REVIEW

Eur. J. Anat. 17 (3): 132-141 (2013)

Seasonal anatomical changes in the testis of the one-humped camel: a review

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SUMMARY

The male camel shows sexual activity during specific days of the year (breeding or rutting period). This is influenced by testicular morphology which varies with the season of the year. These anatomical changes in the camel testis are well established, but some morphometric variations in the seminiferous tubules are still dubious. This article reviews the basic concepts of male camel reproduction with special reference to the seasonal anatomical changes in the testis.

Key Words: Reproduction – Male camel – Season – Anatomy – Testis

INTRODUCTION

There are about 19.3 million camels in the world, of which 15 million are found in Africa and 4 million in Asia. Of this estimated world camel population, 17 million are one-humped (*Camelus dromedarius*) and 2 million two-humped camels (*Camelus bactrianus*). Out of African camel population, 70% are found in Somalia and Sudan, while Ethiopia, Chad and Kenya contain 12% camels. Pakistan, with one million heads, possesses about 23% of the camel population of Asian countries, and rates fourth in the world following Somalia (6.2 millions), Sudan (3.3 millions), and Mauritania (1.3 millions) (FAOSTAT, 2005). Improvement in camel production requires better knowledge of the physiology of reproduction at the molecular and cellular levels. The knowledge of reproductive anatomy and physiology will contribute to the application of a more efficient, environmentally optimal and economically reliable camel production by speeding up genetic evaluation and facilitating the use of breeding technologies.

REPRODUCTION IN THE ONE-HUMPED MALE CAMEL

The one-humped camel is a seasonal breeder, and shows sexual activity during specific period of the year known as rut or *musth*. Rut is characterized by remarkable changes in the macroscopic (Zayed et al., 2012; Pasha et al., 2011a, b; Hussain, 2010; Masood, 2007; Tingari et al., 1984; Ismail, 1982; Singh and Bharadwaj, 1978a; Abdel-Raouf and Owaida, 1974), microscopic (Abd-Elaziz, et al., 2012; Zayed et al., 2012; Hafez et al., 2011; Pasha et al., 2011b; Hussain, 2010; Abd-Elmaksoud et al., 2008; Masood, 2007; Zayed et al., 1995; Tingari et al., 1979b; Tingari and Moniem., 1979a; Singh and Bharadwaj, 1978b) and ultrasonographic (Pasha et al., 2011a; Hussain, 2010) morphology of genital organs, and results into a vivid increase in andro-

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Submitted: 17 January, 2013. *Accepted:* 27 March, 2013.

gen levels in blood, which directly affect the male behavior and its sexual desire. Spermatogenesis is continuous throughout the year, but this process becomes very much active during the rut season (Hussain, 2010; Elwishy, 1988; Osman and Ploen, 1986b; Tingari et al., 1984; Singh and Bharadwaj, 1978a; Abdel-Raouf et al., 1975).

ANATOMY OF THE CAMEL TESTIS

Macroscopic anatomy

The testes of the one-humped camel are ovoid, lie obliquely to the vertical axis, and are surrounded by a tough *tunica albuginea*. These are located in the scrotum close to the body in the perineal region. The parenchyma of mature camels is brown, and a longitudinal strand of mediastinum testes extending lengthwise through the center of the testis, and a lobule of seminiferous tubules are arranged radially around it (Pasha et al., 2011b; Degen and Lee, 1982). The size and weight of right and left testis are not significantly different (Pasha et al., 2011b; Ismail, 1982; Abdel-Raouf and Owaida, 1974). Testicular weight and dimensions (length, width, and circumference) increase with the age, reach their maximum values at 10-15 years of age, and then start decreasing slightly (Singh and Bharadwaj, 1978a). During the rutting season, and due to extensive development of interstitial tissue, it occupies a larger area in the testicular parenchyma as compared to seminiferous tubules; as a result, the weight and size of the testis increased significantly (Pasha et al., 2011b; Tingari et al., 1984; Ismail, 1982; Hussein, 1980). The testicular size and weight varies among different breeds of camels – the mean weights of Pakistani, Indian, Israeli, and Egyptian camels are depicted in Table 1 A and B.

