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Review Paper

Special Features in the Reproductive Anatomy, Physiology, and Behavior of Male Camels (*Camelus dromedarius*)

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ABSTRACT

The peculiarities of anatomic and physiologic features of dromedary camels are elucidated in this review and compared with Bactrian, camels, and other species. Both dromedary and Bactrian camel scrotum varies in length from 10-20 cm and the testes are in the perineal region behind the thighs (like dogs) and weigh from 80-90 gm and length varies from 10-14 cm. Compared to ram and buck, camel epididymis has a higher weight (20-46 g) and has a unique structure called the intra-epithelial glands. Both dromedaries and Bactrian camels do not have seminal vesicles. Male camels have specialized secretory glands behind the ears known as poll glands that are bigger in the Bactrian camels compared to dromedary camels and similar glands are not seen in any of the other domestic species. Camels have a special reproductive behavior during the breeding season known as rut and include extrusion of the soft palate, copious froth from the mouth, gurgling sounds, splashing of urine, increased secretion from the poll glands and loss of appetite with considerable reduction in body weight. Such behaviors are not evidenced by any other domestic species including buffalo. Serum testosterone rises substantially in male camels during rut (2-42 ng/mL) compared to the non-rutting season (0.6-8 ng/mL) and the resultant increase in the size of the testes, number, and functionality of Leydig cells and secretion of poll glands. The serum thyroidal hormones also increase significantly during the rut season. It is concluded that male camels have some special anatomic and physiologic features of reproduction not observed in other domestic species.

Keywords: Camel, male, testes, seasonality, poll glands, rut

In the year 2000, we analyzed the research on dromedary reproduction (Purohit and Pareek, 2000) and found that very few research were carried out on camel reproduction from 1977-1999. Since then, the interest in camel reproduction is increasing, however, some of the physiological events continue to be less known. Subtle differences do exist in this species both in the female (Purohit *et al.* 2020) and male (El-Wishy, 1988; Ismail, 1988; Al-Eknah, 2000) reproduction compared to other domestic animal species. Special anatomic features of male camels are known since the last many years, whereas some of the details have been either known recently or confirmed. Very few studies have addressed the

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anatomy and physiology of male Bactrian camels and largely appear to be like dromedary camels (Zhao, 2000; Hafez and Hafez, 2001). Studies comparing anatomic features of male camel, rams, and bucks have shown some differences in the testes (Mahmud *et al.* 2015a), epididymis (Mahmud *et al.* 2015b) and penis (Mahmud, 2017). Interestingly, water buffaloes have breeding seasons like camels, yet the expression of sexual behavior is not that intense in male buffalo bulls compared to male camels. Male camels have testicular weights comparable to buffalo bulls and the testicular length is like rams and bulls and camels have higher epididymal weight compared to rams and bucks (Mahmud *et al.* 2015a; Mahmud *et al.* 2015b; Sofi, 2022). Camels have a non-pendulous scrotum that increases in dimensions during the breeding season and interestingly camels do not have seminal vesicles (Ali *et al.* 1978; Vyas and Pareek, 1982; Hafez and Hafez, 2001). The camel penis is fibroelastic, with a pre-scrotal sigmoid flexure, the glans penis has a bone, and due to an additional lateral preputial muscle, the camel penis can rotate cranially and caudally during mating and urination respectively (Hafez and Hafez, 2001). Male camels exhibit specific morphologic and functional changes in their testes and sexual behavior, commonly known as the rut season (Khan, 1971; Bhakat, 2006). Camels have special secretory glands located behind the ears, known as poll glands, that are not seen in any other domestic species and known to secrete androgens during the breeding season. The testosterone secretion is very high in male camels during the breeding season and male buffaloes do not evidence that high testosterone secretion alterations. High testosterone leads to special sexual behaviors (not seen in any other domestic species) including extrusion of the soft palate, copious froth from the mouth, gurgling sounds, splashing of urine, increased secretion from the poll glands and loss of appetite with considerable reduction in body weight (Khan, 1971; Khan and Kohli, 1972; Sharma and Vyas, 1981). Most published literature on camel reproduction appears to be too old, yet many new publications have appeared in recent years. Thus, in the present review we present summarized data on male camel reproductive anatomy and physiology with focus on dromedary camels and comparison with Bactrian camels and other species.

1. Seasonality

The breeding season in camels is commonly known as the rutting season (Ismail, 1988). Distinct effects of season have been observed on the reproductive characteristics of male camels (Al-Eknah, 2000; Marai *et al.* 2009; Ainani *et al.* 2018). Female camels also show seasonal breeding (Purohit *et al.* 2020) with only a few females evidencing follicular growth during non-breeding season (Ali *et al.* 2007; Vyas *et al.* 2004) yet males show interest in estrus females only during the breeding season (Swelum *et al.* 2018a; Swelum *et al.* 2018b). During the breeding season, female camels that were not pregnant in the previous breeding season evidence early follicular activity, yet males show rut late in the breeding season (Vyas, unpublished data). A recent study found that the libido of male camels was lower in September than in December (Manjunatha *et al.* 2022). Distinct changes in endocrine hormones and semen production have been observed in several studies in male camels (El-Harairy and Attia, 2010; El Khasmi *et al.* 2011; Farh *et al.* 2018; Swelum *et al.* 2018b). Similarly, seasonal changes in testicular biometry and echogenicity of the testicular parenchyma have been observed in the past (Pasha *et al.* 2011a; Pasha *et al.* 2011b). Breeding seasons in camels worldwide has been summarized earlier (Ainani *et al.* 2018; Marai *et al.* 2009) depicting the winter seasons and shorter day lengths favoring reproductive function and typical male behavior (El-Wishy, 1988; Al-Eknah, 2000; Hafez and Hafez, 2001). Peak breeding season has been recorded (during the cooler season) in countries like India, Pakistan, China, Israel, and Egypt to occur during the months of November to March (Marai *et al.* 2009).

In Somalia, the male camel ruts in spring from April to June (Novoa, 1970; Schmidt, 1973) and then October to December, coinciding with the two rainy seasons. In Morocco, the rutting season occurs in winter and spring (Sghiri, 1988). A clearly defined reproductive season was observed in male camels in Oman ranging from December to March, with peak reproductive function occurring during December-January (Al-Bulushi *et al.* 2019). Differences in the breeding behavior of male camels throughout the year have also been described (Padalino *et al.* 2015). Camels in Kenya are known to breed throughout the year (Wilson, 1986). Hammadi (2003) reported

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that in Tunisia, camels are in ruts from December to March. Results from studies in Saudi Arabia indicate that in the non-breeding season, male camels will not express symptoms of sexual behavior and even refuse to approach an estrous female (Swelum *et al.* 2018a; Swelum *et al.* 2018b).

Thus, distinct seasonal effects on reproduction in camels have been recorded. In Russia, wild Bactrian camels have been reported to be seasonal, mating in winter and early spring, but domesticated ones were said to be capable of mating year-round (Gauthier-Pilters and Dagg, 1981). Other authors reported the breeding season in Chinese Bactrian camels from mid-December to April, with most females showing estrus in January and February (Abdel-Rahim *et al.* 1994; Zhao, 2000). Like other mammals, the dromedary camel shows daily (Vyas *et al.* 1997) and seasonal (El Allali *et al.* 2005) rhythms in melatonin secretion, as a principal photoperiodic cue regulating reproduction in the seasonally breeding species. During the non-breeding season, high levels of plasma prolactin have been observed in camels (El-Allali *et al.* 2018). It seems that hyperprolactinaemia is a causative factor of low fertility and libido in the male camel during the non-breeding season (Khan *et al.* 2003). This is probably due to its action in reducing the synthesis and secretion of FSH and LH. There is also a possibility that prolactin has an anti-gonadotrophic action at the gonadal level (Khan *et al.* 2003). The maximal testicular size was recorded during the rutting season. In this period, the interstitial tissue occupied high area and volume with significant increase of the inter-tubular constituent's volume, hypertrophy of the Leydig cell, and maximal number of Leydig cells per testis (Gherissi *et al.* 2018). The thyroid hormone (T3 and T4) levels increased significantly ($P < 0.05$) in the rutting than the non-rutting season with significantly better semen quality during the breeding season (Ibrahim M *et al.* 2016). Exposure of males to female camels can enhance rut activity in male camels (Vyas *et al.* 2001; Bhakat *et al.* 2005).

Studies in female (Dholpuria *et al.* 2012) and male camels (Swelum *et al.* 2016; Dholpuria *et al.* 2021) have shown that melatonin implants induced reproductive activity one month ahead of the breeding season (Swelum *et al.* 2016; Dholpuria *et al.* 2021). It has also been mentioned that kisspeptin (Kp) and RFamide related peptide (RFRP) neurons are present in the camel hypothalamus (Ainani *et al.* 2018). As a rule, the breeding season in the dromedary camel occurs when the photoperiod is short and the temperature is low associated to some precipitation (Ainani *et al.* 2018). In the equatorial area, camels can breed throughout the year as rainfall and good food availability are quite stable all along the year (Ainani *et al.* 2018). It seems that the rainfall cues can partially or totally override the effect of photoperiods in camels located near the equator (Mukasa-Mugerwa, 1981; Musa *et al.* 1993).

2. Puberty

Unfortunately, the camel has a slow rate of growth (Faraz, 2022) and this genetic handicap, in addition to the general lack of feed supplementation under pastoral management systems, results in advanced age at puberty for the dromedary (Mukasa-Mugerwa, 1981). Given that camels are raised in arid environments with high temperatures and limited feed availability, this could be a beneficial adjustment by nature (Zeleke and Bekele, 2001). It has been observed in male dromedary camels that the first sexual signs of the onset of puberty started between 3-5 years of age and sexual activity can continue until 20 years of age (Sharma and Vyas, 1981; Yagil, 1985; Khanna *et al.* 1987). Similarly, in Bactrian camels, the age at puberty was mentioned to be 4 years with full reproductive potential being attained at 5-6 years (Zhao, 2000). Marked increase in the size and numbers of Sertoli cells in camels aged between 3 and 4.5 years of age was recorded in one study (El-Harairy and Attia, 2010). A recent study (Gherissi *et al.* 2020) evaluating puberty in camels found that pubertal changes were displayed usually at 4 to 5 years with increased sperm reserves, seminiferous tubule volume, diameter and total length, high relative volume of interstitial tissue components, high individual Leydig cells volume and total number of Leydig cells. At this age, the first reductional miotic splits and the first spermatids and spermatozoa in the seminiferous lumen tubules were significantly developed leading to increase the mean germ cells number and tubular fertility indexes. Animals in this age category showed the highest proportion of first mating (50%), while mating frequency and time were higher. These reproductive traits were improved significantly with spermatogenesis efficiency in mature animals aged

> 6 years old. Previous studies indicated that sexual maturity is attained in male camel's between 5 to 7 years (Dafalla and El-Eknah, 1993), however; wide variability in this age has been reported in many previous studies. Studies on the puberty of camels in Saudi Arabia using slaughterhouse material and impression smears from the epididymis suggested that sexual maturity is attained at the age of 6 years (Dafalla and EI-Eknah, 1993). Nutrition and good management are the main factors affecting the age of puberty in camels (Arthur *et al.* 1982; Abdel-Rahim *et al.* 1994). An effect of breed was also noticed and Mojaheem camels reached sexual maturity at a significantly younger age and heavier weight (164 weeks and 360 kg) than Wadah camels (182 weeks and 336.5 kg) ($P < 0.001$) both maintained under good nutrition in Saudi Arabia (Abdel-Rahim, 1997). The weight at which puberty can be expected is poorly studied and can occur at a body weight of 340 kg (Abdel-Rahim, 1997). Studies to enhance puberty in male camels by increasing protein (13% crude protein) in the diet have resulted only in marginal improvements in testicular size without an increase in testosterone production (Al-Saiady *et al.* 2013).

3. Anatomic features of male reproductive tract

The earliest report on the description of anatomic structures of male camels 'dates to 1903 (Lesbre, 1903). Later studies also mentioned the morphologic features of male camel reproductive organs and found seasonal changes in the testicular weight and dimensions (Abdel-Rouf *et al.* 1975; Singh and Bhardwaj, 1978b, c; Osman *et al.* 1979). Hafez and Hafez (2001) mentioned the peculiarities of male camels as left testis bigger than right; scrotum not pendulous; vas deferens very convoluted with 2 mm diameter; prostate divided into 2 parts by septum, with many ducts; bulbourethral (Cowper's) glands well developed and seminal vesicle absent; fibro-elastic penis has "prescrotal" sigmoid flexure and the glans resembles crochet needle; triangular-shaped prepuce directed posteriorly to open to the rear, and can move cranially or caudally during erection or urination, respectively.

3.1 Scrotum

The scrotum of the camel is in the perineal region (Tayeb, 1945) and generally covered by the tail but could be seen in the standing position. The scrotum is oval, and each testis is separately situated in its own compartment and sparsely covered with hair (Yagil, 1985). A faint median raphe divides the two testicles (El Naggar and Rath, 1990; Bello and Umaru, 2013). The scrotum varies in length from 10-20 cm (Abdullahi, 1970; Mobarak *et al.* 1990). The scrotal sac descends, on average, 86.8315.74 days after birth, and the testes descend 170.67±29.14 days after birth (Bissa *et al.* 1988). Along with the testes, the scrotal size increases at puberty. The scrotum of the camel is not pendulous (Hafez and Hafez, 2001). The scrotal circumference of camels was recorded as 23.73±1.43cm (Ibrahim A *et al.* 2012b) and 30.9± 0.8cm (Stephen *et al.* 2019; Saleh *et al.* 2021). Significantly higher scrotal circumference was noticed in camels during the breeding season compared to the non-breeding season (Zeidan and Abbas, 2004; Gherissi *et al.* 2017; El-Mahdy *et al.* 2019). Buffalo bulls of 3-4 yr age had a scrotal circumference of 28.87±0.59 cm (Osman *et al.* 2020). The scrotal circumference of 2-year beef bulls of various breeds varied between 32 to 36 cm (Coulter *et al.* 1987). Thus, camels have lower scrotal circumference compared to bulls but are comparable to buffalo bulls.

3.2 Testes

The testes of the camel descend after birth (Arthur *et al.* 1982; Bissa *et al.* 1988). They are very small, up to 3 years of age (Degen and Lee, 1982), but a dramatic increase in size occurs at the onset of puberty (Khan *et al.* 2003). The maximum testicular weight is attained at 10 years and maintained thereafter up to 20 years (Marai *et al.* 2009).

