (Abbasi *et al*., 2014), rabbit (Al-Murshidi, 2015) and in different animal species (Menakab and Puri, 2015). The acini were composed of two types of cells: serous cells and mucous in dog and sheep (Ross and Pawlina, 2009) and Roe deer (Klećkowska-Nawrot *et al*., 2013). The

Philippine Water Buffalo lacrimal glands were predominantly mucous (Maala *et al.*, 2007). However, the gland is described as serous in the cattle, horse and rabbit and mucous in the pig and goat (Ross and Pawlina, 2009). It has also been observed that the gland was serous in the cats and mixed in dogs (Sisson and Grossman, 1975; Ross and Pawlina, 2009). Furthermore, Dellmann and Eurell (1998) and Sisson and Grossman (1975) describe the gland as mucous in pig.

In this study and studies by Abdalla *et al.* (1970), Mohammadpour (2011) and Ibrahim and Abdalla (2015), the camel lacrimal gland was tubuloalveolar. However, Awkati and Al-Bagdadi (1971) reported that the camel gland was compound alveolar. In most domestic mammals the lacrimal gland was compound tubuloalveolar (Dellmann and Brown, 1981; Burkitt *et al.*, 1999; Bacha and Bacha, 2000). The gland was also described as compound tubuloacinar in some animals including sheep (Gargiula *et al.*, 1999), Philippine water buffalo (Maala *et al.*, 2007), Roe deer (Klećkowska-Nawrot *et al.*, 2013), European bison (Klećkowska-Nawrot *et al.,* 2015) and Bactrian camels Chengjuan *et al.* (2008).

The glandular secretory units in the current study were lined by tall simple cuboidal (pyramidal) cells which were surrounded by myoepithelial (basket) cells. This has also been mentioned in dromedary (Abdalla *et al.*, 1970; Awkati and Al-Bagdadi, 1971; Ibrahim and Abdalla, 2015) and Bactrian camels (Chengjuan *et al.*, 2008). The myoepithelial cells were also found in the gland of black goat and Awasi sheep (Daryous and Ahmed, 2012_b) and Roe deer (Klećkowska-Nawrot *et al.*, 2013). The present study shows that the intralobular duct was lined by low simple columnar epithelium. This is similarly,in the same species (Ibrahim and Abdalla, 2015).

In the present study the interlobular duct was lined by simple to stratified columnar epithelium. Similar findings have been stated by Sadegh *et al.* (2007). However, it was reported that in the dromedary camel the interlobular ducts were lined by stratified cuboidal or stratified columnar epithelium and some large ducts were lined by pseudostratified columnar epithelium (Ibrahim and Abdalla, 2015). According to Daryous and Ahmed (2012_b) the duct was lined with two layers of stratified cuboidal to stratified columnar epithelium in black goat and Awasi sheep (Abbasi *et al*., 2014). Al-Murshidi (2015) states that the rabbit interlobular ducts were lined with cuboidal and stratified cuboidal, pseudostratified columnar epithelium Abbasi*et al*. (2014). Furthermore, the interlobular ducts have stratified cuboidal epithelium (Sinha and Calhoun, 1966) and they are rich in large goblet cells and surrounded by loose connective tissue containing diffuse lymphocytes, blood vessels and nerve fibres (Sinha and Calhoun, 1966; Ibrahim and Abdalla, 2015).

4.2.2. The excretory ducts:

The excretory duct in the current investigation was lined by stratified columnar epithelium with many large goblet cells. In camel and Awasi sheep and black goat this is in agreement with that mentioned by Awkati and Al-Bagdadi (1971) and Daryous and Ahmed (2012b). The ducts were also described to be rich in melanin granules (Awkati and Al-Bagdadi, 1971; Ibrahim and Abdalla, 2015). In small ruminants, pig and rabbit the excretory ducts were lined with pseudostratified columnar epithelium with goblet cells (Sinha and Calhoun, 1966; Kuehnel and Scheele, 1979; Al-Murshidi, 2015). Moreover, the duct was lined with stratified cuboidal and pseudostratified columnar epithelium with some goblet cells in Lori sheep (Abbasi *et al.,* 2014). Asreported in the present work the camel excretory duct was surrounded by a connective tissue containing blood vessels, nerve fibres and adipose tissue, lymphocytes and groups of mucous glands. In the same species Ibrahim and Abdalla (2015) claimed that the excretory ducts were rich in lymphocytes and melanin granules and the lamina propria was madeup of dense irregular connective tissue containing mainly collagenous fibres, adipose tissue, some smooth muscle fibres and blood vessels. In sheep and goats the lamina propria was composed of dense collagenous connective tissue (Sinha and Calhoun, 1966).