The epididymis is situated on the dorsocranial border with the head curving on the cranial pole of the testis. Gross anatomically, it is subdivided into three parts: head, body and tail. However, histologically the epididymis of a camel is further subdivided into proximal, intermediate, and distal portions. The weight of epididymis (g) diverges from season to season; (spring: 26.83±2.21), (summer: 18.50±5.63), (autumn: 18.95±1.08), and (winter: 18.82±1.15) (Zayed et al., 2012). The ductus deference is coiled initially, but it becomes enlarged at the terminal portion, where it enters the urethra ventral to the prostate body. The diameter (µm) of epididymis varies from season to season, initial segment of epididymis (spring: 279.73±19.60, summer: 298.5±10.70, autumn: 301.01±22.90, winter: 293.41±3.43), middle segment of epididymis proximal part (spring: 285.4±4.42, summer: 276.12±7.86, autumn: 273.26±11.30, winter: 231.51±10.71), middle segment of epididymis intermediate part (spring: 290.31±14.50, summer: 221.4±7.86, autumn: 234.26±3.39, winter: 207.08±10.80), middle segment of epididymis distal part (spring: 352.34±16.10, summer: 262.83±6.97, autumn: 248.64±19.41, winter: 250.06±7.65), terminal segment of epididymis (spring: 392.05±22.41, summer: 328.52±10.11, autumn: 363.7±14.63, winter: 373.12±4.14) (Zayed et al., 2012). The length (mm) of head, body, and tail of the one-humped camel epididymis approximately ranges from (21-43), (59-94), and (19-36 mm) respectively (Masood, 2007).

Microscopic anatomy

Histologically testes are covered by the tunic comprised of dense irregular connective tissue with a deeply located tunica vasculosa and delicate septula testis. Lobuli testes are radially arranged around the mediastinum. In immature male camels, the seminiferous tubules are lined by peripheral spermatogonia, and contain many tall columnar Sertoli cells. Many clusters of small, inactive Leydig cells of 4-6 mm are present in the interstitial connective tissue among seminiferous tubules. While in mature dromedaries, large clus-

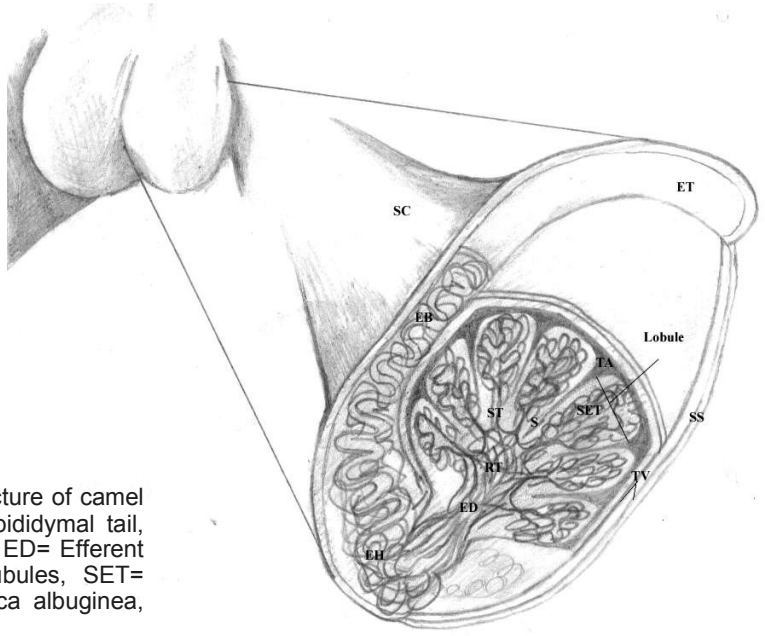

Fig. 1. Schematic diagram of anatomical structure of camel testis elaborating; Sc=Spermatic cord, ET=Epididymal tail, EB= Epididymal body, EH= Epididymal head, ED= Efferent ductules, RT= Rete testis, ST= Straight tubules, SET= Seminiferous tubules, S= Septula, TA= Tunica albuginea, TV= Tunica vaginalis, SS= Scrotal skin.