The camel testes are oval and located in the perineal region behind the thighs (like dog and boar) a few cm below the ischial arch (Vyas and Pareek, 1982) and lie obliquely with their long axes running cranio-ventrally (Osman and El-Azab, 1974). The testes of Bactrian camels are similarly placed (Zhao, 2000). The posterior border is slightly higher than the anterior, and compared to the body size of the camel, the testicles are small (Vyas and Pareek, 1982). Yassen and Mahmoud (2009) have noticed that in buffalo bulls the testicular size of buffalo bulls was half that of a domestic bulls of similar body weight. Similarly, Mahmud *et al.* (2015a) noticed that the testicular weights were significantly ($P<0.05$) higher in Uda rams compared to camels, although rams have very low body weight compared to camels. Both testes have limited mobility and normally they present a soft consistency (El-Jack, 1980) and in an animal of 3 years measure 7–10 cm in length, weighing 80–100g each (Bello and Umaru, 2013). Mahmud *et al.* (2017) found the testicular length of 11.10±0.31 cm and 10.83±0.69 cm and an average testicular weight of 83.50 ±11.07g and 83.50±6.33g for the left and right testicles of camel respectively. For Bactrian camels, the length and breadth were 12-14 cm and 4.5-5.5 cm, respectively, and the testicular weight ranged from 80-120 gm (Zhao, 2000). One study compared the testicular dimensions of 3 breeds of Egyptian camels and observed only minor differences (El-Mahdy *et al.* 2019). Similarly, another previous study observed marginal breed differences (ElWishy, 1988). Normally, the right testicle is smaller than the left one both in dromedaries (Vyas and Pareek, 1982) and Bactrian camels (Zhao, 2000), probably due to an enlarged pampiniform plexus on the left side (El-Jack, 1980; Yagil,1985). A study on camels in Nigeria described the right testis weight to be 78.45±12.96 whereas the left testis weight was 69.66±12.53 gm respectively with only marginal differences in the left and right epididymal weight (Ali-Abdullahi *et al.* 2012) and similarly another study noticed non-significant differences in the length, weight, and volume of left and right testes (Stephen *et al.* 2019). Some studies noticed non-significant differences in the weights of left and right testes in camels (Abdel -Raouf and Owaida, 1974; Ismail, 1982; Pasha *et al.* 2011b).

The parenchyma of the testes as well as the epididymides are covered by a white fibrous, non-elastic and thick (0.5-3.9 mm) tunica albuginea (Singh and Bharadwaj, 1978c) which contributes 16.8-20.6% of the total testes weight (El-Wishy and Omar, 1975; Ismail, 1979). The tunica albuginea of the camel testis is very thick. The tunica albuginea gives off several trabeculae that divide the parenchyma of the testis into lobules (El-Naggar and Rath, 1990). These trabeculae converge centrally and merge with the mediastinum testis, which extends along the proximal three-fourths of the testis (El-Jack, 1980). The number of germ cells per gram tissue in the camel testis is less than that in other animals (Osman and El-Azab, 1974).

The capsule of the testis is composed of irregularly arranged dense fibroblastic tissue. The elastic fibers play an important role in seasonally breeding animals in which the testes become turgid during the rutting period and flaccid during the non–rutting period. The interstitial tissue is rich in polyhedral cells of Leydig's (Vyas and Pareek, 1982). The amount of interstitial tissue varies with the period of years; the maximum in rutting period and reduces during the non-rutting period (Singh and Prakash, 1964).

The size of the testes varied marginally between breeds of mature male camels. The mean weights mentioned for different age camels at different locations vary slightly (Table 1). A significant increase in testis weight during the breeding season due to increased development of interstitial tissue (Singh and Bharadwaj, 1978c) and increased diameter of the seminiferous tubules (Abdel Raouf *et al.* 1975) has been reported. The mean paired testis weights of 140 and 165 g and 164.3 and 180.2 g were given by Charnot (1963) in Morocco and Tingari *et al.* (1984a) in Saudi Arabia during the non- breeding and breeding seasons, respectively.

The camel testis undergoes fluctuations in weight and marked histological changes which are related to the age of the animal and season of the year (Abdel-Raouf *et al.* 1975; Singh and Bharadwaj, 1978b, c; Osman *et al.* 1979). Records have shown that testicular weight reaches a seasonal peak during the rutting months, and, according to Singh and Bharadwaj (1978c) and Tingari *et al.* (1979), there is also an increase in the volume and activity of the interstitial cells of Leydig, as revealed by their ultrastructure. The testis increased greatly in weight and size during the rutting season (Abdel-Raouf and Owaida, 1974; Ismail, 1982) due to the extensive development of interstitial tissues at this time (Ismail, 1982). A few later studies also noticed an increase in testicular weight in camels during winter and a marked decrease in summer (Zeidan and Abbas, 2004; El-Mahdy *et al.* 2019).

Age related changes in the dimensions of the testes were recorded (Table 1). Significant increase in testicular and epididymal measurements was recorded in camels with increasing age with maximum values during the breeding season (Al-Qarawi *et al.* 2000; Gehrissi *et al.* 2014). Substantially higher testis weights were recorded during the cooler breeding season (Dec to March) in Indian camels compared to other seasons (Singh and

Table 1: Age related changes in the testicular weights of camels (Mean ±SEM.)

Testicular parameters	Up to 3 years		3-5 years		6 year and above		Reference
	Right	Left	Right	Left	Right	Left	
Weight g	2.4±0.4	2.3±0.4	43.1±7.9	38.7±9.5	129.2±1.9	114.2±16	Degen and Lee (1982)
Weight g	—	—	78.46 ± 12.96	69.66 ± 12.53	—	—	Ali Abdullahi *et al.* 2012
Weight g	—	—	—	—	80-142	85-144	Pasha *et al.* 2011b
Weight g	—	—	—	—	61.1-80.5	61.3-92.8	Abdel Raouf and Owaida (1975).
Weight					70.8	78.4	Singh and Bhardwaj (1978b)

Bhardwaj, 1978b). Likewise, significantly higher testicular weight, testicular volume, and scrotal circumference were recorded in Egyptian camels during the breeding season compared to non-breeding season (Maiada *et al.* 2013). One study recorded non-significantly higher testicular weights and diameter of seminiferous tubules in camels during the months of October to March compared to other months of the year (Tingari *et al.* 1984a). Similarly, other studies noticed higher testicular lengths in camels above 6 years (Abdullahi, 1970; Abdel-Rouf and Owaida, 1975; Derar *et al.* 2012).

During the past few years, the ultrasonographic features of camel testes for breeding soundness evaluation have been described (Waheed *et al.* 2014). Studies also described the ultrasonographic changes in the testicular parenchyma with changing season. During the winter season, the parenchyma was hyperechoic, and the mediastinum testis was seen as a thin hyperechoic line. In spring, the echogenicity of the parenchyma was moderate, and the mediastinum appeared a relatively thick central hyperechoic line. (Pasha *et al.* 2011; Sary *et al.* 2022). In summer and autumn, echoic parenchyma and thick band of mediastinum was recorded. Biometric studies showed significantly ($P<0.01$) higher scrotal length and width of the testis during the winter and spring season. Measurements of testicular width, depth, length, and volume by either vernier caliper, ultrasound calipers, and magnetic resonance calipers revealed nonsignificant differences (Sary *et al.* 2022). However, the left testis morphometric parameters were significantly ($P<0.05$) higher compared to the right one. One study determined the blood flow to the camel testes using pulsed wave color Doppler ultrasonography (Kutzler *et al.* 2011). The testicular artery originates from the ventral surface of the aorta, gives rise to an epididymal branch, and becomes very tortuous as it approaches the testis. Within the supra-testicular arteries, peak systolic velocity (PSV) was higher in fertile males compared to infertile males ($P = 0.0004$).

Testicular weight and length were compared in different species including camel (Mahmud *et al.* 2015a) and ram, buck, and bull (Sofi, 2022). The testicular weights in camels are comparable to buffalo bulls, but lower than rams and bulls (Table 2). The testicular length in camel was like rams and bulls (Table 2).

3.3 Seminiferous tubules

Adel-Raouf *et al.* (1995) calculated the average diameter of the seminiferous tubules to be 210μ. While the diameter did not differ significantly between the right and left testes, it varied significantly ($P< 0.005$) according to season, being the smallest during the summer (189.40—203.26μ) and the largest in spring (209.68—226.20μ). Like other animals, the seminiferous tubule of the camel can be divided into three zones. The major portion is highly coiled and is the site of sperm production. It is lined by many layers of spermatogenic cells and a single layer of Sertoli cells (Singh and Bharadwaj, 1978c). Both ends of the convoluted seminiferous tubules continue as transitional zones or tapering terminal segments which are lined with modified Sertoli cells. The straight tubule is a continuation from the transitional zone and leads to the rete testis (Singh and Bhardwaj, 1980).

The outer diameter of the seminiferous tubules of Indian camels aged 4-20 years ranged from 113 to 250 μm (Singh and Bharadwaj, 1978c). An increase from 193.5 ±21.7 μm at 6 years to a mean of 215.71±19.57 μm at 9 years with slight variations up to the age of 18 years was described by Abdel-Raouf *et al.* (1975) in Egyptian camels. Highly

Table 2: Testicular weight and length in different species

Testicular weight (g)	Camel	Ram	Buck	Bull	Buffalo bull	Reference
Left testes	83.5±11.07	155.4±21.42	43.40±5.76	—	—	Mahmud *et al.* 2015a
Right testes	83.5±6.33	163.45±24.69	42.20±5.43	—	—	
Left testes	—	145.6±3.91	139.4±3.64	196.8±2.77	—	Sofi, 2022
Right testes	—	148.6±1.14	141.2±1.3	199.6±3.50	—	
Left testes	—	—	—	—	87.89±3.45	Saurabh *et al.* 2018
Right Testes					78.41±3.45	
Testicular Length (cm)						
Left testes	11.10±0.31	11.63±0.43	7.50±0.41	—	—	Mahmud *et al.* 2015a
Right testes	10.83±0.69	11.63±0.47	7.62±0.31	—	—	
Left testes	—	9.3±0.22	8.66±0.19	11.24±0.37	—	Sofi, 2022
Right testes	—	9.0±0.21	8.14±0.11	10.94±0.16	—	
Left testes	—	—	—	—	8.14±0.18	Saurabh *et al.* 2018
Right testes	—	—	—	—	7.77±0.17 cm	

Table 3: Season wise diameter of seminiferous tubules of camel

Parameters	Spring Season	Summer Season	Winter season	References
Diameter (μm)	189.40—203.26	209.68—226.20		Adel-Raouf *et al.* (1995)
	240.69±190.2	193.41±146.15	252.34±156.55	Gherissi *et al.* (2016)
		176.4	162.6	Tingari *et al.* (1984a)

significant seasonal variations were described by these authors. The smallest diameter was noted during the summer (195.85±14.56 μm) and the largest during spring (218.35±22.29 μm). Seasonal changes in the seminiferous tubules were recorded in some studies (Table 3). During the rutting season, the outer and inner diameters of the seminiferous tubules (ST) were significantly higher, accompanied by dense and high seminiferous epithelium (56.42±14.52 μm) that occupied 85.50±8.45% of the ST surface. This high seasonal activity was also characterized by increased volume of ST and ratio of seminiferous tubules to interstitial area (IT) and volume, respectively. The average diameter of the Sertoli cell nuclei was significantly high during the rutting and post-rutting seasons indicating high activity of these cells compared with the non-rutting season (P<0.001) (Gherissi *et al.* 2016).

3.4 Sertoli and Leydig cells

The Sertoli cells in the camel extend from the basal to the ad-luminal compartment of the seminiferous tubules, the two compartments are, however, separated by junctional complexes that function as a major part of the blood-testis barrier (Osman and Ploen, 1986a). The nucleus is large and varies in shape from round, oval, pear-shaped to elongated (Osman *et al.* 1979). The nucleolus is very prominent but lacks vacuoles which characterize the nucleoli of Bovidae and some Cervidae. The number of Sertoli cells in mature camels varied neither with age nor with season (Abdel-Raouf *et al.* 1975). Activity of the Leydig cells becomes maximal during the rutting season (Tingari *et al.* 1984a), but are less active in the non-breeding season with a resulting reduction in steroidogenic activity in the testes (ElWishy, 1988; Zayed *et al.* 1995). Another study showed that there is hypertrophy of Leydig cells and maximal numbers of Leydig cells per testis are present during the rutting season in camels (Gherissi *et al.* 2018). Previous investigations agreed that the season has an obvious effect on the testicular tissue and Leydig cells activity as revealed by their ultrastructure (Abd-Elaziz *et al.* 2012; Pasha *et al.* 2013) and by serum concentrations of melatonin, LH, testosterone, and prolactin in adult camels (Al-Qarawi and El-Mougy 2008). The rise in testicular measurements was associated with an increase in the area and volume of the interstitial tissue and its constituents (blood vessels, Leydig cells, and connective tissue) (Zayed *et al.* 1995). The maximal individual Leydig cells volume was recorded in the rutting season, but the highest Leydig cell nucleus size and volume were obtained in the post-rutting season (Gherissi *et al.* 2016). The Sertoli cells appear normal throughout the year (Tingari *et al.* 1984b). However, remarkable morphometric and ultrastructural 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 (Friedlander *et al.* 1984; Pasha *et al.* 2011b; Abd-Elaziz, *et al.* 2012).

3.5 Spermatogenesis

Spermatogenesis in the camel was generally like that of most mammalian species, although some features specific for the camel were observed. Spermatogenesis continues throughout the year (Abdel-Raouf *et al.* 1975; Osman *et al.* 1979; Osman and Ploen, 1986b) with a high rate during the colder months of the breeding season (Tingari and George, 1984) and slows down, but does not stop completely, when external signs of rut are not present. The testis of the male dromedary camels during the breeding season consisted of numerous seminiferous tubules (ST) with different shapes and sizes (oval, ovoid, and circular) that were highly active. The ST lined by spermatogenic cells at different maturation stages (spermatogonium, spermatocytes, spermatid, and spermatozoa) are present compared to camels during non-breeding season either hot-dry or hot-humid months (Maiada *et al.* 2013). Spermatogonia, spermatids, and spermatozoa increase substantially during the breeding season (Charnot, 1963; Charnot, 1965). The number of spermatozoa per gram of testicular tissue varies from about 27 – 30 million in quiescent males to 36 – 47 million during rut (Osman and El-Azab 1974; Abdel-Raouf *et al.* 1975). Telocytes (TCs) are stromal cells. Camel TCs in the efferent ductules evaluated by scanning electron microscopy revealed that TCs had a cell body and multiple telopodes (TPs), and most TCs had indented nuclei that exhibited prominent intra-nucleolar chromatin. TPs in summer had delicate ramifications, whereas, in the spring, TPs displayed fine arborization and became more corrugated, suggesting that hormonal alterations during the reproductive cycle impact the morphology and secretory behavior of TCs (Abdel-Maksoud *et al.* 2019).

