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GENITAL MORPHOMETRIC VARIATIONS AND ENDOCRINE CHANGES OF THE ONE-HUMPED MALE CAMEL IN RELATION TO REPRODUCTIVE ACTIVITY

Gherissi Djallel Eddine[1,2,*], Bouzebda Zoubir[1,3], Bouzebda Afri Farida[1,3] and Lamraoui Ramzi[1,4]

[1]Laboratory of Animal Productions, Health and Biotechnologies, El-Tarf University 36000, ALGERIA
[2]Department of Veterinary Medicine of Souk Ahras, ALGERIA.
[3]Department of Veterinary medicine of EL TARF, ALGERIA
[4]Department of Biological Sciences, University of Batna, ALGERIA
*biotech.zootech@gmail.com

ABSTRACT

One hundred ninety-nine male dromedary camels of Sahraoui breed aged between 1-13 years were used to study the reproductive activity in relation to three pubertal stages (prepubertal; peripubertal and mature) and three consecutive breeding seasons (breeding, post breeding and non breeding). A total of nine testicular and epididymal measurements (TEMs) and two serum reproductive steroid hormones concentrations (SHCs) were evaluated. There were significant positive correlations ($P<0.05$, $P<0.01$, $P<0.001$) between different studied parameters. A gradual increase of the TEMs and SHCs occurred with age categories and the maximum values of TEMs were noted during the breeding season which persisted high in post breeding season and dropped significantly during the non breeding season, however the important steroidogenic activity was limited to the breeding season. Mature animals responded most to the effect of the season, thus, they showed maximum seasonal variations of the studied parameters between breeding/non breeding seasons, however scrotal circumference (SC) and progesterone concentration (P4) were the only measurements significantly variable between breeding/post breeding and pared testicular weight (PTW) was significantly variable between post breeding/non breeding seasons. It was concluded that the morphological and endocrinological methods are useful for monitoring the testicular function of dromedary in relation to pubertal age and seasonal activity.

Key words: Age, Sahraoui camel, season, testicular and epididymal measurements, steroid hormones.

One humped camel is a seasonal breeder and their reproduction is different as compared to other livestock as both male and female evidence seasonal breeding It is known that their reproductive efficiency under natural pastoral condition is low (Skidmore, 2005). Puberty in the male is generally defined as the time when he is capable of successfully mating a female and getting her pregnant (Skidmore, 2005). In the dromedary there were some studies that defined the age of puberty but it varies widely, ranging from 2 to 5 years in different countries (Abdel-Rahim, 1997). Sexual maturity is considered to be attained at an age of 8 years (Charnot, 1964), and known to vary in different breeds of camels, and also affected by genetics, nutrition and climatic changes. The breeding season (sometimes described as the rutting season) is very variable; it coincides with the cold season: periods of low humidity, low temperature, increased precipitation (Gombe and Oduor-Okelo, 1977; Yagil and Etzion, 1980) and increasing photoperiod (Ismail, 1988). In India, the breeding season continues from late September to March (Rai *et al*, 1988), in sub-Saharan regions of Morocco, the greatest sexual activity of camels occurred from October and May (Sghiri, 1988), in Tunisia, Ismail (1990) reported that the breeding season of camels occurred between November and March with a peak in January, in Egypt it extends from winter until the summer with a peak in spring (Zeidan *et al*, 2001; Abd-Elaziz *et al*, 2012). Skidmore and Adams (2000) concluded that camels in the Middle East showed a strong tendency to be a seasonal from late October to late April. It is well known that steroid hormones play an important role in controlling the reproductive functions of the male and female animals. Testicular measurements are considered as useful tool for assessing fertility in male dromedary due to their strong correlations with testicular spermatogenic activity (Akingbemi and Aire, 1991; Tibary and Anousassi, 1997a, b). Significant variations of testicular measurements and endocrine changes were reported by Abdel Rahim (1997) in relation with the beginning of spermatogenesis in camels at the prepubertal

stage, thereby contributing to specify the average age of puberty and sexual maturity in this species. The available literature indicates the lack of any previous study on reproductive biology of Algerian male dromedary camel, especially the sexual cycle in different pubertal and seasonal stages. The present study was conducted to generate basic data on patterns of changes around the pubertal period and seasonal vs. non-seasonal trends of reproduction in Algerian Sahraoui dromedary camel by (1): Describing biometric changes of camel testis and epididymis, (2): Studying the pattern of changes in plasmatic reproductive steroid hormones (testosterone and progesterone), and (3): Clarifying the effects of different pubertal stages, seasons and their interaction on reproductive steroid hormones concentrations and biometric measurements.