4.2.3. The lacrimal ducts (Canaliculi):

The lacrimal ducts in this study are lined by stratified columnar epithelium with many large goblet cells.It was surrounded by a thick lamina,dense connective tissue with smooth muscles, irregular blood vessels and lymphocytes. Similarly, Abdalla *et al.* (1970) and Ibrahim (2003) stated the same findings except that it was rich in melanin granules. Some other mammalian lacrimal ducts were lined by stratified columnar epithelium (Dellmann and Eurell, 1998). In the horse the lining epithelium is squamous or columnar (Banks, 1993). In small ruminants it was squamous or cuboidal near the puncta and stratified columnar with a few goblet cells in other parts (Sinha and Calhoun, 1966).

According to the current study and those of Abdalla *et al.* (1970) and Ibrahim and Abdalla (2015) the camel lacrimal duct was lined by two layers of columnar epithelium with a few goblet cells. In the horse the lining epithelium was columnar (Sisson and Grossman, 1975) squamous or columnar epithelium (Banks, 1993).

4.2.4. The lacrimal sac:

The lacrimal sac was lined by stratified columnar epithelium with goblet cells in small ruminants (Sinha and Calhoun, 1966) and black goat and Awasi sheep (Daryous and Ahmed, 2012b). In the pig the lacrimal sac was lined with transitional epithelium (Sisson and Grossman, 1975).

The present investigation also shows that the lacrimal sac was lined by stratified columnar epithelium and its mucosa was somewhat irregular followed by a thin lamina propria of loose connective tissue rich in blood vessels (venous plexuses). This confirms the findings of Abdalla *et al*. (1970) and Ibrahim (2003). However, Abdalla *et al.* (1970) stated that the outermost layer was formed of a dense sheath of collagenous fibres parallel to each other and interposed with fibroblasts, whereas the superficial one contained irregular venous plexuses.The lamina propria is well-developed and highly vascular with cavernous plexuses in the horse (Dellmann and Brown, 1981) and small ruminants (Sinha and Calhoun, 1966).

4.2.5. The nasolacrimal ducts:

In the domestic mammals the epithelium of the nasolacrimal ductswas stratified columnar, except in the pig in which the epithelium was transitional (Dellmann and Brown, 1981), in the black goat and Awasi sheep the lacrimal ducts were also lined with stratified columnar epithelium cells with goblet cells (Daryous and Ahmed, 2012b), in pigs the nasolacrimal duct was lined with simple columnar epithelium (Dellmann and Eurell, 1998).

The present study shows that the nasolacrimal duct was lined by stratified columnar epithelium. It was divided into distal and proximal parts; the distal part has a few or no goblet cells, whereas the proximal part was rich in goblet cells. According to Abdalla *et al.* (1970) and Ibrahim (2003), the initial part of the nasolacrimal duct was lined with simple cuboidal or low columnar epithelium, without goblet cells; elsewhere the lining of the duct was stratified columnar epithelium with numerous goblet cells. In sheep and goat a few area of pseudostratified columnar epitheliumwith numerous goblet cells and the lamina propria of the distal part contains numerous seromucous glands and venous plexuses (Sinha and Calhoun, 1966).

4.3. Histometry of the lacrimal gland:

Seasonal histometric studies on the mammalian lacrimal apparatus seem to be lacking in the literature reviewed.

According to Daryuos and Ahmed (2012a) there were no significant differences in the measurements of glandular diameter, luminal diameter and epithelial height of the secretory units in the Awasi sheep and black goat.