3.6 Seminal epithelial cycle

The microscopic and ultrastructural features of the cellular elements involved in the process of spermatogenesis in camel have been described by Singh and Bharadwaj (1978c) and Osman and Ploen (1986b). The cycle of the seminiferous epithelium in the camel can be divided into eight stages, each stage having its characteristic cellular association (Osman *et al.* 1979; Ismail, 1982). During the rutting season, the outer and inner diameters of the seminiferous tubules (ST) were significantly higher, accompanied by dense and high seminiferous epithelium (56.42±14.52 μm) that occupied 85.50±8.45% of the ST surface (Gherissi *et al.* 2016). The average diameter of the Sertoli cell nuclei was significantly high during the rutting and post-rutting seasons indicating high activity of these cells compared with the non-rutting season ($P<0.001$) (Gherissi *et al.* 2016).

3.7 Epididymis

Epididymis of the camel is large and lies mainly on the dorsolateral aspect of the testis. The head (caput epididymidis) measured 4-6 cm in width, 3-4 cm in length (Abdullahi,1970). The weight of the epididymis ranged from 10-40 gm in adult camels (Vyas and Pareek, 1982). The epididymis of the camel adheres to the cranial border and both extremities of the testis (Tayeb, 1945; Singh and Bharadwaj, 1978b). Anatomically, the epididymal duct of a camel consists of three parts, i.e., head, body, and tail. Histomorphologically, the epididymal duct is subdivided into initial, middle and terminal segments, of which the middle segment is further subdivided into proximal, intermediate, and distal parts (Zayed *et al.* 2012). The head is rather flat and curves forward and downward over the cranial pole of the testis. The body is a narrow, thick, and rounded rather than flattened structure (Osman and E1-Azab, 1974; Degen and Lee, 1982). It forms the epididymal sinus with the testis. The tail is a small, somewhat flattened part. It is closely attached to the corresponding pole of the testis in mature camels, but it clearly projects beyond the pole of the testis in young camels. The ductus epididymis was surrounded by circular smooth muscle fibres and a thin loose connective tissue of the epididymis along with embedded blood and lymph vessels (Saini *et al.* 2022).

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Table 4: Mean (±SEM) of epididymal length, epididymal weight, and vas deferens length in one humped camel, Uda rams and Sokoto bucks (Mahmud *et al.* 2015b)

Parameters	Camel	Ram	Buck
Epididymal length cm	14.88±1.33b	19.00±1.72a	13.06±0.35b
Epididymal weight g	46.55±1.28a	24.21±3.67b	07.18±0.35c
Vas deferens length cm	35.67±1.27a	29.81±0.76b	15.00±0.53c

Means with different superscripted letters in a row are significantly (P<0.05) different.

The mean weight of the epididymis of mature camels from Egypt and Sudan was 14.7-14.9 g and 11.7-12.4 g, respectively (Osman and E1-Azab, 1974). Somewhat higher weights of 16.3-16.7 g and 20.4 g were given by El-Wishy and Omar (1975) and Degen and Lee (1982), respectively. A comparison of epididymal biometry between camel, ram, and buck revealed significantly higher epididymal weight and vas deferens length in camels compared to ram and buck (Table 4).

The cauda epididymidis contributes the least proportion (20-22%) to the whole mass of the organ while the corpus forms the largest (42%) part (Ismail, 1979; Tingari and Moneim, 1979). Although many aspects of epididymal function have not been studied in the camel, it can be assumed, as known in other animals, that the initial and middle segments are concerned with sperm maturation while the terminal part is for sperm storage (Glover and Nicander, 1971). The intra-luminal cellular contents (histogram in pixels), epithelial and stereocilia heights, and muscular coat thickness were maximal in the epididymal head. The epididymal tail showed wider luminal and tubular diameters than the head and body. The tubular diameter and histogram were positively correlated (p<0.05) with sperm motility in the head and body segments (Rashad *et al.* 2018). The changes in the morphology of the acrosome and the sub-acrosomal space of the camel sperm during their epididymal transit resembled those observed in other species (Osman and Ploen, 1986c). Nevertheless, migration of the cytoplasmic droplet was not complete in all spermatozoa in cauda epididymidis. In the stallion and bull, loss of the cytoplasmic droplet occurs in the middle of the caput, while in the ram and boar, it occurs immediately distal to the caput (Setchell, 1977).

The epithelium lining the epididymal duct is ciliated pseudostratified columnar (Tingari, 1989) comprising mainly offive cell types, namely, principal, basal, apical, dark and halo cells (Zayed *et al.* 2012a; Ibrahim Z and Singh, 2014). It displays numerous intraepithelial glands in the middle segment. In general, there is a gradual increase in the total diameter and decrease in the epithelial height of the epididymal duct from the initial to the terminal segment (Zayed *et al.* 2012a). The muscular coat of the middle and terminal segments of the epididymis is the thickest during the rutting season that may be helpful for powerful ejaculation (Zayed *et al.* 2012b).

The secretory activity of the principal cells was amplified in the breeding season, while its endocytotic function became more active in the non-breeding season, suggesting that the reproductive activity has a significant impact on the immune histochemical and ultrastructural profiles of the epithelial cells lining the Egyptian dromedary camel epididymis (Ibrahim D and Abdel-Maksoud, 2019). Significantly higher values of scrotal circumference, paired testicular weight, and paired testicular volume, the outer and inner diameters of the seminiferous tubules (ST), the average number of spermatozoa per seminiferous tubule, and high sperm reserves were observed in all epididymal segments during the rutting season in Algerian camels (Gherissi *et al.* 2016).

Seasonal changes in the morphology and activity of the epididymal epithelium in the initial and middle segments were described by Singh and Bharadwaj (1980). During the non-breeding season, the epithelial cells were distorted, and their height was one-third to one-half of that observed during the breeding season. This might be related to decreased sperm production during this season. The spatial distribution of different proteins in camel epididymis showed similarities and differences with other mammalian species. The region-specific topographic distribution of different proteins and cell types might indicate that the caput and cauda are metabolically more active than those of the corpus (Alkafay *et al.* 2011).

The epididymis of camels has a unique structure called the intraepithelial gland. Transmission electron microscopic study revealed that the camel intraepithelial gland has a significant impact on the reproductive activity through their secretory microenvironment during the breeding season. Moreover, it recycles the unused organelles or proteins for reuse or to supply energy under stress conditions in the non-breeding season (Abdel-Maksoud *et al.* 2019). The nervous innervation of camel epididymis was recently described (Saleh *et al.* 2002).

3.8 Epididymal sperm reserve

The relative distribution of sperm in the different segments of the epididymis, determined by sperm count in tissue homogenates, revealed that only about one-third of the sperm reserve is contained in the cauda epididymidis (Table 5). This is much less than the 61-72.6% reported in bulls (Almquist and Amann, 1961; Igboeli and Rakha, 1971) and 47.3-60.4% in stallions (Gebauer *et al.* 1974; ElWishy *et al.* 1972).

Table 5: Epididymal sperm reserves in mature camels

Epididymal segment	Sperm reserve both sides × 10^6	Relative distribution (%)
Head	673.8	11.5
Body	3004.5	51.1
Tail	2197.4	37.4

Ismail, (1979).

3.9 Spermatic cord

The spermatic cord of the camel is relatively long, measuring about 45-50 cm. It is voluminous at its attachment to the testes due to the large sized pampiniform plexus of the veins (Tayeb, 1945). Like other animals, the vascular portion occupies the anterior part while the deferent duct, contained in a special fold of the tunica vaginalis, runs along the caudomedial part. The external cremastric muscle is attached along the caudolateral portion of the spermatic cord (Tayeb, 1945).

3.10 Ductus deferens

The deferent duct in the camel is a flexuous tube which extends as a continuation of the cauda-epididymidis to terminate at the dorsal wall of the pelvic urethra (Abdullahi, 1970). A notable feature of the deferent ducts of the camel is their highly flexuous disposition except at the ampullary enlargement which may be slightly winded (ElWishy *et al.* 1972). Each pursues a short course in a deep groove on the ventral surface of the corpus prostate, narrows gradually, pierces the dorsal wall of the prostatic urethra, and then opens internally into the colliculus seminalis. A distinct ampulla was not discernible in Bactrian camel, although luminal alterations are present with the biggest part about 40 mm in external diameter and much smaller than that of the stallion and bull (Zhao, 2000).

The mucosa is folded and lined with pseudostratified columnar epithelium. The tunica muscularis is thick and consists of a circular smooth muscle layer together with longitudinal smooth muscle bundles disposed peripherally (Ali *et al.* 1978). The ampullary enlargement is primarily due to the presence of a thick layer of simple branched tubular glands occupying the entire thickness of the lamina propria. They are peripheral, central, and submucosal. The epithelium lining the ampullary glands is composed of simple columnar cells with round nuclei. The muscularis of the ampulla is much thinner than the rest of the deferent duct (Ali *et al.* 1978; Degen and Lee, 1982).

The ampullae of the deferent ducts are about 14 cm in length and 4 mm diameter (ElWishy *et al.* 1972). In mature Egyptian camels, they have a mean weight of 3.85 ± 0.04 g with highly significant variations ($P < 0.01$) between seasons (Abu-Ahmed *et al.* 1988). A recent study described the light and scanning electron microscopic features of the ampulla of camels. The wall of the ampulla was composed of mucosa, submucosa, muscularis, and serosa or adventitia. It was lined by pseudostratified columnar epithelium containing intraepithelial glands. The lamina propria and tunica submucosa formed together the thickest part of the ampullary wall. This study concluded that the camel ampulla ductus deferentis performs a storage function in addition to its secretory one, and both are subject to seasonal variations (Saleh *et al.* 2020).

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3.11 The accessory sex glands

3.11.1 Vesicular glands

Several reports have mentioned that the camel lacks vesicular glands (seminal vesicles) (Vyas and Pareek, 1982; Ismail, 1988; Skidmore, 2000).

3.11.2 Prostate gland

The prostate gland of the camel consists of a dorsal corpus prostate and a ventral pars disseminata overlying the prostatic urethra (ElWishy *et al.* 1972; Ali *et al.* 1976a, 1978; Degen and Lee, 1982). The corpus prostate is formed of a single disc-shaped mass situated on the superior surface of the first part of the pelvic urethra at the neck of the bladder (Tayeb,1945). In mature Egyptian camels, it measures about 4 x 5 cm in longitudinal and transverse directions and 2.2 cm in thickness. In Bactrian camels, the prostrate measured 50x50x13 mm (Zhao, 2000).

For camels above 5 years of age, mean weights of 19.6 and 22.9±5.1 g were given by ElWishy *et al.* (1972) and Degen and Lee (1982) for Egyptian and Israeli camels, respectively. Seasonal changes in the weight of this gland (15.17±0.92 g in spring and 11.75±1.06 g in summer; $P<0.05$) described by Abu-Ahmed *et al.* (1988) are correlated with testicular activity.

The pars disseminata is confined mainly to the prostatic urethra. Caudally it becomes continuous with the glandular pelvic urethra. The prostatic ducts (15-20) open within and lateral to the colliculus seminalis (Ali *et al.* 1976b; ElWishy,1988).

3.11.3 Bulbourethral glands

The camel has a pair of almond-shaped bulbourethral glands. They are situated on the lateral side of the terminal part of the pelvic urethra with the ischial arch, partly covered by the bulbo-cavernosus muscle. Each gland opens by a single duct into the terminal part of the pelvic urethra (Tayeb, 1945; ElWishy *et al.* 1972; Ali *et al.* 1978; Degen and Lee, 1982). The glands were 20 x 20 mm and had a 20 mm long excretory duct that opened into the urethra with a small opening (Zhao, 2000).

The mean weight of paired glands of mature Egyptian camels above 5 years was 5.2 g (ElWishy *et al.* 1972). Significant seasonal variations ($P<0.05$) were described by Abu-Ahmed *et al.* (1988). Higher mean weights of 5.2 ±2.4 and 6.0± 0.8 g for the right and left glands, respectively, were reported by Degen and Lee (1982) for mature Israeli camels.

The glands are covered externally by striated muscle and internally by a thick, mostly fibrous capsule (Ali *et al.* 1978; Degen and Lee, 1982).

The reasons for the presence of high concentrations of fructose (706.0 mg %) and citric acid (105.8 mg %) in the seminal plasma of the camel (Abdel-Raouf and E1-Naggar, 1976) have been poorly investigated specially with reference to their origin.

3.12 Pelvic urethra

The pelvic urethra is thick, flattened dorso-ventrally and averages 13-14 cm in length. Its terminal part forms a narrow constriction where the bulbourethral glands open (Tayeb, 1945; ElWishy *et al.* 1972). It is entirely glandular. The urethral glands extend a short distance from the caudal end of the corpus prostrate to the level of the urethral bulb. The glands are continuous with the pars disseminata cranially (Ali *et al.* 1978). In transverse macroscopic sections, the parenchyma is thick dorsally, comparatively thin laterally, and indiscernible ventrally (Ali *et al.* 1978).

3.13 Penis

The penis of the camel is of the fibroelastic type, like that described in the bull (Mobarak *et al.* 1972; Hafez and Hafez, 2001), having a prescrotal sigmoid flexure. It consists of three parts: a root or radix which is attached to the ischial arch by two crura, a body or corpus which is the main portion, and a free end or pars libra (Tayeb, 1945; Mobarak *et al.* 1972; Degen and Lee, 1982). The cranial end of the penis is curved in a spiral manner to form a sickle shaped glans penis which varies between 17 and 26 mm in length. The latter is a cartilaginous, sometimes ossified tube obliterated at the free end, and bears a loose fold of membrane on its ventro-lateral aspect, which is a modification of the visceral layer of the prepuce (El-Jack, 1980). A true glans penis that corresponds in structure to that of the human and stallion does not exist in the camel (Degen and Lee, 1982). A slender nonflexible and sharply pointed urethral process (4-6 mm) projects from the end of the body of the penis and extends over the concave side of the sickle-shaped glans.

The total length of the penis in mature camels is about 60 cm. Its transverse diameter decreases from 2.2 cm at the root to 1.6 cm in the body and 0.4 cm just behind the twisted terminal part (Degen and Lee, 1982). One report on penis structure in the dromedary camel considered it to be of an intermediary type between fibroelastic and hemodynamic because of increased blood cavity compared to the penis of bulls and rams (Moborak *et al.* 1972).