Materials and Methods

Animals and samples collection

The present study was conducted in one hundred ninety-nine males Sahraoui camels slaughtered in central abattoir of El Oued (South-East of Algeria, lat. 33 - 34 °N and lon. 6 - 8 °E, at the Tunisian and Libyan borders, average altitude of 80 m, average annual temperature of around 25 °C, max 52 °C, min 2 °C, average annual precipitation of 80 mm: max 160 mm 20 mm min especially between November and February). The animals were allotted to three pubertal ages: prepubertal <3 years (n=65), peripubertal 3-5 years (n=77) and mature 6-13 years (n=57). Samples were collected during three reproductive seasons: breeding season from December to February (n=68), post breeding season from March to May (n=70) and the non breeding season from July to September (n=61). The number of animals, their body measurements and their body weight are given in Table 1. Age determination was based according to the dentition formula given by Rabagliati (1924). In ante-mortem examination, camels were examined for physical defects especially at the testicular region and the following body measurements were taken with measuring tape on standing position in cm according to Abdallah and Faye (2012) i. e. The circumference of the neck at the middle of the neck (CN); thigh circumference at the middle of the thigh (TC) and hump length (HL). The body weights of animals (kg) were estimated according to Kamili *et al* (2006) formula:

Live weight (kg) = 4.06 x Age (year) + 3.05 x CN (cm) + 3.38 x TC (cm) + 1.38 x HL (cm) - 191 with 94% of the explained variance.

Before slaughter, blood was collected by jugular vein puncture, then after slaughter paired testes and epididymis were collected through a longitudinal incision in the scrotum region (scrotal sac). The testes and epididymis in good condition and free from pathological lesions as judged by ante-mortem examinations were dissected from the surrounding tissues and fixed for further studies.

Testicular and epididymal measurements (TEMs)

Eight measurements were carried out for each camel.

Testicular length (TL) recorded as the length from the cranial to the caudal pole, testicular thickness (TT) as the cranio-caudal diameter, testicular width (TW) as the diameter perpendicular to testicular thickness in the greatest distance at sagittal circumference (Al Asaad, 2007; Derar *et al*, 2012), at this level, scrotal width was also measured (SW) as distance between right and left sides of the scrotum. These measurements were determined using a vernier caliper and the dimensions of ATL, ATW, and ATT were recorded for each camel as the average values of both testes. Scrotal circumference (SC) was measured on the testes down into the lower part of the scrotum by placing a measuring tape around the widest point (Al Asaad, 2007; Pasha *et al*, 2011a). These five measurements were recorded *in-situ* in centimeters. On the other hand, paired testicular weight (PTW) and paired epididymis weight (PEW) to the nearest 0.01 g and paired testes volume (PTV cm^3) were calculated *ex-situ* respectively by digital scale (Charnot, 1964) and using the equation for ellipsoid volume: 4/3 ð TLxTWxTT, TL.TW.TT = axes of ellipsoid (Al-Saiady *et al*, 2013).

Reproductive steroid hormones concentrations (SHCs)

Serum samples were analyzed for reproductive steroid hormones concentrations (SHCs): Testosterone (TC) and progesterone (P4) by radioimmunoassay method (RIA) as described by Palta *et al* (1996) and El-Kon *et al* (2011) using highly specific commercially available test kits. A series of calibrators and controls were used by six labeled antibody-coated tubes for the standard curve. Hormone calibration solutions were transferred to the six tubes from one to six, respectively. 500 µl of I^{125} as a tracer was added to each standard or sample tube. All tubes were shaked well and incubated in water bath at 37 °C for 3 h, than all tubes were decanted, dried and subjected to gamma-counter for 1 min. The concentration of testosterone (ng/ml) and

progesterone (pg/ml) was determined according to the standard calibration curves.

Statistical analyses

The analyses of data base were done using the GLM procedure of the statistical analysis system (SPSS program, version 20.0, 2013). Results are given as Mean±SD.