Seasonal morphometic studies on the Harderian gland (orbital tear secreting gland of tetrapodes) of some reptiles and amphibians showed increased activity during the hottest months of the year; this has been determined by increased glandular secretory units and epithelial height in gecko (Baccari *et al.*, 2000) and frog harderian glands (Minucci *et al*. (1990). Similarly, in the present study, it could be suggested that there was increased secretory activities of the camel lacrimal gland in hot Summer season in which the epithelium of the glandular secretory units was insignificantly higher during the Summer season than that in Winter season. Insignificant increase was also observed in the secretory unit diameter and glandular interstitial tissue thickness in Summer as compared to that in Winter.

4.4. Histochemistry of the lacrimal gland:

The histochemiscal reactions of PAS, alcian blue and aldehyde fuchsin in the lacrimal apparatus have earlier been studied in the camel and different other mammalian species (Kühnel, 1968; Abdalla *et al.*, 1970; Awkati and Al-Bagdadi, 1971; Martin *et al.*, 1988; Ibrahim, 2003; Klećkowska-Nawrot *et al.*, 2013and

Ibrahim and Abdalla, 2015). According to the available literature, the present study was the first attempt dealing with the seasonal histochemistry of the lacrimal gland in domestic animals.

4.4.1. Alcian blue (pH2.5) reaction:

Martin *et al*. (1988) claimed that the tubular epithelium in the dog was Alcian blue (pH2.5) negative, whereas the predominant acinar cells were alcian blue (pH2.5) positive. In the ox some glandular cells were rich in alcian blue negative material (Kühnel, 1968). According to Abbasi *et al*. (2014) the mucous cells show high affinity to alcian blue staining in Lori Sheep. Klećkowska-Nawrot *et al*.(2013) stated that the Roe Deer glandular secretory cells were generally Alcian blue (pH2.5)negative. Moreover, the secretory acini show only a weak reaction to Alcian blue (pH1.0) stain and the ducts reaction was negative in Philippine water buffaloes Maala *et al*. (2007).

Positive alcian blue reaction has also been observed in the lacrimal secretory units of dromedary camels (Ibrahim and Abdalla, 2015), Bactrian camels (Chengjuan *et al*., 2008) and dog (Kühnel, 1968). According to Ibrahim and Abdalla (2015) the camel glandular tubules react strongly to alcian blue (pH2.5), whereas the reaction was weak or negative in the acini and connective tissue.

The present study shows that in Winter season the dromedary lacrimal gland reaction to alcian blue (pH2.5)was negative to weak in the acini and positive to strong in most tubules, intralobular ducts, interlobular ducts and excretory ducts. The reaction intensity was increased in the different glandular tissue in Summer season.

4.4.2. Periodic acid Schiff (PAS) reaction:

It has been stated that the ox glandular secretory cells contained PAS positive granules (Kühnel, 1968). In the dog the tubular epithelium was PAS negative, whereas the predominant acinar cells were PAS and Alcian blue (PH2.5) positive (Martin *et al.*, 1988). The secretory acini have also been found to react strongly to the periodic acid Schiff (Maala *et al.*, 2007) in Philippine water buffaloes. In Lori sheep the mucous cells show high affinity to PAS staining (Abbasi *et al.*, 2014). The glandular tubules and acini show a positive PAS reaction in Bactrian camels (Chengjuan *et al.*, 2008). In contrast, the secretory cells were generally PAS negative in Roe Deers but the apical parts of the excretory ducts demonstrate a slightly positive PAS reaction (Klećkowska-Nawrot *et al.*, 2013).

PAS positive reaction has been observed in most of the secretory units and ductal goblet cells of camel lacrimal gland (Ibrahim and Abdalla, 2015).

In the current study, the secretary units in Winter contained strongly PAS positive granules in the acini, tubules, intralobular ducts, interlobular, excretory ducts and connective tissue septa; the reaction in Summer was comparatively stronger, especially in the acini, tubules, intralobular ducts, interlobular ducts, excretory ducts and connective tissue septa.

4.4.3. Alcian blue/ PAS sequence:

The present study shows that the epithelial cells of the glandular tubules and intralobular ductswere strongly PAS positive, whereas Alcian blue reaction was observed in a few epithelial cells. However, the epithelial cells of the acini are only PAS positive. The present study also repots strong positive Alcian blue reaction in many goblet cells of the interlobular and excretory ducts and some cells show mixed Alcian blue and PAS reaction. The intensity of these reactions was observed to increase in Summer season as compared to Winter.