The pudendal nerve in the free part of the camel penis was inclined to the lateral aspect from the proximal extremity to the distal extremity of free part of the penis (Yousefi 2013). The penile length and weights were compared between camel, ram, and buck and it was found that the penile length and weights were significantly higher in camels compared to ram and buck (Mahmud *et al.* 2017). The size of the corpus cavernosum was the smallest in camels and had more connective tissue compared to rams or bucks (Mahmud *et al.* 2017).

Muscles of the penis

Two dorsal and two ventral ischio-cavernosus skeletal muscles were demonstrated by Mobarak *et al.* (1972) and Degen and Lee (1982) in the camel. The dorsal pair has a fleshy origin from the ischial tuberosity, partially surrounds the crura of the penis, and inserts after a course of 10-12 cm in the tunica adventitia at the right and left sides of the penis. The ventral pair has a tendinuous origin from the ischiatic tuber, and a fascia covering the retroperitoneal part of the ventral aspect of the rectum and inserts into the ventral aspect of the root of the penis, 3-5 cm caudal to the ischial arch. A pair of retractor penis smooth muscles arises from the inferior surface of the first and second coccygeal vertebrae and proceeds to either side of the rectum. They converge caudally and extend forward along the ventral side of the penis to be inserted on the second curve of the sigmoid flexure 3-4 cm from the preputial fornix.

3.14 Prepuce

The prepuce of the camel is a voluminous, fleshy, conical mass flattened from side to side and situated in the inguinal region (Leese, 1927; Tayeb, 1945; Mobarak *et al.* 1972). The integument of the prepuce is of darker color than the neighboring skin and it presents short scattered fine hair. Two black rudimentary teats are always found on either side of the base of the prepuce near its caudal border. The inferior free conical extremity of the prepuce presents the prepeutial orifice which is located 40-42 cm behind the umbilicus. It is directed caudo-ventrally, free from hair, and darker in color (black) than the rest of the prepuce.

The prepuce of the camel is formed of a single fold consisting of external and internal laminae. The latter is attached to the pars libra penis by loose connective tissue. The internal lamina and the skin of the pars libra penis remain fused in immature camels up to the age of 2 years. By 3 years, the layers are separated and a cavum preputiale is formed (Degen and Lee, 1982). Separation of the penis from the prepuce is known to be accomplished under the control of testosterone, which is secreted at an increasing rate prior to puberty in the camel (Gombe and Oduor-Okelo, 1977).

A well-developed lateral preputial muscle, in addition to the cranial and caudal muscles on either side, has been described by Tayeb (1945) and Mobarak *et al.* (1972). It is due to the action of all these muscles that the preputial orifice can be directed either cranially or caudally during erection and micturition, respectively (Khan *et al.* 2003). Moreover, fibres from these muscles interweave together to form a large conical mass around the prepeutial orifice controlling its dilation and constriction.

Hafez and Hafez (2001) mentioned the camel prepuce as triangular-shaped, pendulous, and directed posteriorly to open to the rear. Preputial canal 12–17 cm long, 2–3 cm diameter, urine flows out first in the prepeutial canal then to exterior, the direction being downward first and then backward. Because of the backward-facing sheath, the male urinates toward the rear. Prepuce forms 2 layers: parietal/visceral, with 3 muscle groups in anterior muscles, or protractors of Lesbre; posterior muscles; or retractors of Lesbre: and lateral muscles (Hafez and Hafez, 2001). Thus, the prepuce can move cranially or caudally during erection or urination, respectively, to control dilation, constriction of the preputial orifice.

3.15 Poll glands

There are two subcutaneously located exocrine glands situated on the back of the neck just behind

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the ears known as the poll glands or occipital glands (Purohit and Singh, 1958; Singh and Bhardwaj, 1978a; Taha and Abdalla, 1980; Tingari and George, 1984). Leese (1927) reported that poll glands were present only in males, while Pocock (1910) reported that the poll glands are also present in females but not active. These glands are present since birth with sequential growth with advancing age in intact males and regression after castration (Singh and Bhardwaj,1978a). Marie (1987) noted that poll gland weight can increase from 40-100g in non-breeding season to 200-240 g in the rutting season. The copious secretion from the poll (occipital) glands (Charnot, 1963) is dark brown with acrid smell and androgens are present (Yagil and Etzion, 1980). Anatomical, histological, histochemical, and morphological changes in the poll glands during the breeding and non-breeding seasons were reported by Singh and Bharadwaj (1978a). Tingari *et al.* (1984a) reported that histologically the poll gland resembles endocrine glands, and the gland is histologically like the mammary gland (Purohit and Singh, 1958). The secretory cells have apocrine as well as merocrine modes of secretion and possess the ability to uptake hormones and concentrate them (Taha *et al.* 1994). The immune localization of microfilaments and actins and cytokeratins were studied in camels (Ebada *et al.* 2012) and known to be altered in relation to male seasonal sexual behavior (Ibrahim Z and Al-Kheraije, 2021). A recent study (Ibrahim Z *et al.* 2020) found that the alveolar diameter and epithelial height was significantly ($P<0.05$) increased during the breeding season together with significantly increased inter-alveolar tissue thickness during non-breeding season and similar observations were recorded earlier (Ebada *et al.* 2012) suggesting a pivotal role of poll glands in seasonal sexual activity in male camels. Scanning electron microscopy revealed that the luminal surface of secretory cells was covered with microvilli and that secretory cells pinched off smooth-surfaced apocrine blebs (Atoji *et al.* 1998).

4. Physiology of reproduction in male camels

4.1 Sexual behavior

4.1.1 Pubertal sexual behavior

Young males may show sexual interest (show sexual desire) in females at 1 year of age, but they are incapable to mate due to adhesion of the penis to the prepuce (Gombe & Odour-Okelo, 1977; Abdel Rahim, 1997). The adhesions separate at about 124-136 weeks of age with small drops of blood oozing at separation (Abdel-Rahim, 1997). The complete shedding of the peno-preputial adhesions does not occur until puberty is reached (Marai *et al.* 2009). Such anatomical change is accompanied with a hormonal shift and is essentially an androgen-induced phenomenon influenced by the plane of nutrition (Fernandez-Buca, 1993; Sumar, 1996). Increasing amounts of testosterone produced from the testes as the animal matures induces the development of secondary sexual characteristics; in addition, it allows the animal to grow. At 3 years, all males are without penile adhesions and puberty occurs at 3-4 years (Beil, 1999).

The full reproductive potential of the male camel is reached at 5-6 years (Novoa, 1970; Vyas and Pareek, 1982). However, Al-Qarawi et al. (2001) reported that the first ejaculum that contains high concentrations of spermatozoa is produced at 6 years old in a dromedary camel. Full overt sexual activity may be delayed until 6-8 years (Novoa, 1970; Khanvilkar *et al.* 2009). Physiological capacity may increase up to 10 years, then remains at a constant or fairly high level until 18-20 years of age (Yasin and Wahid, 1957; Matharu, 1966).

4.1.2 Sexual behavior in adult camels (Rut)

Behavioral changes are observed in male camels during the breeding season and the camel is called as being in rut or *musth (Persian)* (Vyas and Pareek, 1982; El-Wishy, 1988). The peculiar features of rut behavior have been classified as aggressiveness, soft palate ejection, marking, urine spraying, smudging, and female seeking (Skidmore, 2000). Detailed descriptions on the rut behavior were mentioned previously (Khan and Kohli, 1972; Vyas and Pareek, 1982; Vyas *et al.* 2001) and tabulated later (Padalino *et al.* 2013) (Table 6). Sexual behaviors in bactrian camels in rut were like those in dromedary camels (Lensch, 1999), however, Vyas *et al.* (2015) observed no signs of rut in Bactrian camels in Ladakh (India) kept exclusively for riding with no females in vicinity.

Aggressiveness

Manifestation of rut is accompanied with many of the masculine signs: fighting instincts are aroused, control is difficult or impossible, and males become hostile to each other and noisy (Vyas and Pareek, 1982; Abdul Mohsen *et al.* 2018). In mixed herds, after initiation of rutting, usually one male becomes dominant due to his size or fighting ability. At the same time, subdued males quickly go out of rut or show reduced activity (Abdul Mohsen *et al.* 2018). However, rutting males are more preoccupied with females than with other males. In full rut, males grind their teeth, suck air, belch, draw the head back, raise the upper lip, lash the tail, crouch with jerky movements of the pelvis, and generally make themselves look strange (Vyas and Pareek, 1982; Hafez and Hafez, 2001). Sexual desire can be diminished or quelled, if sexually active males (rutting) are put on hard work (Mukasa-Murgewa, 1981). Males that are confined show increased pacing and anxiety and may make several attempts to break out of the corral or pen (Skidmore, 2000). If they are kept with females, they spend most of their time guarding the herd and surveying it for the presence of other strange males (Skidmore, 2000). Camels in ruts are potential dangers to the handlers and they should exercise sufficient care to avoid bites from males and injuries due to their aggressive behavior (Padalino *et al.* 2015). Proper training and management would probably reduce such behavior in camels and improve camel welfare and production (Padalino *et al.* 2015). Dietary supplementation of 40g active dried yeast was suggested in a recent study to reduce the aggressiveness of male camels during the rutting season (El-Shoukary and Mahmoud, 2021).

Soft palate ejection

The male in the rut extrudes off the soft palate (gula or dullah) from its mouth by filling air from the trachea (Arnautovic and Abdelmagid, 1974; Khan and Kohli, 1972). The protrusion of the soft palate occurs all day long at intervals of 15 - 30 minutes and is accompanied by loud gurgling and roaring sounds (Vyas and Pareek, 1982). The protrusions become more frequent with increased excitement such as the presence of other males and females (Khan and Kohli, 1972; Sharma and Vyas, 1981). During copulation, the soft palate ejection may be replaced by grinding of the teeth and frothing of the mouth. This frothing is generally attributed to increased secretion of the salivary glands and the frequent exteriorization of the soft palate (Khan and Kohli, 1972). Air is retained for about 5 to 10 seconds, after which it is expired with a gurgling sound, the pressure is released, and the gula

Table 6: Description of typical sexual behavior in the male dromedary camels (Vyas *et al.* 2001; Padalino *et al.* 2013)

Behavior	**Definition**
Sniffing	The dromedary camel male sniff female perineal region and or the vulva
Nervousness	Increased pacing, anxiety, and sound loading
Flehmen	After sniffing the female vulva, the male raises the head and curls upper lip for few seconds
Grinding of teeth / whishtling	The male moves the lower jaw to the left and right side, with closed mouth, grinding the teeth and producing a typical squeaking/whistling sound
Yawing	An involuntary sequence consisting of mouth opening deep inspiration, brief apnea, slow expiration
Urinating	The dromedary male assumes the urinating position, with the spread hind legs and emits small quantity of urine
Opened leg	Before, during and urination the sire stands with opened hind legs
Tail flapping /beating	The tail held under the prepuce and then it is beaten up and down 4 to 5 times, spreading urine over the croup and surrounding areas
Poll Gland Secretion	The occipital poll glands become thick and large and produce a tarry and dark secretion that color occipital area and first part of the neck
Neck rubbing	The male rubs the neck, occipital area, on walls, trees, fence bars etc
Blathering	Emissions of typical metal and gurgling sound
Dulaa extrusion	Exteriorization of the soft Plates usually named “dulaa”

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collapses. The dullah appears as a pinkish organ on one side of the mouth and remains visible for 1-3 minutes (Vyas and Pareek, 1982). The male produces a gurgling sound during the extrusion of dullah with plenty of salivary froth (Vyas and Pareek, 1982). The typical gurgling sound is produced by camels in rut and is termed blathering (Vyas *et al.* 2001; Padalino *et al.* 2013).

Marking

Skidmore (2000) considers that this is one of the main sexual behaviors exhibited during the breeding season. It generally takes on two forms: that of (i) urine spraying and (ii) smudging of poll gland secretions.

Urine Spraying

This behavior is generally increased in the presence of another male or when females are passing nearby (Skidmore, 2000). A camel in rut stands with hind legs apart, flapping the tail up and down with frequent micturition and splashing urine over the back again and again (Vyas and Pareek, 1982). During urine spraying, the dromedary assumes the crouched urination posture and urine is ejected towards the back in small quantities and spread over the croup of the animal and surrounding areas with regular tail beating. The tail is held under the prepeutial opening for a few seconds and soaked with a stream of urine which then is sprayed by 4 to 5 beats of the tail (Skidmore, 2000). This spraying activity is continued throughout the day and often the skin over the sacral region becomes dark and thickened due to the formation of a crust of mixed urine and sand (Vyas and Pareek, 1982).

Smudging

Skidmore (2000) mentioned the increased secretion of poll glands in male camels in rut as smudging. The secretions are light brown/amber in color when first excreted but become tarry and dark after a few minutes. It can easily be seen dribbling down the neck of the male and has a very strong smell (Vyas and Pareek, 1982). The area corresponding to the poll glands becomes large and darkened due to this increased activity. Yagil and Etzion (1980) found that in the months of January to April large amounts of testosterone were found in the poll glands (34-36 ng/ml compared with ~0 ng/ml throughout the remaining months). The poll glands were considered apocrine with the ability to uptake and concentrate circulating hormones (Taha *et al.* 1994). Physical damage to the poll glands or castration resulted in a significant decline in plasma testosterone concentrations and a decline in the sexual activity of male camels (Sareha, 1998), suggesting a pivotal role of this gland in the androgen activity of camels. The functions of these glands continue to be poorly understood, although the secretory activity of these glands was noticed to be increased in males with increased testicular function during the rutting season (Tingari and George, 1984). The poll gland secretion has been reported to contain some types of pheromones (Skidmore, 2005) and these hormones are believed to mark a mating area for the male in a certain herd. Recently, poll gland secretion has been found to display potent antioxidant activity (Batdorj *et al.* 2017). It has also been found that the poll gland of the rutting male Bactrian camel is bigger, and its secretion contains antioxidant activity which is correlated with its protein level (Nomin *et al.* 2017).

Female Seeking

During the breeding season, male camels continue to seek receptive females. They sniff the perineum and flank of the females and frequently display a Flehmen reaction (Yagil and Etzion, 1980). Males that roam freely with females will often chase them and force them to sit down by putting pressure on the neck and biting the hump, even if they are not receptive (Skidmore, 2000).

Other behaviors

The rutting dromedary displays a frequent rolling and rubbing activity of the neck on small bushes or on sand, especially when introduced into a new environment to disseminate the secretions (Skidmore, 2000). Camels in rut become nervous and easily excitable and evidence flehmen (Padalino *et al.* 2013).