The model took into account the following factors:

- The season (breeding vs. post breeding vs. non breeding)
- The age (<3 years vs. 3-5 years vs. 6-13 years)
- The TEMs (ATL (Average Testicular Length), ATW (Average Testicular Width), ATT (Average Testicular Thickness), SW (Scrotal Width), SC (Scrotal Circumference), PTW (Paired Testicular Weight), PTV (Paired Testicular Volume), PTW/LW (Ratio Paired Testicular Weight to Live Weight) and SHCs were used as dependent variable within each animal group (season, age).

The influence of age and season on the biometric changes was assessed by calculating Linear Regression Coefficient (b) as well as Determination Coefficient (r^2) to measure the strength of such effect and express the amount of common variation between the two variables. Means were compared by One-way ANOVA for Multivariate Tests of Significance and using Paired-Samples t-test., linear correlation was used when there is only one predictor variable and multiple linear correlation was used when there is more than one predictor variable.

Results

Overall means of TEMs and SHCs

The distributions of TEMs and SHCs in studied animals showed essentially asymmetrical figures with Gaussian distribution (P<0.05). The means of TEMs and SHCs according to age, season and their interaction are presented in Table 2. The overall averages of the following parameters: ATL, ATW, ATT, SW, SC, PTW, PEW, TV, PTW/LW, TC and P4 were 8.1±2.82 cm, 3.36±1.21 cm, 2.48±0.78 cm, 8.9±2.64 cm, 23.18±6.58 cm, 127.67±97.39 g, 29.45±20.72 g, 89.78±74.32 cm^3, 1/3595, 1.58±3.22 ng/ml and 3.17±4.88 pg/ml, respectively. No significant difference was found between the left and right morphology of the testes and epididymis (P>0.05) and significantly positive correlations (P<0.05, P<0.01 and P<0.001) were found between the different parameters (r=0.3 to 0.93) (Table 2).

Variations of TEMs and SHCs in relation to the pubertal age

Means and variations of TEMs and SHCs according to pubertal stages presented in the table 2revealed that age influenced very significantly all TEMs (P<0.001) and SHCs (P<0.01), the most important results were shown in mature males aged 6 to 13 years and were lower in prepubertal young males aged under 3 years, indeed, we found strong significant correlation (r=0.35 to 0.8, P<0.05) between different measurements and age.

All TEMs displayed a very highly significant increase with age (P<0.001): ATL (b=2.72 cm/year R^2= 0.58), ATW (b=0.95 cm/year R^2=0.61), ATT (b=1.24 cm/year R^2=0.39), SW (b= 3.95 cm/year R^2=0.62), SC (b=8.85 cm/year R^2=0.72), PTW (b=45.71 g/year R^2=0.49) and PTV (b=40.74 cm^3/year R^2=0.48), while SHCs displayed highly significant increase (P<0.01) for P4 (b=2.42 pg/ml R^2=0.23) and significant increase (P<0.05) for TC (b=1.48 ng/ml R^2=0.15). Only PEW (b=17.62gr/year R^2=0.07) showed no significant change with age (P>0.05). According to three studied age groups, the variations of the studied variables between prepubertal and peripubertal animals were very highly significant (P<0.001) for SC (39%), highly significant (P<0.01) for TC (185%), significant (P<0.05) for ATW (39%), SW (35%), PTW (124%) and PTV (146%) and not significant (P>0.05) for ATL (21%), ATT (34%), PEW (-5%), PTW/LW (20%) and P4 (10%). The differences of testicular measurements and hormone concentrations between peripubertal and mature males were considerable and very highly significant (P<0.001) for the ATL (53%), ATW (45%), SW (32%) and SC (32%), highly significant (P<0.01) for PTW (112%) and PTV (128%) and significant (P<0.05) for ATT (22%), PEW (47%), PTW/LW (70%) and P4 (507%). Moreover, clear and maximum variations with very highly significant differences were noted for all testicular parameters (P<0.001) and highly significant (P<0.01) for the ratio PTW/LW between the prepubertal males and mature males, the comparison of plasmatic hormones concentrations between this two age categories showed highly significant difference (P<0.01) for P4 concentration and significant difference for TC (P<0.05).