Table 1A. Age-wise changes in the testis weight of one-humped camels reported at different locations

Age (Years)	Location	Testes weight (g)		Authors
		Right	Left	
3 years	Israel	2.4	2.3	Degen and Lee (1982)
5 years	Israel	43.1	38.7	Degen and Lee (1982)
	Egypt	22	25	Abdel-Raouf and Owaida (1974)
4-7 years	Pakistan	80-142	85-144	Pasha et al. (2011b)
8 years	Israel	129.2	114.2	Degen and Lee (1982)
	Egypt	78.0	79.4	Abdel-Raouf and Owaida (1974)
9 years	Egypt	56.0	59.7	Abdel-Raouf and Owaida (1974)
10 years	Egypt	86.2	82.6	Abdel-Raouf and Owaida (1974)

Table 1B. Season-wise changes in the testis weight of one-humped camels reported at different locations

Location	Weight of testis (g)				Author
	Spring	Summer	Autumn	Winter	
Egypt	99.93	77.80	88.5	68.68	Zayed et al. 2012
Pakistan	LT: 123.47	LT: 93.21	LT: 85.73	LT: 144.13	Pasha et al. 2011b
	RT: 122.19	RT: 92.48	RT: 81.55	RT: 142.53	
India	-------	**4-8 years**:			Singh & Bharadwaj, 1978a
		RT: 56.2	RT: 58.8	RT: 70.8	
		LT:58.6	LT: 60.8	LT: 78.4	
		9-14 years:			
		RT: 146.5	RT: 162.17	RT: 186.33	
		LT: 159.83	LT: 168.17	LT: 194.66	
		16-20 years:			
		RT: 123.5	RT: 166.0	RT: 186.0	
		LT: 143.0	LT: 168.o	LT: 199.0	

RT= Right testis, LT= Left testis

ters of active, polyhedral, Leydig cells (9-14 mm) with prominent nucleolus, are found in the interstitial tissue. The tubuli recti and the rete testis are lined by a low cuboidal epithelium (Degen and Lee, 1982), while the ductuli efferentes are lined by an epithelium of varying height with tall ciliated and shorter non- ciliated cells. Like other animals, the seminiferous tubule of camels can be divided into three parts; the major portion of the tubule is highly coiled and is the site of sperm production, which is lined by many layers of spermatogenic cells and a single layer of Sertoli cells (Singh and Bharadwaj, 1980). The convoluted ends of the seminiferous tubules transit into tapering terminal segments, which join the straight tubules and lead to rete testis (Fig. 1). The straight tubules are divided into three portions: a receptacle, a narrow main part, and a wide distal part, which are lined by simple cuboidal to columnar cells (Osman and Ploen, 1986b; Singh and Bharadwaj, 1980). The extratesticular rete testis joins to form a sac, from which 6-7 convoluted ductuli efferentes originate. Later on, these join to form the ductus epididymis. The epithelium of ductuli efferentes changes from simple cuboidal to columnar cells with alternating groups of high columnar ciliated and low columnar non-ciliated cells. The ductus epididymis is lined by pseudostratified epithelium, with taller cells having stereocilia, which gradually decrease in height from head towards the tail (Zayed et al., 2012; Hafez et al., 2011). The epithelial height (µm) of different segments of the epididymis differs from one season to another: initial segment (spring: 76.95±6.50, summer: 88.96±8.28, autumn: 94.75±6.70, winter: 86.19±4.90), middle segment proximal part (spring: 51.93±2.21, summer: 49.48±0.96, autumn: 55.29±4.50, winter:

55.63±3.57), middle segment intermediate part (spring: 44.18±2.77, summer: 47.03±2.22, autumn: 50.57±1.45, winter: 47.02±2.03), middle segment distal part (spring: 53.49±3.57, summer: 51.28±1.64, autumn: 50.53±2.33, winter: 46.15±2.05), terminal segment (spring: 44.17±2.03, summer: 43.32±1.17, autumn: 47.06±3.42, winter: 46.17±1.18) (Zayed et al., 2012). There are five different types of cells in the epithelium of the epididymis of the camel: principal, basal, halo, apical and dark cells. The principal cells are the main components of the epithelial lining with ultrastructural features characteristics of absorption in the proximal and intermediate parts of the middle segment, and secretion in the terminal segment. Basal cells are relatively simple in structure, being characterized by a general paucity of organelles. Halo cells are with a large nucleus and scanty cytoplasm. Apical cells have scanty mitochondria and possess a small Golgi complex. Dark cells are similar to the adjacent principal cells. They are considered as dying principal cells with the variation in their cytoplasmic density interpreted as intermediate stages prior to death (Tingari, 1989). Morphometric changes in the testes of the *Camelus dromedarius* during different seasons of the year are presented in Table 2.

Ultrastructural anatomy

The tunica albuginea of the camel testes is composed of collagenous and a few elastic fibers. Isolated bundles of the smooth muscle fibers are present in the capsule. The mediastinum testes and its radiating septula into the parenchyma also consist of mainly collagenous and a few elastic fibers. The testis of camel has three functional compartments, like other mammals, including the interstitium (Mainly Leydig cells, blood vessels, lymph vessels); the other two compartments are within the seminiferous tubules, namely basal and adluminal made up as a result of tight junctions between the adjacent Sertoli cells (Osman and Ploen, 1986 a). The interstitium contains blood, lymph vessels, nerves, fibroblasts, collagen fibers, free cells and mainly Leydig cells (Abd-Elaziz, et al., 2012; Pasha et al., 2011b; Zayed et al., 1995; Singh and Bharadwaj, 1978a). Leydig cells of camel are polygonal in shape, having abundant tubular smooth endoplasmic reticulum (SER), well developed Golgi complex in many parts of the cytoplasm, a modest number of mitochondria, occasional lipid droplets, lysosomal bodies, microfilaments, peroxisomes, and few patches of rough endoplasmic reticulum and glycogen particles, being the principal source of testicular androgens (Bedrak et al., 1983; Tingari and Moniem., 1979a). Delicate septa originated from tunica albuginea divide the testicular parenchyma into a number of lobules, which are radially arranged around the mediastinum of the testis. The boundary tissue of the seminiferous tubule is comprised of three layers: inner fibrous, inner cellular and outer cellular. The seminiferous tubule of a camel can be divided into three zones. The major, highly coiled, portion is the site of sperm production, comprised of spermatogenic cells layers and a single basal layer of the Sertoli cells, this coiled portion ends in straight tubules which leads to the rete testis. The camel Sertoli cells are irregular, tall columnar extending from the basal lamina to the lumen of the seminiferous tubules. The nuclei are very irregular in outline, having deep indentations, located in the basal portion of the cell with prominent nucleolus (Pasha et al., 2011b). The chromatin material is uniformly fibro-granular with low electron density.

Table 2. Light microscopic changes in the seminiferous tubules and testis of the one-humped camel during different seasons of the year

Parameters	Seasons			
	Winter	Spring	Summer	Autumn
RTV (cm^3)	135.48±1.48^{A}	116.15±0.82^{B}	87.91±1.14^{C}	77.52±0.55^{D}
LTV (cm^3)	137.00±1.28^{A}	117.37±1.01^{B}	88.60±1.26^{C}	81.50±1.06^{D}
RTW (g)	142.53±1.56^{A}	122.19±0.87^{B}	92.48±1.20^{C}	81.55±0.58^{D}
LTW(g)	144.13±1.35^{A}	123.47±1.07^{B}	93.21±1.33^{C}	85.73±1.12^{D}
VST (cm^3)	1307.5±12.45^{B}	1221.2±12.25^{C}	1336.9±22.82^{B}	1428.7±17.47^{A}
STD(µm)	166.50±1.59^{B}	155.17±1.62^{C}	169.83±2.88^{B}	181.50±2.26^{A}

Means sharing similar letters in a column are statistically non-significant (P>0.05). RTV=Right testis volume, LTV= Left testis volume, RTW= Right testis weight, LTW= Left testis weight, VST= Volume of seminiferous tubules, STD= Seminiferous tubules diameter (Pasha et al., 2011b).

