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CAMELS' REPRODUCTIVE AND PHYSIOLOGICAL PERFORMANCE TRAITS AS AFFECTED BY ENVIRONMENTAL CONDITIONS

[EFECTO DE LAS CONDICIONES AMBIENTALES SOBRE CARACTERÍSTICAS REPRODUCTIVAS Y FISIOLÓGICAS DEL CAMELLO]

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SUMMARY

The male camel is described as a seasonal breeder with a marked peak in sexual activity (the rut) during the breeding season and it is generally thought that the male is sexually quiescent for the remainder of the year, but it is capable of mating and fertilizing an estrous female at any time of the year. Similarly, the she-camel, although it shows strong tendency to be regarded as a seasonal breeder, pregnancy can occur at any season of the year as a polyestrus animal. However, in all cases, sexual activity of the females coincides with that of the males and both respond to the same environmental conditions. Globally, the breeding season of the camels begins at different dates beginning of September and ends at different dates until June in the different parts of the Northern World and from June to September in the Southern parts of the World, which are the mildest periods of the year, but with decreasing and / or increasing daylight, while the non-breeding season is in summer hot months. The severe hot conditions (which are strongly related to the length increase of the photoperiod) under which the camel lives directly without any shelter in summer (usually) disturb the physiological functions that affect deleteriously the sexual activity and all the related traits of the camels' polyoestrous nature. However, although photoperiodic variations have a strong influence, yet there is some evidence suggesting that the suprachiasmatic nucleus (SCN) may be sensitive to changes in ambient temperature, with some cells being more responsive to cold and others more responsive to heat. Furthermore, the molecular mechanisms that regulate rhythmicity, such as the cyclic changes in the expression of clock proteins, can be altered by temperature changes. Further studies on the importance of SCN in reproductive functions of the camel, are needed.

Key words: breeding and non-breeding seasons, *Dromedary* camel, males and females, physiological background, reproductive activity.

RESUMEN

El camello macho es descrito con actividad reproductiva estacional con un increment en actividad sexual durante la temporada de apareamiento. En general es aceptado que el macho es inactivo durante el resto del año, pero es capaz de aparearse y fertilizar a una hembra en estro en cualquier momento. De manera similar, la hembra, aún cuando tiene una tendencia estacional marcada, puede gestar en cualquier momento del año al ser poliestricas. Sin embargo, en todos los casos, la actividad sexual de la hembras coincide con la de los macho y ambos responden a los mismos estímulos ambientales. En el mundo la estación de apareo de los camellos inicia en diferentes fechas a partir de Septiembre y concluye en diferentes fechas hasta Junio (Hemisferio Norte), y de Junio a Septiembre en el Hemisferio Sur. Estas son las estaciones templadas, pero con decremento y/o incremento de horas luz. La estación de inactividad corresponde a los veranos cálidos. Las condiciones de calor severas (relacionadas con el incremento en el fotoperíodo) en el habitat del camello que es carente de protección natural, perturba la funciones fisiológicas e influye negativamente la actividad sexual. Sin embargo, aunque la variación del fotoperíodo tiene una fuerte influencia, existe evidencia que sugiere que el nucleo supraquiasmático puede ser sensible a cambios en la temperatura ambiental, con algunas células más responsivas al frío

y otra al calor. Más aún, los mecanismos moleculares que regulan los ritmos, tales como los cambios ciclícos en la expresión de proteínas pueden ser alterados por cambios en la temperatura. Se requieren estudios adicionales sobre la importancia del nucleo supraquiasmatico en las funciones reproductivas.

Palabras clave: Estación reproductiva, *D*romedarios, machos, hembras, fisiología, actividad reproductiva.

INTRODUCTION

Globally, onset of the breeding season of the camels begins at different dates during the mild period of the year, beginning of September and ends at different dates until June in the different parts of the Northern World and from June to September in the Southern part of the World, but with either decreasing and / or increasing daylight length, while the non-breeding season occurs in the summer months (Table 1).

In the literature, information about the stimuli of the onset of the dromedary camel breeding season, are rather conflicting. Some studies showed that decreasing daylight appeared to be the stimulus to seasonality (Merkt *et al.*, 1990; Musa *et al.*, 1990). Other studies reported that factors such as nutrition, management (Wilson, 1984) and rainfall (Bono *et al.*, 1989; Arthur, 1992) may override the effects of photoperiod and allow breeding to occur throughout the year near the equator (Arthur *et al.*, 1985). In other words, the breeding season can adapt to climatic and nutritional change. Similarly, the zoos throughout the world show that, in general, the *Camelidae: dromedary, bactrian, guanaco, Ilama, alpaca* and *vicuna* maintain a short breeding season adapted for latitude**.** Cristofori *et al.* (1986) added that rainfall and subsequent availability of improved nutrition were the main trigger for camel sexual receptivity. Arthur *et al.* (1982) stated that camels can be truly polyestrus with a continuous supply of sufficient food.