Weight loss

As the season advances, males' loose conditions and tend to go off feed and sometimes evidence mild diarrhea (Vyas and Pareek, 1982; Bhakat, 2005). Because of this continuous stress, there is a reduction in food intake and frequent diarrhea resulting in a loss in weight - sometimes up to 35%

(Vyas and Pareek, 1982). This probably occurs due to increased sexual interest, loss of electrolytes in froth and diarrhea and appears to be a nature's adjustment for reducing the weight of male camels for easy performance of mating that occurs in a sitting position with both male and female facing the same direction (Vyas and Pareek, 1982).

Effects of housing on the rut of male camels

Housing is known to have distinct effects on the behavior of male camels. Higher stocking densities of 5 male camels on 60 m^2 of pen had a bad effect on aggression, body condition score, and sexual performance of male camels during the rut period (El-Shoukary *et al.* 2020). Improved housing with ample space availability had positive effects on the sexual behavior of male camels (Fatnassi *et al.* 2014). For camels housed in boxes in Tunisia and fed judiciously, testosterone levels and expression of sexual behaviors were stimulated by visual and olfactory contacts with females (Aube *et al.* 2017). Movement control had significant effects on blood serum metabolites and hormone concentrations. Fenced and exercised male dromedaries had better sexual behavior and higher ($p < 0.05$) concentrations of blood serum transaminases, free radicals, glucose, cholesterol, and testosterone and lower ($p < 0.05$) concentrations of cortisol and triiodothyronine (T3) than tied male dromedaries in Egypt (El-Shoukary *et al.* 2020).

An increase also occurs in each of the accessory gland sizes and secretions, but such increase was striking in the number of poll gland secretion (Merkt *et al.* 1990).

4.2 Male camel endocrinology

4.2.1 Testosterone

After attaining puberty (3.5 years), the testosterone concentrations increased annually in camels to reach a maximum at 10 years of age and declined precipitously after 13 years (El-Harairy and Attia, 2010). In prepubertal and post-pubertal camels, the testosterone concentrations were 0.31 ± 0.05 ng/mL and 2.92 ± 0.37 ng/mL, respectively (El-Haraiary and Attia, 2010). Physiologically, the onset of rut is marked by an increase in activity in the alpha and beta secreting cells in the anterior pituitary, which have a priming action on the gonads (Ainani *et al.* 2018). Age related changes in plasma testosterone concentrations were recorded in camels. Plasma testosterone concentrations (mean+/-S.E.) did not exceed 1.4 ng/ml in prepubertal animals with a 3-4-fold increase in peripubertal (3.2+/-0.4 ng/ml) and mature (4.8+/-0.6 ng/ml) camels (5-<15 years) followed by about 50% decrease (2.6+/-0.3 ng/ml) in aged ones (>/=15 years) (Al-Qarawi *et al.* 2000). Peak testosterone (T) concentrations occur in mature camels during the breeding (winter) season and different reports depicted low testosterone concentrations during the non-breeding (summer) seasons (Table 7). The rise in T concentration is negatively correlated with the environmental temperature and rainfall (Deen, 2008; Farh *et al.* 2018). Libido in males subsides in March or April, and cessation of libido and ability to copulate appears to be associated with a decline in T concentration (Deen *et al.* 2005). In addition, the elevation of the ambient temperature during summer (non- rutting season) seemed to play the main role in affecting camel reproductive activities through disturbance of testis function (Maha *et al.* 2016).

Hormonal changes associated with rut in camels during the rainy season in Somalia include increased corticoids and testosterone (Bono *et al.* 1989). The increase in testosterone was associated with increased steroidogenic enzymes in the testes (Bedrak *et al.* 1983). The average plasma levels of androgens recorded in males ranged from 42.63 ± 97.38 to 1072.00 ± 500.13 pg/ml. The lowest levels were found during the dry season, and the highest levels during the rainy season (Bono *et al.* 1989). High testosterone concentrations tend to increase the libido (El-Kon *et al.* 2011) and the secretory activity of accessory sex glands. Immunohistochemical studies showed that the distribution of mucous secretion varied between rutting and non-rutting seasons and even among the reproductive organ itself. However, the highest secretory activity was found during the rutting season in the ampulla of ductus deferens, disseminated part of the prostate, and bulbourethral gland (Abdulhakeem *et al.* 2021).

Like camel, buffalo bulls tend to show peak libido during winter months (Javed *et al.* 1998), however, studies also reflected that buffalo bulls had good sexual behavior scores throughout the year with better sexual behavior during winter compared

Table 7: Circulating levels of testosterone (ng/mL) in rutting (winter) and non-rutting periods (summer) in male camels

Winter	Summer	Reference
7.56 ± 0.20	2.32 ± 0.15	Maha *et al.* 2016
13.49 ± 1.37	1.58 ± 0.30	Pasha *et al.* 2015
1.63 ± 0.37	3.43 ± 0.37	Al-Saiady *et al.* 2015
42.13 ± 2.11	2.13 ± 1.08	Deen *et al.* 2005
8.23 ± 2.12	7.88 ± 1.72	El-Khasmi *et al.* 2011
7.95 ± 1.85	2.89 ± 0.26	El-Bahrawy and El-Hassanein, 2011
2.74 ± 0.48	1.11 ± 10.25	El-Harairy and Attia, 2010
14.52 ± 2.12	7.88 ± 1.72	El-Kon *et al.* 2011
30.0	02	Yagil and Etzion, 1980
9 + 1	02 + 0.5	Madhi *et al.* 2022
1.92 ± 0.61a	0.99 ± 0.27b	Zia-ur Rahman *et al.* 2007
1.73 ± 0.81	0.69 ± 0.19	Agarwal *et al.* 1987

to summer (Singh *et al.* 2013; Parmar *et al.* 2019). Improvement in semen quality was recorded with better management including provision of mist cooling (Singh *et al.* 2013). The testosterone concentrations in buffalo bulls are lower compared to camels with concentrations ranging from 0.35 to 1.65 ng/ml with peak concentrations in the months of August to December and lowest in May (Perera *et al.* 1979). Another study, however, recorded higher testosterone concentrations in Murrah buffalo bulls during summer compared to winter months (Dixit *et al.* 1985). Thus, male camels have more distinct effects of the season on testosterone.

In camel's, testosterone affects the testicular morphology and function. Significantly higher values of scrotal circumference paired testicular weight and paired testicular volume were recorded during the rutting season (Gherissi *et al.* 2016).

Peak testosterone production occurred in camels at 25.5 degrees C and a relative humidity of 0.75 (Gombe and Odour-Okelo, 1977). Testosterone levels and expression of sexual behaviors were stimulated by visual and olfactory contacts of females and were positively correlated ($r = 0.164$, $P = 0.040$) (Aube *et al.* 2017).

Synchronous with rise in serum testosterone concentrations, concentrations also rise in the poll glands which become active and secrete dark brown material with a pungent odor that is considered to attract females (Yagil and Etzion, 1980; Tingari *et al.* 1984b). Elevated testosterone concentrations are accompanied by increased sexual behavior, seminal volume, and sperm output (Zia-Ur-Rahman *et al.* 2007; El-Kon *et al.* 2011; Pasha, 2015).

Exposure to females improves testosterone concentrations. Overall, 17 h of exposure led to an increase in testosterone and cortisol levels, enhancing sexual behavior and semen color (Fatnassi *et al.* 2021).

In GnRH-treated bulls, testosterone levels showed an upward trend, peaking after 140 minutes, and then slowly decreasing. GnRH administration also led to a decrease in mating time and an increase in spermatozoa concentration. Overall, it seems that administration of 100 µg GnRH might increase testosterone levels temporarily and enhance camel reproductive performance (Monaco *et al.* 2015).

Motility and viability of camel epididymal spermatozoa collected during the rutting season were significantly ($P< 0.05$) higher than that during non-rutting season (Ibrahim Z *et al.* 2016). A new finding in free-ranging dromedary male camels was the hypothermia observed during the rutting season (Grigg *et al.* 2009). One study determined the testosterone concentrations in camels' premating, at mating, and post- mating periods with non-significant changes (14.14±0.58, 26.26±0.85 and 24.03±1.0 ng/mL respectively) during the breeding season (Abdulla *et al.* 2020)

The composition of the blood also appears to be affected by rut. Haemoglobin decreases significantly ($P<0.01$) and leucocytes (white blood cells) increase and the number of erythrocytes (red blood cells) decreases insignificantly (Khan and Kohli 1978; Agarwal *et al.* 1987a; Faraz *et al.* 2021), during the rutting.

4.2.2. Thyroidal hormones and cortisol

Serum levels of both thyroxine (T4) and tri-iodothyroxine (T3) were found to be significantly higher during the rutting than during the non-breeding season and T4: T3 ratio was almost double during the rutting season (Agarwal *et al.* 1987). Similarly, many later reports observed higher concentrations of thyroidal hormones in male camels during winter compared to summer months (Maha *et al.* 2016; Rejeb *et al.* 2011; Tajik *et al.* 2013; Bargaa *et al.* 2016a) and were considered an adaptation to the cold environment (Bargaa *et al.* 2016a). During the cold environment, higher metabolic rates are required, and this probably affects the thyroidal hormones (Farh *et al.* 2018). However, a few reports observed higher thyroidal hormones during summer in camels (Nazifi *et al.* 1999; Zia-ur-Rahman *et al.* 2007) and higher cortisol (Zia-ur Rahman *et al.* 2007) and were postulated to be due to increased interest of males in searching females and less interest in food intake (Zia-ur-Rahman *et al.* 2007).

Studies also found that the age and rutting season influenced steroids, cortisol, and thyroid hormone levels in dromedary male camels (Ibrahim N *et al.* 2017). The thyroid hormones (T3 and T4) levels increased significantly ($P < 0.05$) in the rutting than the non-rutting season.

In dromedary camels, the cortisol levels determined in serum, hair, and feces (Bargaâ *et al.* 2016) in the winter and rainy seasons (rutting season) were significantly higher than those measured in summer (non-rutting season). However, Bono *et al.* 1989, noticed that the average corticoid levels in male camels varied considerably and ranged from 5.45±2.99 ng/ml to 62.03 ± 37.02 ng/ml. High levels were found particularly during the dry season.

4.2.3 LH

The serum concentrations of LH varied non-significantly between peri-pubertal male camels of 3 years of age fed a diet containing 13% crude protein (0.95±0.13 IU/L) or a routine diet (1.08±0.13 IU/L) in Saudi Arabia (Al-Saiady *et al.* 2015). Average LH levels in adult camels were around 0.48 + 0.27 ng/ml and 1.06 + 0.36 ng/ml with constant fluctuations between the different months of the year (Bono *et al.* 1989). Significant increases were found in the LH and testosterone concentrations during the rutting season compared to non-rutting season in male camels (Madhi *et al.* 2022). The elevations in these hormones were attributed to the direct effect of the season on the activity of the pituitary glands, especially the LH, which is responsible for testosterone secretion from the Leydig cells (Al-Bulushi *et al.* 2019).

CONCLUSION

It was concluded that male camels have some special anatomic and physiologic features of reproduction not observed in other domestic species.

REFERENCES

Abd-Elaziz, M.I., Kassem, A.M., Zaghloul, D.M., Derbalah, A.E. and Bolefa, M.H. 2012 Ultrastructure of the interstitial tissue in the testis of Egyptian dromedary camel (*Camelus dromedarius*). *Pak. Vet. J.*, **32**: 65-69.

Abd-Elmaksoud, A., Sayed-Ahmed, A., Kassab, M. and Aly, K. 2008. Histochemical mapping of glycoconjugates in the testis of the one humped camel (*Camelus dromedarius*) during rutting and non-rutting seasons. *Acta Histochem.*, **110**(2): 124–133.

Abd-Elmaksoud, A.S., Ebada, S.M. and Shoaib, M.B. 2012. Localisation of cytokeratin and smooth muscle actin in the accessory genital glands of camels (*Camelus dromedarius*) during rutting and non-rutting seasons. *Bulg. J. Vet. Med.*, **15**: 213–227.

Abdel-Maksoud, F.M., Husein, M.T. and Attai, A.R. 2019. Seasonal Variation of the Intraepithelial Gland in Camel Epididymis with Special Reference to Autophagosome. *Microscopy Microanalysis*, **25**: 1052–1060.

Abdel-Rahim, S.E.A. 1997. Studies on the age of puberty of male camels (*Camelus dromedarius*) in Saudi Arabia. *Vet. J.*, **154**: 79-83.

Abdel-Rahim, S., Abdel-Rahman, E. and El-Nazier, A.E. 1994. Production and reproduction of one-humped camel in Al-Gassim region, Saudi Arabia. *J. Arid. Environ.*, **26**: 53-59.

Abdel-Raouf, M., El-Bab, F.M.R. and Owaida, M.M. 1975. Studies on reproduction in the camel. *J. Reprod. Fertil.*, **4**: 109-116.

Abdel-Raouf, M., Fateh El-Bab, M.R. and Awaida, M.M. 1975. Studies on reproduction in the camel (*Camelus dromedarius*). V. Morphology of the testis in relation to age and season. *J. Reprod. Fertil.*, **43**: 109-116.

 Print ISSN: 2249-6610

Abdel-Raouf, M. and E1-Naggar, M.A. 1976. Studies on reproduction in camels (*Camelus dromedarius*).VI. Properties and constituents of ejaculated semen. *Proc. 8th Int. Congr. Anim. Reprod. and A.I.*, Cracow, pp. 862-865.

Abdel-Raouf, M. and Owaida, M.M. 1974. Studies on reproduction in camels (*Camelus dromedarius*). IV. Gross changes in the morphology of the testis in relation to age and season. *Assuit Vet. Med. J.*, **1**: 215-223.

Abdul Mohsen, M., Al-Shami, S.A., Al-Sultan S. and Al-Ekna M. 2018. Evaluation of mating and the causes of noises at night in small dromedary camel herds. *Emirates J. Sci. Food Agric.*, **30**(8): 709-714.

Abdulhakeem, E., Abdulrahman, A., Marzook, A.E., El-Bahr and Sabry, M. 2021. Immunohistochemical localisation of mucin 1 in male reproductive organs of dromedary camels during rutting and non-rutting seasons. *J. Camel Prac. Res.*, **28**(22): 161-168.

Abdulla, A.K., Al-Bdeery A.H.J. and Ali, B.H.A. 2020. Effect of blood sampling method during a mating time in male camels (dromedary camels). *Plant Arch.*, **20**(1): 1681-1686.

Abdullahi, H. El. J. 1970. On the anatomy of the male genital system of the one-humped camel (*Camelus dromedarius*). M.V.Sc. thesis in university of Khartoum.