The Sertoli cells are conjoined by occluding junctions which divide the seminiferous tubule into basal and adluminal compartments (Osman and Ploen, 1986b).

EFFECT OF CLIMATE AND SEASON ON THE MORPHOLOGY OF THE TESTIS

Male one-humped camels have a distinct and constrained breeding season, which varies with the geographic location and genetic makeup. Spermatogenesis is recorded at its highest during the breeding season. Research workers are in agreement that season has an evident effect on the morphology of the testicular tissue and the activity of Leydig cells in camel (Abd-Elaziz, et al., 2012; Pasha et al., 2011b; Tingari et al*.,* 1984; Friedlander et al*.,* 1984). These seasonal changes are further influenced by ecological location, management and climatic conditions (Pasha et al., 2011b; Lodge and Salisbury, 1970). Male camels have low mating efficiency throughout their reproductive life. Puberty is dependent on the capacity of the testicular endocrine cells to produce sufficient levels of androgens to ensure the maturation of the reproductive system, development of the libido, and the production of a required viable number of sperms from the tubules. Timing of puberty could be assessed by evaluating testicular weights and histological changes associated with spermatogenesis in the testis (El-Agawany et al*.,* 1998; Abdel-Rahim, 1997).

Seasonal light microscopic changes

The testicular weight and size increase significantly (P<0.01) during the breeding season of the camel (Pasha et al., 2011b; Zeidan et al., 2001). The testicular size reflects the spermatogenic activity, which is directly correlated with the testosterone concentration and sexual behavior in seasonal breeders (Lincoln, 1979). In seasonal breeder mammals the spermatogenic activity and sexual behavior are highly dependent on season (Chemineau et al., 2007). The testicular weight tend to be heavier, interstitial connective tissue contents increase, and the diameter of seminiferous tubule become smaller in the period of cooler months or the rutting season (November to March) than in the summer months or non-breeding season (May to September) (Abd-Elaziz, et al., 2012; Pasha et al., 2011b; Tingari et al., 1984). Ismail (1982) documented that one reason of low sperm production rates in camel testes compared with other farm animals may be due to lower contribution of the seminiferous tubules in the parenchymal weight due to the abundant interstitium. The interstitial connective tissue contents increase during the rutting season of camels (Zayed et al., 2012; Pasha et al., 2011b; Zayed et al., 1995; Tingari et al., 1984). The percentage area occupied by the seminiferous tubule remain high in the summer and autumn and low during the winter and spring (Pasha et al., 2011b). The percentage of the seminiferous tubule/interstitium endures high during the summer and lower during the rutting period (spring and winter). So it is obvious from these findings that the interstitial tissue occupies a larger area as compared to the seminiferous tubule during the breeding season of the camel. Tingari et al., 1984 and Zayed et al., 1995 showed that the ratio of seminiferous tubule to interstitial tissue was greater in the summer than

Table 3. Mean weight of testis, diameter of seminiferous tubules and the ratio of seminiferous tubule area to interstitial tissue area of sexually mature camels in Saudi Arabia (Tingari et al., 1984)