The aldehyde fuchsin Alcian blue sequence shows that the tubules were mainly alcian blue positive and the acini were mainly aldehyde fuchsin positive. In Summer however, the secretory units and duct system of the lacrimal gland contained mainly aldehyde fuchsin positive materials.

Dellmann and Brown (1981) reported that the mammalian lacrimal gland was mixed and it was predominantly serous. The gland has been found to be mixed in sheep (Gargiula *et al*., 1999; Abbasi *et al*., 2014) and Philippine water buffalo (Maala *et al*., 2007). According to Gargiula *et al*. (1999) the secretory portions consist of three cell types mucous, serous and seromuocus. However, the mucous cells were found to be dominant in pig (Kuehnel and Scheele, 1979) and Philippine water buffalo (Maala *et al*., 2007). In contrast, the gland was described as purely mucous in dog (Kühnel, 1968) and swine (Menakab and Puri, 2015) and purely serous in the European bison (Klećkowska-Nawrot et al., 2015) and Roe Deer (Klećkowska-Nawrot *et al*., 2013).

The lacrimal gland has also been described as seromucous in Bactrian (Chengjuan *et al*., 2008) and dromedary camel (Ibrahim, 2003; Ibrahim and Abdalla, 2015). It hasalso been found to be predominantly serous (Ibrahim and Abdalla, 2015). However, it has been roported as serous (Abdalla *et al*., 1970; Awkati and Al-Bagdadi, 1971). Mohammadpour (2011) concludes that the dromedary glandular secretory units contain acidic and neutral glycoproteins with different staining patterns.

The secreted granules were histochemically classified as neutral mucosubstances (PAS positive) or acidic mucosubstances alcian blue(pH2.5) negative(Schakelford and Klapper, 1962 and Culling, 1974). On this basis the current study suggeststhat the camel lacrimal gland contains both neutral and acidic mucosubstances.

In cattle and American bison the lacrimal gland histochemistry of mucosubstances reveals acidic and neutral glycoproteins with similar staining patterns (Pinard *et al*., 2003).

The histochemical findings of the present study indicate that the camel lacrimal gland was mixed (seromucous), but predominantly serous, because the acini, which form the majority of the glandular secretory units, were PAS positive and alcian blue(pH2.5) negative. Moreover, although most of the tubules are alcian blue (pH2.5) positive, some of them are negative to the same stain. It could also be suggested that the serous secretion of camel lacrimal gland increases during Summer season as compared to that in Winter because there was anincreasein the acinar cells activity. It should also be mentioned that some mucous secretion comes from the goblet cells in excretory and interlobular ducts.

CONCLUSION AND RECOMMENDATIONS

The slight increase in the weight and dimensions of the lacrimal gland in Winter season compared to that in Summer might be due to the increased drainage of the lacrimal fluid during Summer season which is needed for the washing and moistening of the anterior part of the camel eye during this hot and dusty season. Moreover, there is probably a decrease in the amount of the lacrimal fluid drained by the glandular duct system in Winter season which might also explain the increased weight and dimensions during this season.Similarly, it could be suggested that there is increased secretory and excretory activities of the camel lacrimal gland in hot Summer season which is indicated by the increased epithelial height during the Summer season than that in Winter season.

The lacrimal acidic mucins in Winter are mainly carboxylated and mainly sulphated in Summer.

The camel lacrimal gland is predominantly serous and the serous secretion increased during Summer season as compared to that in Winter. The predominant serous secretion is probably helpful in performing the washing and moistening functions in the anterior surface of the camel eye especially during hot season which is accompanied by many desert storms carrying sand and dust particles.

RECOMMENDATION:

Future work is needed to study:

- The seasonal ultrastructure of the cellular elements in dromedary camel's lacrimal gland.
- The seasonal immunohistochemistry of the plasma cells in dromedary camel's lacrimal gland.

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APPENDIX

Paired Samples Correlations of weight and dimensions of the right and left lacrimal gland in Winter:			
	N	Correlation	Sig.