Variations of TEMs and SHCs in relation to breeding season

Seasonal means and variations of TEMs and SHCs are shown in Table 2. Testicular morphology (P<0.05)

and steroid hormones (P<0.01) were significantly influenced by the season. High average values of TEMs were found in breeding months and also observed during the post breeding season then were lower in summer with very low levels during hot months. One-way analysis of variance revealed high significantly effect of the season on SW, SC and P4 concentration (P<0.01) and significant effect on ATL, ATW, PTW, PTV and TC (P<0.05). The comparison of TEMs between three seasons showed that there were no significant variation (P>0.05) of ATT (b=2.18 cm/season R^2=0.02), SW (b=7.38 cm/season R^2=0.06), SC (b=2.21 cm/season R^2=0.05) and PTW/LW (b=1/6225 R^2=0.04) between the three breeding seasons. However, ATL (b=6.58 cm/season R^2=0.09), ATW (b=2.61 cm/season R^2=0.1), PTW (b=79.10 g/season R^2=0.09) and PTV (b=50.27 cm^3/season R^2=0.1) displayed the following significant variations (P<0.05): 28%, 29%, 30%, 94% and 22%, 26%, 48%, 68% respectively betweens breeding/non breeding and post breeding/non breeding seasons. Finally, we noted that PEW (b=20.64 g/season R^2=0.08) showed a significant difference (P<0.05) only between post breeding and none breeding seasons (40%) and there were no significant differences (P>0.05) on results of all TEMs parameters between rutting and post rutting seasons. On the other hand, the transition from the breeding to the non breeding season was manifested by a lower of TC and P4; this last parameter remained low between post breeding and non breeding seasons.

Interactions pubertal ages-breeding seasons

The effect of interaction between different pubertal stages according to the breeding seasons of the study on TEMs and SHCs are summarized in Table 1 and 2. In young prepubertal animals (<3 years), both ATL and SC parameters expressed significant differences only between breeding and post breeding seasons (P<0.05), the rest of TEMs did not show significant variation between seasons, but endocrine changes revealed significant difference (P<0.01) only for P4 concentration between breeding/post breeding and breeding/non breeding seasons. In peripubertal animals (3-5 years), PTW was the only testicular parameter that expressed significant difference (P<0.05) between breeding/post breeding and breeding/non breeding seasons, in this same age category, TC and P4 showed significant differences between post breeding/non breeding seasons (P<0.001, P<0.05) and breeding/non breeding seasons (P<0.01, P<0.001). In mature animals (6-13 years), changes of the morphologic studied parameters were clearly marked between breeding/non breeding seasons. Thus, a very highly significant (P<0.001) changes were noted for ATW and SC, highly significant differences (P<0.01) for ATL, PTV and P4, finally, a significant variations (P<0.05) were noted for the SW, PEW and TC. However, only SC (P<0.001) and P4 (P<0.05) were significantly different between breeding/post breeding seasons and PTW (P<0.01) between post breeding/non breeding seasons.

In general, age influenced very significantly testicular morphology (P<0.001) and reproductive steroid concentrations (P<0.01). TEMs (P<0.05) and endocrine parameters (P<0.01) were significantly affected by season, the variations had been stronger on SW, SC and P4 (P<0.01) and significant on ATL, ATW, PTW, PTV and TC (P<0.05) (P<0.05) (P<0.05) but no significant effect on ATT, PEW and PTW/LW. Indeed, we noted that the effect of the interaction between age and the season was very significant on all morphological parameters of the testis (P<0.001), PTW/LW (P<0.01) and steroids hormones (P4: P<0.001; TC: P<0.01) and not significant on epididymal weight (P>0.05).

Discussion

The present study was performed to record the biometric changes of TEMs and SHCs patterns in relation to three breeding seasons and three categories of age in Sahraoui one-humped camel breed. It was clear that the general morphology of the testis of the camel was less variable than in other species, as is the case with the bulls that frequently reveal long cylindrical or round testicles or rounded testicles and normal ovoid scrotum (Islem *et al*, 2010).

The overall means of ATL, ATW, SC, PTW and PEW were similar to those recorded by Al Asaad *el al* (2007) and Ali Abdullahi (2012) respectively in Shami and Nigerian camel males. The results of ATL in prepubertal and mature males were higher than those recorded by Derar *et al* (2012), but ATW and ATT were close to those recorded by these same authors in the three age classes. PTW was higher than that reported by Singh and Bharadwaj (1978a) in male prepubertal camels in India, and lower than that reported by Al Qarawi *et al* (2001) in peripubertal males in Saudi Arabia, but consistent with that found by these last authors in mature male camels. Differences in breed studied, season, nutrition, body condition scoring and other management factors may be crucial factors on this respect (Al-Saiady, 2013).