Abdul-Raouf, M., El-Bab, M.R.F. and Owaida, M.M. 1995. Studies on Reproduction in the camel (*Camelus dromedarius*) V. Morphology of the testis in relation to age and season. *J. Reprod. Fertil.*, **43**: 109-116.

Abu-Ahmed, M.M., Seida, A.A., Ghallab, A.M., Ismail, S.T. and ElWisy, A.B. 1988. Effects of age and season on weight and some biochemical attributes of the accessory genital glands of the one-humped camel (*Camelus dromedarius*). *Zuchthygiene*, **23**: 26-32.

Agarwal, S.P., Agarwal, V.K., Khanna, N. and Dwarknath, P.K. 1987. Profiles of steroid hormones in male camel. *Indian J. Anim. Sci.*, **57**: 659-61.

Agarwal, S.P. and Khanna, N.D. 1990. Endocrine profiles of Indian camel under different phases of reproduction. In: Proceedings of the workshop "Is it possible to improve the reproductive performance of the camel?" Paris, pp. 77–100.

Ainani, H., Achabaan, M.R., Tibary, A., Pevet, P., Simmoneaux, V. and El-Allali, K. 2018. Environmental and neuroendocrine control of breeding activity in the dromedary camel. *Rev. Mar. Sci. Agron. Vét.*, **6**(2): 143-157.

Al-Bulushi, S., Manjunatha, B.M., de Graaf, S.P. and Rickard, J.P. 2019. Reproductive seasonality of male dromedary camels. *Anim. Reprod. Sci.*, **202**: 10-20.

Al-Eknah, M.M. 2000. Reproduction in old world camels. *Anim. Reprod. Sci.*, **60-61**: 583-592.

Ali Abdullahi, I., AL-hassanmusa, H. and Jibril, A. 2012. Scrotal circumference and testicular morphometric characteristics of the camel (*Camelus dromedarius*) in the Semi- Arid Environment of Northern Nigeria. *Int. J. Morphol.*, **30**(4): 1369-1372.

Ali, H.A., Moniem, K.A. and Tingari, M.D. 1976a. Some biochemical studies on the prostate, urethral and bulbourethral glands of the one-humped camel (*Camelus dromedarius*). *J. Histochemistry Cytochem.*, **8**: 565-578.

Ali, H.A., Moniem, K.A. and Tingari, M.D. 1976b. Some histochemical studies on the prostate, urethral and bulbourethral glands of the one-humped camel (*Camelus dromedarius*). *Histochem. J.*, **8**: 565-578.

Ali, H.A., Tingari, M.D. and Moniem, K.A. 1978. On the morphology of the accessory male glands and histochemistry of the ampulla ductus deferentis of the camel (*Camelus dromedarius*). *J. Anat.*, **125**: 277-292.

Ali, S., Ahmad N., Akhtar N., Rahman Z. and Sarwar M. 2007. Effect of season and age on the ovarian sizeand activity of one-humped Camel (*Camelus dromedarius*). *Asian Australasian J. Anim. Sci.*, **20**(9): 1361-1366

Alkafafy, M., Rashed, R., Emara, S., Nada, M. and Helal, A. 2011. Histological and immunohistochemical studies on the epididymal duct in the dromedary camel (*Camelus dromedarius*). *Anat. Cell. Biol.*, **44**(4): 284-94.

Almquist, J.O. and Amann, R.P. 1961. Reproductive capacity of dairy bulls. II. Gonadal and extra-gonadal sperm reserves as determined by direct counts and depletion trials; dimensions and weight of genitalia. *J. Dairy Sci.*, **44**: 1668-1678.

Al-Qarawi, A.A., Abdel-Rahman, H.A., El-Belely, M.S. and El-Mougy, S.A. 2000. Age-related changes in plasma testosterone concentrations and genital organs content of bulk and trace elements in the male dromedary camel. *Anim. Reprod. Sci.*, **62**: 297–307.

Al-Qarawi, A.A., Abdel-Rahman, H.A., El-Belely, M.S. and El-Mougy, S.A. 2001. Intratesticular morphometric, cellular and endocrine changes around the pubertal period in dromedary camels. *Vet. J.*, **162**: 241–249.

Al-Qarawi, A.A., Abdel-Rahman, H.A., El-Belely, M.S. and El-Mougy, S.A. 2000. Age-related changes in plasma testosterone concentrations and genital organs content of bulk and trace elements in the male dromedary camel. *Anim. Reprod. Sci.*, **62**(4): 297-307.

Al-Qarawi, A.A. and ElMougy, S.A. 2008. Seasonality and the melatonin signal in relation to age as correlated to the sexual cycle of the one humped male camel (*Camelus dromedarius*). *Biol. Rhythm Res.*, **39**(2): 131-142.

Al-Saiady, M.Y., Mogawer, H.H., Al-Mutairi S.E., Bengoumi M., Mussad. A, Gar-Elnaby, A. and Faye, B. 2013. Effect of different feeding system on body weight, testicular size developments, and testosterone level in pre-pubertal male camel (*Camelus dromedarius*). *African J. Agric. Res.*, **22**: 2631-2636.

Arnautovic, I. and Abdelmagid, A.M. 1974. Anatomy and mechanism of distension of gula of one humped camel. *Acta. Anat.*, **88**: 115-124.

Arthur, G.H., Rahim, A.T.A. and Al-Hindi, A.S. 1982. The Camel in Health and Disease. (7). Reproduction and Genital disease of the Camel. *British Vet. J.*, **141**: 651-659.

Atoji, Y., Sayed, R., Yamamoto, Y. and Suzuki, Y. 1998. Poll glands of the one-humped camel (*Camelus dromedarius*): histochemical and scanning electron microscopic study. *European J. Morph.*, **36**: 29-36.

Aubè, L., Fatnassi, M., Monaco, D., Khorchani, T., Lacalandra, G.M., Hammadi, M. and Padalino, B. 2017. Daily rhythms of behavioral and hormonal patterns in male dromedary camels housed in boxes. *Peer J.*, **5**: e3074.

Batdorj, B., Purev, M., Bayandorj, T., Lkhagvasuren, D. and Tsendsuren, O. 2017. Chemical Composition and antioxidant activity of thepoll gland secretions of the bactrian camel (*Camelus bactrianus*). *Central Asian J. Med. Sci.*, **3**(2): 132–139.

Bedrak, E., Rosenstrauch, A., Kafka, M. and Friedlander, M. 1983. Testicular steroidogenesis in the camel (*Camelus dromedarius*) during the mating and the non-mating seasons. *Gen. Comp. Endocrinol.*, **52**: 255-264.

Beil, C. 1999. Reproduction in female camels (*Camelus dromedarius* and *Camelus bactrianus*). Thesis, Tierarztliche Bochschule Hannover, Hannover, Germany, pp. 180.

Bello, A. and Umaru, M.A. 2013. An overview on the anatomy and physiology of male one humped camel (*Camelus dromedarius*) reproductive system. *Sci. J. Rev.*, **2**(12): 340-347.

Bhakat, C., Raghvendra, S. and Sahani, M.S. 2005. Effect of different management conditions on rutting behavior of Indian dromedary camel. *Emirates J. Agric. Sci.*, **17**(2): 01-13.

Bhakat, C. 2006. Camel production and management. In: Chakrabarti Ed. Handbook of animal husbandry sciences. Kalyani Publishers New Delhi, pp. 260-280.

Bissa, U.K., Rai, A.K. and Khanna, N.D. 1988. Testicular descent and development of scrotum in camel calves of Bikaneri breed. *Indian J. Anim. Sci.*, **58**(10): 1200-1201.

Bono, G., Dahir, M., Comin, A. and Jumale, M.A. 1989. Plasma LH, corticoid and sex steroid variations in camels (*Camelus dromedarius*) in relation to seasonal climatic changes. *Anim. Reprod. Sci.*, **21**: 101-113.

Charnot, Y. 1965. Sexual endocrinology and dehydration in the male dromedary. *C.R. Seances Soc. Biol.*, **159**: 1103-1105 (Anim. Breed. Abstr. 34, No. 1608, 1966).

Charnot, Y. 1963. Synchronization of growth of the palatal expansion and the testis during the sexual cycle in the dromedary. *Bull. Soc. Sci. Nat. Physiol. Moroc.*, **43**: 49-54 (Anim. Breed. Abstr. 34, No. 1607, 1966).

Coulter, G.H., Mapletoft, R.J., Kozub, G.C. and Cates, S. 1987. Scrotal circumference of two-year-old bulls of several beef breeds, *Theriogenology*, **27**(3): 485-491.

Dafalla, E.A. and El-Eknah, M.M. 1993. Age of puberty in Najdi camels. Proceedings of the 14th Saudi Biological Symposiun. Jeddah 16-18 Feb. Saudi Biological Society. dans la function de reproduction chez la chamelle (*Camelus dromedarius*). Thèse de doctorat.Faculté universitaire des sciences agronomique Gembloux, Belgique, pp. 160.

Degen, A.A. and Lee, D.G. 1982. The male genital tract of the dromedary (one-humped camel). Gross and miscropic anatomy. *Zentralbl. Veterinaermed. Reihe.*, **11**: 267-282.

Dholpuria S, Purohit, G.N. and Vyas, S. 2021. Exogenous melatonin administration improves behavioural signs, serum melatonin, testosterone, and semen quality in male dromedary (*Camelus dromedarius*) camels. *Reprod. Fertil. Dev.*, **33**(2): 160.

Dholpuria, S., Vyas, S., Purohit, G.N. and Pathak, K.M. 2012. Sonographic monitoring of early follicle growth induced by melatonin implants in camels and the subsequent fertility. *J. Ultrasound.*, **15**(2): 135-41.

Dioli, M., Schwartz, H.J. and Steimmelmayr, R. 1992. Management and handling of the camel. *In:* Schwartz HJ and Dioli M (Eds). The one-humped camel in eastern Africa: A pictorial guide to diseases, health care and management. Verlagjosef margrave Scientific Books, Germany, pp. 62-68.

Dixit, N.K., Agarwal, S.P., Agarwal, V.K. and Dwaraknath, P.K. 1985. Seasonal variation in serum levels of steroid hormones and their relationship with seminal quality and libido in buffalo bulls. *Theriogenology*, **24**(3): 293-303.

Ebada, S., Helal, A. and Alkafafy, M., 2012. Immunohisto-chemical studies on the poll gland of the dromedary camel (*Camelus dromedarius*) during the rutting season. *Acta Histochemica*, **114**: 363-369.

El Allali, K., Achaâban, M.R., Vivien-Roels, B., Bothorel, B., Tligui, N.S. and Pévet, P. 2005. Seasonal variations in the nycthemeral rhythm of plasma melatonin in the camel (*Camelus dromedarius*): seasonal plasma melatonin in the camel. *J. Pineal Res.*, **39**: 121–128.

El Allali, K., Sghiri, A., Bouâouda, H., Achaâban, M.R., Ouzir M., Bothorel, B., El Mzibri, M, El Abbadi, N., Moutaouakkil, A., Tibary, A. and Pévet, P. 2018. Effect of Melatonin Implants during the Non-Breeding Season on the Onset of Ovarian Activity and the Plasma Prolactin in Dromedary Camel. *Front. Vet. Sci.*, **5**: 44.

El Naggar, M.A. and Rath, H.M.D. 1990. Anatomy and physiology of reproduction. *In:* Rath *et al.* Eds. Reproduction in camels A review FAO production and health paper 82.

El Shoukary, R.D. and Mahmoud, F.A. 2021. Effect of Dietary Yeast on Male Dromedary Camels During the Rut: Behavioral and Biochemical Insights. *Asian J. Anim. Vet. Adv.*, **16**: 20-29.

El-Harairy, M.A. and Attia, K.A. 2010. Effect of age, pubertal stage, and season on testosterone concentration in male dromedary camel. *Saudi J. Biol. Sci.*, **17**: 227-230.

El-Jack, A.H. 1980. The anatomy of the male genital system of the one-humped camel (*Camelus dromedarius*). *Anat. Histol. Embryol.*, **9**: 92.

El-Khasmi, M., Riad, F., Safwate, A., Tahri, E.H., farh, M., El-Abbadi, N., Coxam, V. and Faye, B. 2011. Circulating levels of 25-hydroxyvitamin D and testosterone during the rutting and non-rutting periods in Moroccan dromedary camels (*Camelus dromedarius*). *Emir. J. Food. Agric*., **23**(4): 368-374.

El-Kon I.I., Heleil, B.A. and Mahmoud, S.A. 2011. Effect of age and season on the testicular sperm reserve andtestosterone profile in camel (*Camelus dromedarius*). *Anim. Reprod.*, **8**: 68-72.

Print ISSN: 2249-6610

El-Mahdy, A.M.M., El-Darawany, A.A., Zeidan, A.E. and Peris, S.I.E. 2019. Testicular changes and sperm characteristics in the different dromedary camel breeds during the breeding and non-breeding seasons. *Zagazig J. Agric. Res.*, **46**(6B): 2359-2370.

El-Shoukary, R.D., Nasreldin, N., Osman, A.S., Hashem, N.M., Saadeldin, I.M. and Swelum, A.A. 2020. housing management of male dromedaries during the rut season: effects of social contact between males and movement control on sexual behavior, blood metabolites and hormonal balance. *Anim.*, **10**: 1621 (1-11).

El-Shoukary, R.D., Osman, A.S. and Mohammed, A.A. 2020. Effects of stocking density on some behavioral and some blood biochemical parameters in camel during the rut period. *Egypt. J. Vet. Sci.*, **51**(2): 253-262.

El-Wishy, A.B. 1988. Reproduction in the male dromedary (*Camelus dromedarius*): a Review. *Anim. Reprod. Sci.*, **17**: 217-241.

ElWishy, A.B., Mobarak, A.M. and Fouad, S.M. 1972. The accessory genital organs of the onehumped male camel (*Camelus dromedarius*). *Anat. Anz.*, **131**: 1-12.

ElWishy, A.B. and Omar, A.M. 1975. On the relation between testis size and sperm reserves inthe one-humped camel (*Camelus dromedarius*). *Beitr. Trop. Landwirtsch. Vet. Med.*, **13**: 391-398.

Faraz, A. 2022. Growth Assessment in Camel (*Camelus dromedarius*): A Meta-Analysis Study. *J. Zool. Res.*, **4**(1): 16-21.

Faraz, A., Waheed, A., Tauqir, N.A., Mirza, R.H. and Nabeel, M.S. 2021.Haematological profile of marecha male camel (*Camelus dromedarius*) during rutting and non-rutting season under farming system. *Adv. Anim. Vet. Sci.*, **9**(2): 175-181.