However, although the above results showed that environmental variations have a strong influence on the onset of the breeding season, yet there is some evidence suggesting that the suprachiasmatic nucleus (SCN) may be sensitive to changes in ambient temperature, with some cells being more responsive to cold and others more responsive to heat, in rodents **(**Burgoon and Boulant, 2001). In this respect, there is a vast amount of information suggesting that the SCN is an important structure regulating circadian and seasonal rhythms of most biological functions in mammals (Pando and Sassone-Corsi, 2001), particularly reproductive function and behaviour, including the phasic and tonic release of hormones, reproductive heat and in some cases gonadal size

In the present article, the available information on the reproductive activities of male and female dromedary camel and the physiological background, during the breeding and non-breeding seasons, are reviewed. Information on another animals may be included.

PUBERTY

The change in body weight of the camel has major implications on reproductive function beginning by onset of puberty. Attainment of puberty is influenced by the overall growth and weight of the animal that are affected by nutrition. Therefore, encouragement of rapid growth during the pubertal period by the good nutritional and environmental conditions can assist early sexual development and breeding maturity in dromedary camels.

Particularly, Abdel-Samee and Marai (1997) idicated that the camels' body weight gain declined significantly in the non-breeding season (summer) than in the breeding season (milder weather) as a function of heat stress, similar to that recorded in most animals such as rabbits, sheep, goats, cattle and buffaloes (Habeeb *et al.*, 1992; Marai and Habeeb, 1998, Ibrahim, 2001; Marai *et al*., 2002a, 2007, 2008)**.**

In males

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. Shedding of the penopreputial adhesions (that adhesions make normal copulation impossible) does not occur until puberty is reached. Such anatomical change is accompanied with hormonal shift and is essentially androgen-induced phenomenon influenced by plane of nutrition (Fernandez-Buca, 1993; Sumer, 1996), as is the case with ruminants (Brown, 1994). Increasing amounts of testosterone produced from the testes as the animal matures facilitates 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). In alpacas, only 8% have penile separation from the adhesions at 1 year of age, while at 2 years of age 10% of the males are capable for intromission when the body weight reaches about 50 kg (Sumar, 1985) and do not reach full maturity until 5 years of age. However, it is a common practice to use male alpaca for mating from 3 years of age.

Table 1. Variations in the onset of breeding season of camels with some geographic, climatic and nutritional data.

Male in rut	Females in heat	Area	References	Climate	Nutritional status
Nov – Mar		India	Matharu (1966)	Daylength decreasing then increasing	'Depending on level of nutrition' but not specified.
Nov – Feb		India	Singh and Praksah (1964)		
Oct – Mar		India	Khan and Kohli (1972)		
	Dec – Feb	India	Joshi *et al.* (1978)	Increasing daylength	
	Dec-Mar	Pakistan	Yasin and Abdul-Wahid (1957)		
	Mid-Jan-End May	Turkestan	Abdunazarov (1970)	Very cold becoming warm: rapidly increasing daylength	Probably poor, at least in early period
	Jan - Fab	Iran	Islamy (1950)	Only when weather is cold followed by rapid increase in daylength	
Jan – Mar		S. Israel	Volcani (1952)	Cool to warm; rain; increasing in daylength	Short growing season, rising plane
Mar - Apr		Egypt	Abdel- Raouf and El -Naggar (1964)	Increasing daylength: warm to hot	
	Mar-May	Egypt	Shalash and Nawito (1964)		
Spring		Egypt(+ Sudanese camels)	Osman and El-Azab (1974)		Fairly good
	Nov-Apr	S. Tunisia	Burgemeister (1975)	Daylength decreasing then increasing; rain; cool to warm	Fairly good
Dec-May		Morocco	Charnot (1963a)	Daylength decreasing, then increasing; cool to hot	
Nov-Apr		Morocco	Charnot (1965)		Good
	Aug-Sept	Mali	Swift (1979)	Daylength decreasing; rain	Depends on winter conditions
	Feb-Mar	Mali	Swift (1979)	Daylength increasing; warm to hot	Good
June		Somalia	Leese (1927)	Daylength static	
Sept-Nov		Somalia	Leese (1927)	Daylength slowly decreasing	
	Jun-Sept	Australia	McKnight (1969)	Daylength increasing	

In females

In the dromedary female foetus, large polygonal FSH cells appear at 24-28 weeks of age. Prolactin and LH cells appear at 32-36 weeks of age. Primary ovarian follicles are seen at 8-12 weeks and secondary follicles at 20-24 weeks of age. Uterine glands appear at 16-20 weeks of age (Marai *et al.*, 1990). Puberty of the she-camel is reached at 3-4 years of age (Shwarts, 1992; Musa *et al.*, 1993).

SEXUAL MATURITY

In males

Sexual maturity is attained before full physical maturity. However, it is greatly influenced by breed (Leupold, 1968).

Seminiferous tubule diameter increases up to about 9 years of age and the number of spermatozoa increases during the following years, then declines gradually. Meanwhile, there is little variation in total germinal cells-spermatogonia, primary spermatocytes and spermatids between 6 and 18 years of age (Abdel-Raouf *et al.,* 1975).