Months	Testis weight (g)	Diameter of seminiferous tubules (μm)	Ratio of area of seminiferous tubule/ interstitial tissue
January	98.1±29.8	155.6±11.8	0.807±0.043
February	85.6±15.8	163.1±7.0	0.875±0.141
March	95.3±16.6	152.8±11.2	0.929±0.087
April	82.1±36.7	152.6±12.0	1.555±0.034
May	63.1±1.1	171.5±12.8	1.575±0.244
June	57.1±16.7	162.7±11.4	1.364±0.286
July	77.0±11.7	179.1±15.4	1.395±0.185
August	74.2±26.9	177.6±6.6	1.174±0.055
September	85.5±32.4	202.3±7.9	1.058±0.02
October	92.5±29.8	170.1±2.0	1.216±0.200
November	95.7±36.6	170.2±8.4	0.616±0.199
December	109.2±34.3	162.9±7.1	0.757±0.135

in the winter (breeding season). The boundary tissue investing the seminiferous tubule was thicker during the period from June to August than in the period from November to January, when the spermatogenic activity was at its peak. During the rutting season, due to the extensive development of the interstitial tissue, it occupies a larger area in the testicular parenchyma as compared to the seminiferous tubules, as the weight and size of the testis increased significantly (Pasha et al., 2011b; Tingari et al., 1984; Ismail, 1982; Hussein, 1980). This increase in the interstitial tissue and decrease in the seminiferous tubule diameter during the breeding season of camels is a different trend as compared to other seasonal breeders. Contrary to this, some research workers reported that the seminiferous tubule diameter increased during the rutting or breeding season of camels (Volcani, 1953; Novoa, 1970; Abdel-Raouf et al., 1975), like jungle crows (Islam et al., 2010), mice (Sicher and Bradshaw, 1967), Arabian rams (Dorostghoal et al., 2009) and grey-headed fruit bats (McGuckin and Blackshaw, 1987). The weight of the testes, the volume of the interstitial tissue, ultra-structural changes in the Leydig cells, and the rate of testosterone synthesis are correlated, since both increase during the mating/breeding season, and both diminish during the non-breeding season of camels (Zayed et al., 2012; Pasha et al., 2011b; Hussain, 2010; Zayed et al., 1995; Friedlander et al., 1984; Tingari et al., 1984; Yagil and Etzion, 1980) and boars (Rottner and Claus, 2009). There is a positive correlation between the testosterone concentration, copulation time and volume of semen ejaculated in camels. So there is direct relation between the increase in interstitial connective tissue, size of testis, concentration of testosterone, semen production, copulation time, and sexual libido of camels.

Seasonal ultrastructural changes

The interstitial tissue is composed of Leydig cells and a network of reticular fibers. These cells increase in volume in the rutting period from December to March, and reduce in volume in non-rutting period from April to November. The seminiferous tubules are 113-250 µm in diameter, and are lined by many layers of spermatogenic cells and a single layer of Sertoli cells. The spermatogenesis is a continuous process throughout the year, particularly in the camels between 4-15 years of age (Singh and Bharadwaj, 1978a). The seasonal month wise variations in the testis weight, diameter of seminiferous tubules and the ratio of seminiferous tubule area to interstitial tissue area of sexually mature Arabian camels is depicted in Table 3. The intertubular tissue occupy a comparatively large portion of the camel testis ranging from about 24% in autumn to about 39% in spring. The volume percentages of the different intertubular tissue constituents, namely Leydig cells, blood vessels, lymph vessels and various connective tissue components, also display clear seasonal changes. Early in winter, the intertubular tissue is richly vascularized by blood vessels (18% of intertubular volume), whereas lymph vessels constitute only about 3%. In spring, an immense expansion of lymph vessels occurs (Up to 10% of intertubular tissue) without any change in the blood vessels. While the Leydig cells constitute only about 19% of total in the spring. In summer, the vascular compartment occupies nearly the same volume as in early winter, but with less blood and more lymph vessels. The Leydig cells volume percentage markedly increase (39.3%) as compared to the spring. In the autumn, blood and lymph vessels occupy lowest volume percentages (12% and 2.5% respectively), and Leydig cell volume also decreases as compared to the summer (Zayed et al., 1995). During the non-breeding season, the Leydig cells become inactive, which is obvious with the ultrastructural studies; they become smaller and separated by abundant matrix comprised mainly of collagen fibers and fibroblasts (Pasha et al., 2011b; Friedlander et al., 1984; Tingari et al., 1984). During the mating season, a reduction of the tubular smooth endoplasmic reticulum (SER) and proliferation of condensed SER corresponds to the relatively high rate of testosterone synthesis. During the non-mating season, there is a drastic reduction of the smooth endoplasmic reticulum and proliferation of myelin figures within the Leydig cells, which disrupt at the end of their differentiation (Pasha et al., 2011b; Friedlander et al., 1984). The interstitial cells of the camel testis are polygonal in shape, with abundant smooth endoplasmic reticulum occurring as a network of tubules. There are a moderate number of mitochondria with predominantly lamellar cristae, and dense intramitochondrial granules. Lipid droplets vary in number from cell to cell. During the non-breeding season, these cells possess abundant lipid droplets, large lysosomal bodies together with narrow cisternae of SER, i.e. the features of inactivity. Maximal activity is seen during the rutting season correlated with the seminiferous epithelium and the accessory sex glands (Tingari and Moniem, 1979a).