Farh, M., Lektib, I., Bargaa, R., El-Abbadi, N., Riad, F., Tahri, E.H., Safwate, A. and El-Khasmi, M. 2018. Hormonal profile in rutting and non-rutting periods in dromedary camel (*Camelus dromedarius*). *Rev. Mar. Sci. Agron. Vét.*, **6**(2): 168-177.

Fatnassi, M., Padalino, B., Monaco, D., Aube, L., Khorchani, T., Lacalandra, G.M. and Hammadi, M. 2014. Effect of different management systems on rutting behavior and behavioral repertoire of housed Maghrebi male camels (*Camelus dromedarius*) *Trop. Anim. Health Prod.*, **46**: 861-867.

Fernandez-Baca, S. 1993. Manipulation of reproductive functions in male and female New World Camelids. *Anim. Reprod. Sci.*, **33**: 306-323.

Friedlander, M., Rosenstrauch, A. and Bedrak, E. 1984. Leydig cell differentiation during the reproductive cycle of the seasonal breeder *Camelus dromedarius*: An ultrastructural analysis. *Gen. Comp. Endocrinol.*, **55**: 1-11.

Gauthier-Pilters, H. and Dagg, A.I. 1981. The Camel. Univ. of Chicago Press, Chicago, IL.

Gebauer, M.R., Pickett, B.W. and Swierstra, E.E. 1974. Reproductive physiology of the stallion. III. Extragonadal transit time and sperm reserves. *J. Anim. Sci.*, **39**: 737-742.

Gherissi, D.E., Afri-Bouzebda, F. and Bouzebda, Z. 2018. Seasonal changes in the testicular morphology and interstitial tissue histomorphometry of Sahraoui camel under Algerian extreme arid conditions. *Biol. Rhythm. Res.*, **49**(2): 291-301.

Gherissi, D.E., Afri-Bouzebda, F., Bouzebda, Z. and Lamraoui, R. 2014. Morphometric variations and endocrine changes of the one-humped male camel in relation to reproductive activity. *Rumin. Sci.*, **3**(1): 9-18.

Gherissi, D.E., Afri-Bouzebda, F., Bouzebda, Z. and Lamraoui, R. 2016. Testicular Morphology and Stereological Evaluation of the Seminiferous Tubules Around the Rutting Season of Sahraoui Dromedary Camel. *Glob. Vet.*, **17**(6): 568-576.

Gherissi, D.E., Boukhili, M. and Gherissi, A. 2020. Genital histo-morphometrical evaluation and survey on reproductive traits of male camel (*Camelus dromedarius*) in relation to the pubertal age under extreme arid conditions. *Asian J. Agric. Biol.*, **8**(4): 436-446.

Glover, T.D. and Nicander, L. 1971. Some aspects of structure and function in the mammalian epididymis. *J. Reprod. Fertil., Suppl.*, **13**: 39-50.

Gombe, S. and Oduor-Okelo, D. 1977. Effect of temperature and relative humidity on plasma and gonadal testosterone concentrations in camels (*Camelus dromedarius*). *J. Reprod. Fert.*, **50**: 107-108.

Grigg, G., Beard, L., Dörges, B., Heucke, J., Coventry, J., Coppock, A. and Blomberg, S. 2009. Strategic (adaptive) hypothermia in bull dromedary camels during rut; couldit increase reproductive success? *Biology Letters*, **5**(6): 853-856.

Hafez, E.S.E. and Hafez, B. 2001. Reproductive parameters of male dromedary and Bactrian camels. *Arch. Androl.*, **46**: 85–98.

Hammadi, M. 2003. Caracterisation, modulation nutritionnelle et implication du système IGF dans la fonction de reproduction chez la chamelle (*Camelus dromedarius*). Thèse de doctorat. Facultéuniversitaire des sciences agronomique Gembloux, Belgique, pp. 160.

Ibrahim, A.A., Musa, H.A. and Aliyu, J. 2012b. Scrotal circumference and testicular morphometric characteristics of the camel (*Camelus dromedarius*) in the semi-arid environment of northern Nigeria. *Int. J. Morphol.*, **30**(4): 1369-1372.

Ibrahim, D. and Abdel-Maksoud, F.M. 2019. Immunohisto chemical and Ultrastructural Features of the Seasonal Changes in the Epididymal Epithelium of Camel (*Camelus dromedarius*). *Microsc. Microanat.*, **25**: 1273–1282.

Ibrahim, M.A., Abdel-Rahman, H.M.A., Rawash, Z.M. and El-Metwally, E. 2016. Studies on Some Biochemical, Hormonal, Histopathological and Seminal Characters in Relation to Rutting and Non-Rutting Season in Camels. *Alexandria J. Vet. Sci.*, **49**(2): 189-202.

Ibrahim, N.S., Zaid, N.W., Ali, A. and Alwan, A.F. 2017. Comparative study of some hormones during rutting season in dromedary camel. *Al-Qadisiyah J. Vet. Med. Sci.*, **16**(1): 99-105.

Ibrahim, Z.H. and Al-Kheraije, K. 2021. Seasonal morphology and immunoreactivity of cytokeratin and atrial natriuretic peptide in dromedary camel poll glands. *Anat. Histol. Embryol.*, **50**(2): 307-315.

Ibrahim, Z.H., El-Kheraije, K.A. and El-Tigani-Asil, E.A. 2020. Seasonal studies on morphology and immunohistochemical localization of S-100 and alpha smooth muscle actin proteins in poll glands of camel. *J. Camel Prac. Res.*, **27**(1): 39-47.

Ibrahim, Z.H., Joshi, D. and Singh, S.K. 2016. Seasonal immunohistochemical reactivity of S-100 and α-smooth muscle actin proteins in the epididymis of dromedary camel, *Camelus dromedarius. Andrologia.*, **49**: 1–6.

Ibrahim, Z.H. and Singh, S.K. 2014. Histological and morphometric studies on the dromedary camel epididymis in relation to reproductive activity. *Anim. Reprod. Sci.*, **149**(3–4): 212–217.

Igboeli, G. and Rakha, A.M. 1971. Gonadal and extragonadal sperm reserves of indigenous Central African bulls. *J. Reprod. Fertil.*, **23**: 107-109.

Ismail, S.T. 1988. Reproduction in the male dromedary (*Camelus dromedarius*). *Theriogenology*, **29**(6): 1407-1418.

Ismail, S.T. 1979. Factors affecting sperm production in the one-humped camel (*Camelus dromedarius*). M.V.Sc. Thesis, Cairo University, Egypt.

Ismail, S.T. 1982. Studies on the testis and epididymis of the one-humped camel (*Camelus dromedarius*). Ph.D. Thesis, Cairo, University, *Egypt. J.*, **31**: 129–133.

Javed, M.T., Khan, A. and Kausar, R. 1998. Influence of age and season on body mass, scrotal circumference, and sexual behaviour of Nili-Ravi buffalo (*Bubalus bubalis* L.) bulls. *Vet. Arhiv.*, **68**(6): 219-229.

Khan, A.A. and Kohli, I.S. 1972. A study on sexual behavior of male camel (*Camelus dromedarius*). Part I. *The Indian Vet. J.*, **49**: 1007-1012.

Khan, A.A. 1971. Sexual behavior of the male Camel (*Camelus dromedarius*) and some studies on semen. MVSc. thesis, Bikaner University of Udaipur, India.

Khan, A.A. and Kohli, I.S. 1978. A note on some haematological studies on male camel before and during rut. *Indian J. Anim. Sci.*, **48**, 325-336.

Khan, B.B., Iqbal, A. and Riaz, M. 2003. Production and management of camels. Department of Livestock management, University of Agriculture, Faisalabad downloaded from research gate 17th June 2022.

Khanna, N.D., Rai, A.K., Tandon, S.N. and Jindal, H.K. 1987. Camel Reproduction: A Review. *Annals Arid Zone.*, **26**: 143-155.

Khanvilkar, A.V., Samant, S.R. and Ambore, B.N. 2009. Reproduction in camel. *Vet. World*, **2**(2): 72-73.

Kutzler, M., Tyson, R., Grimmes, M. and Timm, K. 2011. Determination of testicular blood flow in camelids using vascular casting and color pulsed wave doppler ultrasonography. *Vet. Med. International*, Article ID 638602, 7 pages doi:10.4061/2011/638602.

Leese, A.S. 1927. Treatise on one humped camel. Mynes and Sons, Lincolshire.

Lensch, J. 1999. The two-humped camel (*Camelus bactrianus*) World Animal Review Series published by FAO [Online]. Avaliable from: http://www.fao.org/docrep/X1700T/X1700T00. htm

Lesbre, J. 1930. Precis d'extgrieur du cheval et des principaux mammifdres domestiques. *Paris, Vigot.*, pp. 597.

Madhi, A.S., Khudhair, N.A. and Alsalim, H.A. 2022. Comparison of reproductive hormone levels in male and female camels (*Camelus dromedarius*) during rutting and non-rutting seasons and their relation with some minerals and antioxidant status. *Caspian J. Environm. Sci.*, **20**(3): 527-532.

Mahmud, A.M., Onu, J.E., Shehu, S.A., Danmaigoro, A. and Ahmad, A.M. 2017. Comparative morphological studies on the penises of one-humped camel bull (*Camelus dromedarius*), uda ram and red sokoto buck. *Vom. J. Vet. Sci.*, **12**: 107 – 112.

Mahmud, A.M., Onu, J.E., Shehu, S.A., Umaru, A., Danmaigoro, A. and Atabo, M.S. 2015b. Morphological studies on epididymis and vas deferens of one - humped camel bull (*Camelus dromedarius*), uda ram and red sokoto buck. *Am. J. Bioscience Bioengineering*, **3**(5): 65-71.

Mahmud, A.M., Onu, J.E., Shehu, S.A., Umaru, A., Danmaigoro, A. and Bello, A. 2015a. Comparative gross and histological studies on testes of one-humped camel bull, uda ram and red sokoto buck. *Int. J. Multidisciplinary Res. Infor.*, **1**(1): 81-84.

Maiada, W.A., Allam, E.B. Abdalla, A.E.B., Zeidan,, M.H., Farouk, Abd El-Salaam, A.M. 2013. Morphological and histological changes in the camel testes in relation to semen characteristics during breeding and non-breeding seasons. *J. Amer. Sci.*, **9**(11s): 74-82.

Maiada, W.A., Allam, E.B. Abdalla, A.E.B., Zeidan, M.H., Farouk, A.M. and Abd El-Salaam. 2013. Morphological and Histological Changes in the Camel Testes in Relation to Semen Characteristics During Breeding and Non-Breeding Seasons. *J. Am. Sci.*, **9**(11s): 74-82.

Manjunatha, B.M., Al-Hosni, A. and Al-Bulushi, S. 2022. Effect of advancing the breeding season on reproductive performance of dromedary camels. *Theriogenology*, **179**: 230-236.

Marai, I.F.M., Zeidan, A.E.B., Abdel-Samee, A.M., Abizaid, A. and Fadiel, A. 2009. Camels' Reproductive and physiological performance as affected by environmental conditions. *Trop. Subtrop. Agroecosystems*, **10**(2): 129-149.

Marie, M.E. 1987. Bases Endocriniennes de La FonctionSexuelle Chez Le Dromadaire (Camelus dromedarius). Thèse de Doctorat de L'Université de Paris, France. (Abstract).

Matharu, B.S. 1966. Camel care. *Indian Farming*, **19**: 16-22.

Merkt, H., Rath, D., Musa, B. and El-Naggar, M. 1990. Reproduction in camels. FAO Anim. Prod. Health Pap., No. 82, Rome.

Mobarak, A.M., El Wishy, A.B. and Samira, M.F. 1990. The penis and prepuce of the one humped camel (*Camelus dromedarius*). *Zbl. Vet. Med. A.*, **19**: 787-795.

Mobarak, A.M., ElWishy, A.B. and Samira, M.F. 1972. The penis and prepuce of the one-humped camel (*Camelus dromedarius*). *Zentralblatt Veterinarmedizin Reihe A.*, **19**: 787-795.

Monaco, D., Fatnassi, M., Padalino, B., Aub´e L, Khorchani, T. *et al.* 2015. Effects of a GnRH administration on testosterone profile, libido and semen parameters of dromedary camel bulls. *Res. Vet. Sci.*, **102**: 212-216.

Mukasa-Mugerwa, E., 1981. The camel (*Camelus dromedarius*): a bibliographical review. LCAR Monograph Int. Livestock Centre for Africa, pp. 11-32.

Musa B., Sieme H., Merkt H., Hago B., Cooper M.J., Allen W.R. and Jöchle, W. 1993. Manipulation of reproductive functions in male and female camels. *Anim. Reprod. Sci.*, **33**: 289-306.

Nomin, M., Badamgarav, T.S., Tserendulam, B. and Batjargal, B. 2017. Effects of poll gland protein secretion of camel (*Camelus bactrianus*) on *in vitro* cancer and non-cancer cell lines. *Proceedings of the Mongolian Academy of Sciences*, **57**(2): 34–43.

Novoa, C. 1970. “Reproduction in Camelidae,” *J. Reprod. Fertil.*, **22**(1): 3-20.

Osman, A.M. and E1-Azab E.A. 1974. Gonadal and epididymal sperm reserves in the camel (*Camelus dromedarius*). *J. Reprod. Fertil.*, **38**: 425-430.

Osman, D.I., Moniem, K.A. and Tingari, M.D. 1979. Histological observations on the testis of camel, with special emphasis on spermatogenesis. *Acta. Anatomica.*, **104**: 164-171.

Osman, D.I. and Ploen, L. 1986a. Fine structure of Sertoli cells in the camel (*Camelus dromedarius*). *Anim. Reprod. Sci.*, **10**: 37-46.

Osman, D.I. and Ploen, L. 1986b. Spermatogenesis in the camel (*Camelus dromedarius*). *Anim. Reprod. Sci.*, **10**: 23-36.

Osman, D.I. and Ploen, L. 1986c. Fine structure of epididymal spermatozoa in the camel (*Camelus dromedarius*). *Anim. Reprod. Sci.*, **10**: 177-184.

Padalino, B., Fatnassi, M., Monaco, D., Hammadi, M., Khorchani, T. and Lacalandra, G.M. 2013. A new ethogram for evaluating housed male dromedary camel behavior and libido. In: proceeding of the XI congress of Italian Society of Animal Reproduction (SIRA), Ustica, Italy, pp. 137-142.

Padalino, B., Monaco, D. and Lacalandra, G.M. 2015. Male camel behavior and breeding management strategies: how to handle a camel bull during the breeding season? *Emir. J. Food Agric.*, **27**: 338–349.