Table 1. Description of studied animals

	Seasons			Body measurements			LW (kg)
	Win	Spr	Sum	CN (cm)	TC (cm)	HL (cm)	
Prepubertal (< years)	22	23	20	57.26±4.17[a]	62.97±4.92[a]	32.98±9.23[a]	251.79±34.87[a]
Peripubertal (3-5 years)	29	26	22	84.13±11.9[b]	89.55±12.5[b]	53.30±16.1[b]	460.10±101[b]
Mature (6-13 years)	17	21	19	97.33±4.02[c]	101.3±4.09[c]	66.04±5.12[c]	577.08±30.04[c]
Total/mean	68	70	61	83.08±18.3	87.87±17.77	53.85±16.99	459±148.9

Means with dissimilar superscripts in the same column are significantly different at P<0.05.

Serum reproductive steroid hormones levels observed in the present study corroborated those reported earlier for adult camels for TC (Al-Qarawi *et al*, 2000; Rahman *et al*, 2007), but P4 concentration was much lower than that showed by Rahman *et al* (2007). The TC and P4 were significantly higher (P<0.05) in the breeding season then decreased in post breeding season and still low on non breeding season (P>0.05). These findings suggested that the testicular steroidogenic activity was higher during the breeding season but the conversion capacity of the P4 to the testosterone was limited in the post and non breeding season. Rahman *et al* (2007) suggested that during rutting season a high level of progesterone was readily available for its conversion into testosterone, which, in turn, stimulates breeding activity in this period. Bedrak *et al* (1983) reported that the activity of enzymes as 4á-. 17á-hydroxylase and 17 â-hydroxysteroid oxido-reductase that synthesize testosterone was higher in the breeding than in the non-breeding season. Similarly Dixit *et al* (1987) observed that the serum concentration of androgen was significantly higher (P<0.01) in camels during the rutting than the non-rutting periods.

Same variation of TC was reported by El-Bahrawy and Hassanien (2011) and El-Kon *et al* (2011) but with higher scores of 2.89 ng/ml and 4.43 ng/ml in non breeding vs. 7.95 ng/ml and 10.94 ng/ml in the breeding seasons respectively. This situation can be explained by an increased volume of the interstitial gland during the breeding season in pubertal males (Tingari *et al*, 1984b; Zayed *et al*, 1995; Pasha *et al*, 2011b; Zayed *et al*, 2012). Moreover, males less than 3 years did not express significant seasonal changes of steroidogenic activity. For this age category, our results are similar to those reported by El-Harairy and Attia (2010), who recorded values of TC of 0.20 ng/ml in non rutting season against levels of 0.42 ng/ml during the rutting season, however, season had marked action from the age of 4 years that account for levels of 1.71 ng/ml in non-breeding season and 4.13 ng/ml in breeding season.

There were no morphometric differences between left and right testis. This is contradictory to results recorded by Derar *et al* (2012) and similar to those signaled by Ali Abdullahi *et al* (2012). The preference of left side in male and female camel reproductive functional anatomy and physiology is questionable and yet unexplainable (Derar *et al*, 2012).Significant increase in testicular measurements were found in peripubertal (3-5 years) and adult males (6-13 years) camels compared to younger ones (<3years). These results agree with those recorded previously by Abed Rahim (1997) and Derar *et al* (2012). Singh and Bharadwaj (1987a) reported that the weight and testicular measurements in camels increased from birth until the age of 15 years, and then there was a gradual decline after that age. The change in body weight of the camel had major implications on reproductive function beginning by onset of puberty (Marai *et al*, 2009; Al-Saiady, 2013), thus, attainment of puberty was influenced by the overall growth and weight of the animal that was affected by the nature and quality of food distributed and the relationship of the live body weight with the average development of testicular measurements especially during the growth period (Al-Saiady, 2013).

Table 2. Average TEMs and SHCs according to age, season and their interaction.