Pair1	The right weight&the left weight	10	0.481	0.190
Pair 2	The right Length &the left Length	10	0.398	0.289
Pair 3	The right Length of base&the left Length of base	10	0.549	0.126
Pair 4	The right Thickness&the left Thickness	10	0.886	0.001

Paired Samples Test of weight and dimensions of the right and left lacrimal gland in Winter:

		Paired Differences					t	Df	Sig.(2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95%Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The right weight&the left weight	-.1222	0.9497	0.3166	-.8522	0.6078	-.386	9	0.709
Pair 2	The right Length &the left Length	-.1000	0.9233	0.3078	-.8097	0.6097	-.325	9	0.754
Pair 3	The right Length of base&the left Length of base	.0111	0.2472	0.0824	-.1789	0.2011	.135	9	0.896
Pair 4	The right Thickness&the left Thickness	-.02444	.06766	.02255	-.07645	.02756	-1.084	9	0.310

Paired Samples Correlations of weight and dimensions of the right and left lacrimal gland in Summer:				
		N	Correlation	Sig.
Pair 1	The right weight&the left weight	10	0.849	0.033
Pair 2	The right Length &the left Length	10	0.705	0.034
Pair 3	The right Length of base&the left Length of base	10	0.285	0.458
Pair 4	The right Thickness&the left Thickness	10	0.567	0.112

Paired Samples Test of weight and dimensions of the right and left lacrimal gland in Summer:									
		Paired Differences					T	DF	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The right weight&the left weight	0.5333	0.5317	0.2171	-.0246	1.0913	2.457	9	0.057
Pair 2	The right Length &the left Length	0.3778	0.6099	0.2033	-.0910	.8466	1.858	9	0.100
Pair 3	The right Length of base&the left Length of base	0.0333	0.5050	0.1683	-.3548	.4215	.198	9	0.848
Pair 4	The right Thickness& the left Thickness	0.052778	0.061802	0.020601	.005273	.100283	2.562	9	0.034

Paired Samples Correlations of weight and dimensions of the right lacrimal gland in Winter and Summer:				
		N	Correlation	Sig.
Pair 1	The right weight in Winter&The right weight in Summer	10	-.381	0.457
Pair 2	The right Length in Winter &the rightLength in Summer	10	-.129	0.741
Pair 3	The right Length of base in Winter&the rightLength of base in Summer	10	.189	0.625
Pair 4	The right Thickness in Winter&the rightThickness in Summer	10	.348	0.359

Paired Samples Test of weight and dimensions of the right lacrimal gland in Winter and Summer:									
		Paired Differences					T	DF	Sig.(2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The right weight in Winter & The right weight in Summer	0.0500	1.4195	0.5795	-1.4397	1.5397	0.086	9	0.935
Pair 2	The right Length in Winter & the right Length in Summer	0.3333	1.1916	0.3972	-.5826	1.2493	0.839	9	0.426
Pair 3	The right Length of base in Winter & the right Length of base in Summer	0.0556	0.4613	0.1538	-.2990	.4101	0.361	9	0.727
Pair 4	The right Thickness in Winter & the right Thickness in Summer	0.0155	0.08064	0.02688	-.04643	0.07754	0.579	9	0.579

Paired Samples Correlations of weight and dimensions of the left lacrimal gland in Winter and Summer:				
		N	Correlation	Sig.
Pair 1	The left weight in Winter&The left weight in Summer	10	.764	0.077
Pair 2	The left Length in Winter &the leftLength in Summer	10	-.065	0.868
Pair 3	The left Length of base in Winter&the leftLength of base in Summer	10	.341	0.369
Pair 4	The left Thickness in Winter&the leftThickness in Summer	10	.669	0.049

Paired Samples Testof weight and dimensions of the left lacrimal gland in Winter and Summer:									
		Paired Differences					t	DF	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The left weight in Winter&the left weight in Summer	0.4833	0.7548	0.3081	-.3087	1.2754	1.569	9	0.178
Pair 2	The left Length in Winter&the leftLength in Summer	0.8111	1.1274	0.3758	-.0555	1.6777	2.158	9	0.063
Pair 3	The left Length of base in Winter&the leftLength of base in Summer	0.0778	0.4055	0.1352	-.2339	0.3895	0.575	9	0.581

Pair 4	The left Thickness in Winter&the left Thickness in Summer	0.0927	.095822	0.031941	.019122	0.166433	2.905	9	0.020