Parmar, K.H., Dhami, A.J., Kavani, F.S., Solanki, G.B. and Murthy, K.S. 2019. Seasonal Influence on Sexual Behaviour of Jaffrabadi Buffalo Bulls. *Indian J. Vet. Sci. and Biotech.*, **15**(1): 36-39.

Pasha, R.H., Qureshi, A.S. and Khanum, S.A. 2015. Seasonal variations in the sex-steroid hormones and behavior of one humped male camel (*Camelus dromedarius*) in Punjab, *Pak. Vet. J.*, **3**: 26-32.

Pasha, R.H., Qureshi, A.S, Lodhi, L.A, Jamil, H., Masood, A., Hamid, S., Iqbal, J., Kamran, Z. and Khamas, W.A. 2011a. Seasonal changes in the anatomy of testis of one-humped camel (*Camelus dromedarius*). *J. Camel Pract. Res.*, **18**: 145-153.

Pasha, R.H., Qureshi, A.S., Lodhi, L.A. and Jamil, H. 2011a. Biometric and ultrasonographic evaluation of the testis of one-humped camel. *Pak. Vet. J.*, **31**: 129- 133.

Pasha, R.H., Qureshi, A.S., Lodhi, L.A. and Jamil, H. 2011b. Biometric and ultrasonographic evaluation of the testis of one-humped camel (*Camelus dromedarius*). *Pak. Vet. J.*, **31**(2): 129-133.

Pasha, R.H., Qureshi, A.S., Lodhi, L.A., Jamil, H., Masood, A., Hamid, S., Iqbal, J., Kamran, Z. and Khamas, W.A. 2011b. Morphological seasonal changes in the testis of one-humped camel (*Camelus dromedarius*). *J. Camel Pract. Res.*, **18**: 145-158.

Pasha, R.H., Qureshi, A.S., Zaib-Ur-Rehman and Khamas, W.A. 2013. Seasonal anatomical changes in the testis of the one-humped camel: a review. *Eur. J. Anat.*, **17**: 132-141.

Perera, B.M.A.O., Pathiraja, N., Motha, M.X.J. and Weerasekera, D.A. 1979 Seasonal differences in plasma testosterone profiles in buffalo bulls, *Theriogenology*, **12**(1): 33-38.

Pocock, R.I. 1910. On the specialized cutaneous glands of ruminants. Proceedings of Zoology Society. London, pp. 18-40.

Purohit, G.N. and Pareek, P.K. 2000. Research on dromedary reproduction: The past two decades and future prospective. *Vet. Bull.*, **70**(12): 1265-1274.

Purohit, G.N., Vyas, S., Saraswat, C.S., Kumar, A. and Dholpuria, S. 2020. Interesting features of female dromedary camel (*Camelus dromedarius*) reproduction. *Indian J. Anim. Reprod.*, **41**(2): 1-13.

Purohit, M. and Singh, B. 1958. The poll glands in camel. *Indian Vet. J.*, **35**: 296-8.

Rashad, D.E.M., Kandiel, M.M.M., Agag, M.A, El-Khawagah, A.R.M, Karima, Gh., Mahmoud, M., Ahmed, Y.F., Abou El-Roos, M.E.A. and Sosa, G.A.M. 2018. Histomorphometry of dromedary camel epididymis and its correlation with spermatozoa characteristics during their epididymal transport. *Behna Vet. Med. J.*, **35**(1): 1-11.

Saini, M.K., Thanvi, P.K., Singh, D. and Panwar, A. 2022. Gross morphological study on the epididymis of camel (*Camelus dromedarius*). *The Pharma Innov. J.*, **SP-11**(7): 2659-2662.

Saleh, A.M.M.M., Sayed, R.K.A. and Hamoda, H. 2020. Gross, Light and scanning electron microscopic studies on the ampulla ductus deferentis of dromedary camel with special reference to its seasonal variations. *J. Adv. Vet. Res.*, **10**(1): 41-48.

Saleh, B., Mohammed, A.A., Muhammad, A.M., Isah, A. and Zoaka, E.M. 2021. Testicular morphometry, gonadal and extra-gonadal sperm reserves of camel (*Camelus* *dromedarius*) during the hot dry season in the Sahelian region of Nigeria. *Nig. J. Anim. Prod.*, **48**(2): 53 - 62.

Saleh, M.A.M., Alameldin, M.A., Abdelmoniem, M.E., Hassouna, E.M. and Wrobel, K.H. 2002. On the intrinsic innervation of the epididymis of the camel (*Camelus dromedarius*). *Ann. Anat.*, **184**: 305-315.

Sareha, A.M. 1998. Effect of damaging brown gland (poll-gland) on plasma blood testosterone concentration in male camels. Proceedings of the Third Annual Meeting for Animal Production Under Arid Conditions UAE University, **1**: 122-125.

Sary, R., Khalil, K., Sindi, R.A., Mohamed, R.H., Hussein, H.A., Eid, R.A., Samir, H., Alkahtani, M.M., Swelum, A.A. and Ahmed, A.E. 2022. Characteristics of ultrasound and magnetic resonance imaging of normal testes and epididymis besides angiography of testicular artery in dromedary camel. *Front. Vet. Sci.*, **9**: Article 899570.

Saurabh, Srivastava, S., Kumar, A., Verma, S., Sharma, P. and Gautam, V. 2018. Study of testicular biometry and its correlation with epididymal seminal attribute in buffalo bulls. *The Pharma Innov. J.*, **7**(6): 251-256.

Schmidt, C.R. 1973. Breeding Seasons and Some other Aspects of Reproduction in Captive Camelids. *Internat. Zoo Yearbook*, **13**: 387-90.

Setchell, B.P. 1977. Male reproductive organs and semen. *In:* H.H. Cole and P.T. Cupps (Editors), Reproduction in Domestic Animals, 3rd edition. Academic Press, New York, pp. 229-256.

Sghiri, A. 1988. Evaluation des Performances de Reproduction d'un Troupeau Camelin à Laayoune (*Camelus dromedarius*). Thèse de Doctorat Vétérinaire, Institut Agronomique et Vétérinaire Hassan II, Rabat, Maroc. (Abstract).

Sharma, S.S. and Vyas, K.K. 1981. Studies on sexual physiology of stud camel. *Indian Vet. J.*, **58**: 743-744.

Singh, U.B. and Bharadwaj, M.B. 1978a. Anatomical, histological, and histochemical observations and changes in the poll glands of the camel (*Camelus dromedarius*). *Acta. Anat.*, **102**: 74-83.

Singh, U.B. and Bharadwaj, M.B. 1978b. Morphological changes in the testis and epididymis of camels (*Camelus dromedarius*). *Acta. Anat.*, **101**: 275-279.

Singh, U.B. and Bharadwaj, M.B. 1978c. Histological and histochemical studies on the testis of the camel (*Camelus dromedarius*) during the various seasons and ages. *Acta. Anat.*, **101**: 280-288.

Singh, U.B. and Bharadwaj, M.B. 1980. Histological studies on the testicular seminal pathway and changes in the epididymis of the camel (*Camelus dromedarius*). *Acta Anat.*, **108**: 481-489.

Singh, V. and Prakash, A. 1964. Mating behaviour in camel. *Indian Vet. J.*, **41**: 475.

Skidmore, J.A. 2005. Reproduction in dromedary camels: An update. *Anim. Reprod.*, **2**: 161–171.

Skidmore, L. 2000. Anatomy of the camel reproductive tract. In: Recent Advances in Camelid Reproduction by Skidmore L. and Adams G.P. 2000 ivis.

Sofi, S.A. 2002. Morphological and biometrical study on adult rams, bucks, and bulls testis in duhok province. *J. Univ. Duhok.*, (*Agri. and Vet. Sciences*), **25**(1): 38-45.

Sumar, J. 1996. Reproduction in llamas and alpacas. *Anim. Reprod. Sci.*, **42**: 405-415.

Swelum, A., Saadeldin, I., Ba-Awadh H. and Alowaimer, A. 2016. Effect of melatonin treatment on libido and endocrine function of dromedary camel bulls out of the breeding season. *Reprod. Fertil. Dev.*, **29**: 163-164.

Swelum, A.A., Saadeldin, I.M., Ba-Awadh, H. and Alowaimer, A.N. 2018a. Shortened daily photo period during the non-breeding season can improve the reproductive performance of camel bulls (*Camelus dromedarius*). *Anim. Reprod. Sci.*, **195**: 334–344.

Swelum, A.A., Saadeldin, I.M., Ba-Awadh, H. and Alowaimer, A.N. 2018b. Effects of melatonin implants on the reproductive performance and endocrine function of camel (*Camelus dromedarius*) bulls during the non-breeding and subsequent breeding seasons. *Theriogenology*, **119**: 18–27.

Taha, A.A.M. and Abdalla, A.B. 1980. Observations on the structure of the poll glands of the dromedary. *Acta. Veterinaria Belgrade*, **30**: 247-252.

Taha, A.A.M., Abdel-Magied, E.M., Abdalla, M.A. and Abdalla, A.B. 1994. The poll glands of the dromedary (*Camelus dromedarius*): ultrastructural characteristics. *Anat. Histol. Embryol.*, **23**: 269-274.

Tayeb, M.A.F. 1945. The Anatomy of the Genital Organs of the Camel, Male and Female. I. The Male Genital Organs. M. V.Sc. Thesis, Fac. Vet. Med. Cairo University.

Tingari, M. D., Moniem, K.A. and Kunzel, A. 1979. Observations on the fine structure of the testicular interstitial cells in the camel (*Camelus dromedarius*). *Q. J. Exp. Physiol.*, **64**: 39-45.

Tingari, M.D. 1989. The fine structure of the epithelial lining of the epididymis of the camel (*Camelus dromedarius*) with special reference to regional differences. *J. Anat.*, **165**: 201–214.

Tingari, M.D. and George, M.A. 1984. Studies on the poll glands of the one-humped camel in relation to reproductive activity. II. Ultrastructural observations. *J. Anat.*, **139**: 463-474.

Tingari, M.D. and Moniem, K.A. 1979. On the regional histology and histochemistry of the epididymis of the camel (*Camelus dromedarius*). *J. Reprod. Fertil.*, **57**: 11-20.

Tingari, M.D., Rahma, B.A. and Saad, H.M. 1984a. Studies on the poll glands of the one-humped camel in relation to reproductive activity. I. Seasonal morphological and histochemical changes. *J. Anat.*, **138**: 193-205.

Tingari, M.D., Ramos, A.S., Gaili, E.S.E., Rahma, B.A. and Saad, H.A. 1984b. Morphology of the testis of the one-humped camel in relation to reproductive activity. *J. Anat.*, **139**: 133-143.

Print ISSN: 2249-6610

Vyas, K.K. and Pareek, P.H. 1982. Reproduction in the camel. *In:* Sane CR *et al.* A Textbook of Reproduction in Farm Animals (Theriogenology) Varghese Publishing, Bombay, India, pp. 866-884.

Vyas, S., Pareek, P.K., Purohit, G.N. and Sahani, M.S. 2001. Management practices for augmenting rut in male camel (*Camelus dromedarius*). *Vet. Pract.*, **2**(2): 132-134.

Vyas, S., Rai, A.K., Sahani, M.S. and Khanna, N.D. 2004. Use of real-time ultrasonography for control of follicular activity and pregnancy diagnosis in the one humped camel (*Camelus dromedarius*) during the non-breeding season. *Anim. Reprod. Sci.,* **84**: 229–233.

Vyas, S., Ravault, J.P., Faye, B. and Chemineau, P. 1997. The nycthemeral rhythm of melatonin secretion in camel (*Camelus dromedarius*). *Rev. Elev. Méd. Vét. Pays Trop.,* **50**: 250-260.

Vyas, S., Sharma, N., Sheikh, F.D., Singh, S., Sena, D.S. and Bissa, U.K. 2015. Reproductive status of *Camelus bactrianus* during early breeding season in India, *Asian Pacific J. Reprod.,* **4**(1): 61-64.

Waheed, M., Ghoneim, I., Hassieb, M. and Alsumait, A. 2014. Evaluation of the breeding soundness of male camels (*Camelus dromedarius*) via clinical examination, semen analysis, ultrasonography, and testicular biopsy: a summary of 80 clinical cases. *Reprod. Domest. Anim.,* **49**: 790-796.

Wilson, R.T. 1986. Reproductive performance and survival of young one-humped camels on Kenya commercial ranches. *Anim. Prod.,* **42**: 375-380.

Yagil, R. 1985. The Desert Camel. Verlag Karger Basal, Munchen.

Yagil, R. and Etzion, Z. 1980. Hormonal and behavioral patterns in the male camel (*Camelus dromedarius*). *J. Reprod. Fert.,* **58**: 61-65.

Yasin, S.A. and Wahid, A. 1957. Pakistan camels - a preliminary survey. *Agric. Pakistan,* **8**: 289-297.

Yassen, A. and Mahmoud, M. 1972. Relationship between body weight and testicular size in buffalo bulls. *The J. Agric. Sci.,* **78**(3): 367-370.

Yousefi, M.H. 2013. Microscopic study of the nerve fibers in free part of the penis in one humped camel (*Camelus dromedarius*). *J. Vet. Lab. Res.,* **5**: 129-137.

Zayed, A.E. Aly, K., Ibrahim, I.A.A. and El-Maksoud, F.M.A. 2012b. Morphological studies on the seasonal changes in the epididymal duct of the one-humped camel (*Camelus dromedarius*). *Vet. Sci. Dev.,* **2**: 3.

Zayed, A.E., Aly, K., Ibrahim, I.A. and Abd El-Maksoud, F.M. 2012. "Morphological studies on the epididymal duct of the One-Humped camel (*Camelus dromedaries*)," *Open J. Vet. Med.,* **2**(4): 245-254.

Zayed, A.E., Hifny, A., Abou-Elmagd, A. and Wrobel, K.H. 1995. Seasonal changes in the inter tubular tissue of the camel testis (*Camelus dromedarius*). *Ann. Anat*., **177**: 199–212.

Zeleke, M. and Bekele, T. 2001. Effects of season on the productivity of camels (*Camelus dromedarius*) and the prevalence of their major parasites in eastern Ethiopia. *Trop. Anim. Health Prod.,* **33**: 321-329.

Zia-ur-Rahman, A.N., Bukhari, S.A., Akhtar, N. and Haq, I.U. 2007. Serum hormonal, electrolytes and trace element profiles in the rutting and non-rutting onehumped male camel (*Camelus dromedarius*). *Anim. Reprod. Sci.,* 101: 172–178.