Variables	Age	Breeding (n= 68)	Post breeding (n= 70)	Non breeding (n= 61)	Overall Mean (n= 199)
ATL (cm)	Pre-Pub	4.89±0.73	6.42±0.76	5.65±0.7	5.53±0.98$^{(1)}$
	Peri-Pub	8.80±1.04	7.63±0.91	5.89±1.53	6.71±1.64$^{(1)}$
	Mature	11.53±1.92a	10.16±2.46	8.39±1.29b	10.24±2.27$^{(2)}$
	Mean	**8.87±3.56^{A}**	**8.43±2.41^{A}**	**6.93±1.82^{B}**	**8.10±2.82**
ATW (cm)	Pre-Pub	2.04±0.42	2.36±0.64	1.85	2.12±0.48$^{(1)}$
	Peri-Pub	4.40±0.43	3.53±0.26	2.42±0.93	2.95±1.02$^{(2)}$
	Mature	4.66±0.47	4.39±1.04	3.56±0.28	4.27±0.78$^{(3)}$
	Mean	**3.66±1.37^{A}**	**3.57±1.18^{A}**	**2.83±0.92^{B}**	**3.36±1.21**
ATT (cm)	Pre-Pub	1.50±0.40	2.07±1.17	2.09±0.98	1.79±0.57$^{(1)}$
	Peri-Pub	3.75±0.44	2.70±0.35	2.02±0.76	2.39±0.83$^{(1)}$
	Mature	2.96±0.66	3.01±0.43	2.77±0.47	2.92±0.53$^{(2)}$
	Mean	**2.46±0.96**	**2.65±0.58**	**2.35±0.73**	**2.48±0.78**
SW (cm)	Pre-Pub	5.80±0.62	6.78±2.52	5.46±1.22	6.07±1.53$^{(1)}$
	Peri-Pub	11.9±2.73	9.63±0.64	6.87±2.41	8.2±2.59$^{(2)}$
	Mature	11.16±1.06	11.26±1.18	9.96±0.83	10.84±1.14$^{(3)}$
	Mean	**9.19±2.85**	**9.19±2.85**	**7.99±2.45**	**8.90±2.64**
SC (cm)	Pre-Pub	13.68±1.39	18.25±3.13	15.15±1.06	15.45±2.87$^{(1)}$
	Peri-Pub	26.80±4.91	23.93±3.42	19.48±4.13	21.55±4.46$^{(2)}$
	Mature	31.69±1.48	27.00±2.16	24.75±1.42	28.37±3.46$^{(3)}$
	Mean	**24.63±8.94**	**23.60±4.66**	**21.12±4.50**	**23.18±6.58**
PTW (g)	Pre-Pub	32.10±57.31	49.33±28.94	50.75±22.27	40.95±43.3$^{(1)}$
	Peri-Pub	211.30±42.11	116.03±30.50	59.45±50.56	91.61±46.09$^{(2)}$
	Mature	188.22±43.83	236.35±141.71	161.70±47.29	194.40±84.94$^{(3)}$
	Mean	**131.12±91.79**	**151.04±126.99**	**102.03±69.04**	**127.67±97.39**
PEW (g)	Pre-Pub	28.62±50.17	21.43±3.50	20.75±8.84	24.91±34.20$^{(1)}$
	Peri-Pub	24.30±5.83	27.0±9.35	21.92±7.74	23.68±7.65$^{(1)}$
	Mature	41.54±13.08	37.80±9.84	21.64±4.34	34.79±13.13$^{(1,2)}$
	Mean	**35.62±31.30^{A}**	**30.27±10.73^{AB}**	**21.63±6.04^{B}**	**29.45±20.72**
PTV (cm^3)	Pre-Pub	16.38±8.42	35.46±21.62	29.77±18.42	24.97±16.58$^{(1)}$
	Peri-Pub	152.05±22.15	76.06±13.63	39.11±45.54	61.49±50.09$^{(2)}$
	Mature	171.58±67.39	147.93±77.08	85.68±16.34	140.28±68.71$^{(3)}$
	Mean	**112.16±91.32^{A}**	**96.74±72.75^{AB}**	**57.73±39.59^{B}**	**89.78±74.32**

Means with dissimilar superscripts in the same row are significantly different at P<0.05.
Means with dissimilar numbers in the same colon are significantly different at P<0.05.

Table 2. continued.....