Seasonal ultrasonographic changes

Ultrasound is a non-invasive and safe technique, which has been used for the diagnosis of several types of testicular neoplasms, cystic lesions, orchitis and abscesses in the human medicine. Ultrasonography was established in 1990 as a practical tool for animal production. In Veteri-

nary medicine it has been used mostly for the pregnancy diagnosis and for monitoring the ovarian lesions and morphological changes in the female reproductive tract. The ultrasound technique has been declared as a proficient and dexterous tool for the examination of camel testes and epididymis (Derar et al., 2012; Pasha et al., 2011a). The normal ultrasonographic structure of camel testis resembles other mammals, and season has an apparent effect on the testicular size, echogenicity of the testicular parenchyma and epididymis in one-humped camels (Pasha et al., 2011a). In ultrasound imaging, the parenchyma of testes appear homogenous and moderately echogenic with a coarse medium echo-pattern, independently of the axis or surface used during scanning in camels (Pasha et al., 2011a), bulls (Ali et al., 2011), rabbits (Aksoy et al., 2009), rams (Gouletsou et al*.,* 2003), goats (Ahmad et al*.*, 1991) and humans (Leopold et al., 1979). The mediastinum testes emerge as centrally located hyperechoic line in camels (Derar et al., 2012; Pasha et al., 2011a), rams and goats (Ahmad et al., 1991), dolphins (Brook et al., 2000), and boars (Clark et al., 2003). Of the three segments of epididymis, head and body of the epididymis could not be imaged regularly, while the tail is the only part which could be consistently scanned in the camels (Pasha et al., 2011a), goats and rams (Ahmad et al., 1991), but the tail could not be defined ultrasonically in humans (Leopold et al*.,* 1979). This may be due to the anatomical topographic orientation of the testicles. The tail of the epididymis appears as less echoic than parenchyma with a heterogeneous structure. The scrotal septum appears as a highly echogenic line between the testicles when testes are scanned laterally. It also contains numerous un-echoic rounded or loop-like areas, representing the small spermatic veins. The tunica albuginea appears as a hyperechoic line which surrounds the parenchyma, thin anechoic line representing fluid in the cavity found between the tunica albuginea and surrounding vaginal tunics, fascia and scrotal skin (Pasha et al., 2011a; Clark et al., 2003). Season has obvious effect on the echogenic appearance of the camel testis. During the breeding season (winter and early spring), there is significant increase in the volume of interstitial contents, activity of the tubular germ cells, and increase in the mature germ cells (Singh and Bharadwaj, 1978a; Zayed et al., 1995). As echogenicity related to the activity of the germ cells of seminiferous tubule and presence of increased number of mature germ cells (Evans et al., 1996), the testicular parenchyma appeared as more echogenic during the breeding season of the camel (Pasha et al., 2011a).