Variables	Age	Breeding (n= 68)	Post breeding (n= 70)	Non breeding (n= 61)	Overall Mean (n= 199)
PTW/LW	Pre-Pub	1.0/7577	1.0/5386	1.0/4920	1/6149[(1)]
	Peri-Pub	1.0/2687	1.0/4250	1.0/7165	1/5022[(1)]
	Mature	1.0/3080	1.0/2511	1.0/3443	1/2969[(2)]
	Overall mean	**1.0/3535**	**1.0/2985**	**1.0/4025**	**1.0/3595**
TC (ng/ml)	Pre-Pub	0.22±0.18	0.18±0.02	0.17±0.02	0.2±0.12[(1)]
	Peri-Pub	0.88±00	1.06±0.23	0.27±0.13	0.57±0.41[(2)]
	Mature	5.5±5.62	1.1±0.41	0.59±0.53	2.84±0.4.29[(2)]
	Mean	**3.24±4.89[A]**	**0.81±0.52[B]**	**0.39±0.38[B]**	**1.58±3.22**
P4 (pg/ml)	Pre-Pub	1.08±0.12	0.57±0.41	0.57±0.24	0.83±0.36[(1)]
	Peri-Pub	2.54±1.1	1.27±0.8	0.48±0.32	0.92±0.81[(1)]
	Mature	10.1±6.81	2.54±2.97	1.8±1.41	5.59±6.14[(2)]
	Mean	**6.27±6.74[A]**	**1.64±2.15[B]**	**1.06±1.15[B]**	**3.17±4.88**

On the other hand, the average measurements recorded in breeding and post breeding seasons did not show significant differences, the results for these two seasons were more important than those found in non breeding season, however, the highest results were noted in males studied in the breeding season. Indeed, significant changes in testicular measurements were noted for the ATL, ATW and PTV between breeding/non breeding seasons and post breeding/non breeding seasons, our results were consistent with those observed by Abedel Rahim (1997), Al Eknah (2000) and Pasha *et al* (2011b), who reported maximum levels and significant seasonal variations of the testis dimensions during the coldest months of the year (season rainfall), then they decreased between Spring and Summer. Moreover, Tingari *et al* (1984b) reported that the testes of one-humped camels reached the maximum weight during the coldest months of the year (November to March) on the contrary, the lower testicular weight was observed during the hot months (May to September).

The effect of the interaction age-season on variability of TEMs was most striking in mature males. The SC was the highest parameter that responded significantly to this interaction, these results were in line with the previous findings given by Tingari (1984 a,b) and Al Qarawi *et al* (2001) probably due to the terminal outcome of testicular growth in this age group of animals (sexual maturity). The measurement of scrotal circumference in camels was considered a more reliable indicator for the estimation of testicular activity, by its strong correlation with sperm volume, the quantity and quality of produced sperm (Akingbemi and Aire, 1990). According to many authors (Zayed *et al,* 1995; Abd-Elmaksoud *et al,* 2008; Abd-Elaziz *et al,* 2012; Zayed *et al,* 2012) the testes of one-humped camels undergo changes in their histological structures, thus, on non-breeding season, it was shown inactivity of the germ cells and reduced number of mature germ cells (low mitotic proliferation and meiotic division), the interstitial connective tissue begins to decline and become very narrow in summer and reduced in the autumn (Zayed *et al*, 1995). Though spermatogenesis is a continuous process throughout year (Tingari *et al,* 1984a) but the activity of tubular germ cells start to turn down in summer and become least dynamic in autumn, these seasonal changes influenced directly the weight and testicular measurements (Singh and Bharadwaj, 1978b). This was most recently confirmed by in a few studies (Pasha *et al,* 2011a; Derar *et al,* 2012) using ultrasound scans.

Some studies on the camel species had shown that the reduction in the duration of the day seems to be the stimulus of seasonality (Merkt *et al,* 1990). Other studies reported that factors such as nutrition, management (Wilson, 1984) and rainfall (Bono *et al,* 1989) may override the effects of photoperiod and allow breeding

to occur throughout the year near the equator (Arthur *et al*, 1985). Al-Saiady (2013) showed that the diet (forage availability) as a factor of environment has the greatest effect on testicular weight and sperm production. It was concluded that the testicular measurements and the assay of reproductive steroid hormones were useful tools for monitoring testicular activity in male dromedary camel. It appeared that the important sexual activity during breeding season was accompanied with higher testicular measurements and steroidogenic activity in mature animals. The obtained data could provide a reference values for male camel of Sahraoui breed reared in the arid conditions of the southeastern of Algeria.

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