SPERMATOGENESIS IN CAMELS

In one-humped camels, the cycle of the germinal epithelium is divided into eight stages with different cellular characteristics. The spermatogonia are located towards the basal lamina of the seminiferous tubules: these are classified as typical spermatogonia type A, type B and intermediate. Spermatogonia type A are large, flattened cells with oval nuclei, having large area of contact with the basal surface and conjoined with the neighboring Sertoli cells. The nucleolus is an occasional characteristic of these cells. The cytoplasm has few organelles, including rough endoplasmic reticulum, mitochondria, ribosomes and polyribosomes. The spermatogonia type B are smaller than type-A, round in shape, and have a spherical nucleus with less uniform chromatin material. The intermediate type of spermatogonia has variable size and shape of cell as well as of nucleus. The primary spermatocytes are round in shape and present away from the basal lamina during the Leptotene stage of the cell division (Singh and Bharadwaj, 1978b). During the Zygotene stage, the primary spermatocytes have more cisternae of endoplasmic reticulum; the cristae of mitochondria start to dilate. The synaptonemal complexes appear between the pair of chromosomes in the nucleus. In the pachytene stage, the mitochondria become grouped with dilated cristae. The quantity of endoplasmic reticulum increases, and is found in the form of long cisternae. The first and second meiotic divisions cannot be distinguished morphologically. During the final phase of meiosis, ungrouped mitochondria are distributed throughout the cell. The secondary spermatocytes are smaller in size with homogenous nucleus. Abundant endoplasmic reticulum is found in the cytoplasm of secondary cells. Spermiogenesis is the process by which newly formed spermatids differentiate into individual testicular spermatozoa, which are divided into Golgi, Cap, early acrosome, mid acrosome, late acrosome, transition and maturation phase (Osman and Ploen, 1986; Singh and Bharadwaj, 1978a).

Effect of seasons on spermatogenesis

Spermatogenesis is a continuous process taking place throughout the year in the camel but with distinctive seasonal variations. The period of utmost activity is reported to be February to April in Israel (Volcani, 1957), March to May in Egypt (Abdel-Raouf et al., 1975), and November to February in Saudi Arabia (Tingari et al., 1984). The spermatogenic activity markedly increases during the months of November, December and January, while it becomes moderate from the month of April onwards. Cytoplasmic vacuoles and exfoli-

ated cells become more numerous and larger in the lumina of seminiferous tubules during the months of June, July and August. In September, spermatogenesis again appears to be activated. The Sertoli cells appear normal throughout the year (Tingari et al., 1984). However, remarkable morphometric and ultra-structural changes have been observed in the sertoli and leydig cells during the breeding season of camels, which indicate the activity of the cells during rutting (Abd-Elaziz, et al., 2012; Pasha et al., 2011b; Friedlander et al., 1984). These seasonal changes in the anatomy of testis, which result into vibrant spermatogenic activity, may probably be related to environmental and ecological variations, season, age, breed, and management system of the specific area under investigation.

CONCLUSION

The seasonal anatomical changes (macroscopic, microscopic, ultrastructural, and ultrasonographic), in the camel's testis are well established. However there is dissension about the seasonal changes in the diameter of seminiferous tubules of camel: a group of researchers (Zayed et al., 2012; Pasha et al., 2011a & b; Hussain, 2010; Zayed et al., 1995; Tingari et al., 1984) agree that the seminiferous tubule diameter is comparatively reduced, and the interstitium occupies a larger area during the rutting season of camels, in contrast with other seasonal breeders, others (Novoa, 1970; Abdel-Raouf et al., 1975; Marai et al., 2009) believe that the diameter of the seminiferous tubules become larger during the rutting season, and tends to be smaller in the non-breeding season of the camel. So a more detailed study in the area of camel reproduction regarding seasonal changes in seminiferous tubules using a statistically reliable number of animals is critical. Seasonal breeders like the one -humped camel have drastic changes in the genital system anatomy, which result in hormonal whims and, consequently, the behavior and reproductive activity during different seasons of the year depends on the climate/region/nourishment, as well as the length of the day. Therefore, it is very much important to record the behavior, as well as the anatomic/histologic changes of the male genital system of this unique species, in order to be able to use the data to improve reproduction.

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