Testicular weight and dimensions increase with age and reach their maximum values at 10 to 15 years of age, then they decrease slightly after 15 years (Singh and Bharadwaj, 1978; Ismail, 1979, 1982).

Weight of the testes (Volcani, 1952; Charnot, 1964; Zeidan, 1999; Zeidan *et al.*, 2001) and the number of spermatozoa in the epididymis (Volcani, 1952) show a seasonal peak. Corresponding with these changes, there were also changes in the circulating testosterone level (Yagil and Etzion, 1980; Zeidan, 1999; Zeidan *et al.,* 2001).

Full reproductive potential of the male camel is reached at 5-6 years (Novoa, 1970). However, Al-Qarawi *et al.* (2001) reported that the first ejaculum that contains higher concentrations of spermatozoa is produced at 6 years old in dromedary camel. The full overt sexual activity may be delayed until 8 years. Physiological capacity may increase up to 10 years, then remains at a more or less constant of fairly high level until 18-20 years of age (Yasin and Abdul–Wahid, 1957; Matharu, 1966). Availability of data on daughters of a stud for proper selection, takes about 12-14 years.

In females

Full reproductive capacity of the female camel is reached at 6 years (Singh, 1966; Khetami, 1970), but it can be bred at 3-5 years of age (Matharu, 1966; Williamson and Payne, 1978). Yasin and Abdul-Wahid (1957) reported that the female camel would breed until 30 years of age.

The estrous cycle in the she-camel is incomplete when compared to that of the ungulates. It consists of proestrus (growing follicles), estrus (mature follicles) and diestrus (follicular atresia if mating has not occurred). Correspondingly, the follicular cycle was divided into a growth phase (10.5 $\pm$ 0.5 days), a mature phase (7.6 $\pm$ 0.8 days) and a regression phase (11.9 $\pm$ 0.8 days). However, four distinct uterine activity phases were recorded: the high phase, declining phase, low phase and increasing phase, during the estrous cycle (Al-Eknah *et al.*, 1993). Corresponding follicular, atretic follicular, nonfollicular and growing follicular stages, respectively, were recorded by Nawito *et al.* (1967). Duration of estrous cycle averaged 24.2 days in Egypt (Nawito *et al.*, 1967), 23.4 days in India (Joshi *et al.*, 1978) and 28 days in Sudan (Musa and Abusineina, 1978b). Estrous cycle duration of 4-6 days (Nawito *et al.*, 1967) and 16-30 and 11-27 days (Bakkar and Basmaeil, 1988; Al-Eknah *et al.*, 1993), have been observed. Such varitiaon in estrous cycle duration may be due to that the cyclic ovarian activity and estrous behaviour are largely dependent on the presence or the absence of coital stimulas. The phases of the cycle usually described for species with spontaneous ovulation (estrus and diestrus) do not exist in *Camelidae* unless the female is bred and has ovulated. In the absence of mating there is only a succession of follicular waves with highly variable rhythm (Tibary, and Anouassi, 1997).

Particularly, the she-camels are nearly polyestrus due to that although it shows strong tendency to be regarded as a seasonal breeder, pregnancy can occur in any season of the year (Nawito *et al.,*1967).

In addition, they are considered as induced ovulators and ovulation occurs after mating (Nawito, *et al.*, 1967; Novoa, 1970; Musa and Abusineina, 1978b; El-Wishy and Hemieda, 1984; Cristofori *et al.*, 1986), i.e. ovulation is induced by copulation (Beil, 1999). This also means that no spontaneous ovulation occurs in camels, even in females that are close to, but not mated by male camels (Skidmore *et al.*, 1996). In other words, ovulation tends to be non spontaneous and mating should be carried out for ovulation to occur (Musa and Abusineina, 1978b). The evidence of induced ovulation is the absence of a corpora luteum formation (Nawito *et al.*, 1967; Elias *et al.*, 1984) and serum progesterone concentration is low in unmated females (Skidmore *et al.*, 1996). Noseir *et al.* (1980, cited by Iamail, 1998) clarified that the estrous cycle in the dromedary is restricted only to a follicular development and absence of luteinization and ovulation is induced by copulation.

Serum oestradiol concentration reaches peak values when the dominant follicle measures 1.7±0.1 cm in diameter.

THE BREEDING SEASON

Table 1 shows clearly that onset of the breeding season of the camels begins at different dates during the mild period of the year, beginning of September and ends at different dates until June in the different parts of the Northern World and from June to September in the Southern part of the World, but with either decreasing and / or increasing daylight length, while the non-breeding season is in the summer months.

In males

In the literature, El-Amin (1979) and Yagil and Etzion (1980) reported that the male is a seasonal breeder corresponding to the season of the female and the breeding season extends from late winter to early summer, attaining the maximum activity during spring, in Egypt (Ismail, 1979, Zeidan *et al.,* 2001; Zeidan, 2002).. It was also observed a seasonal peak in the weight of the testes (Volcani, 1952, Charnot, 1964; Zeidan, 1999, Zeidan *et al.*, 2001) and in the number of spermatozoa in the epididymis (Volcani, 1952). Corresponding with these changes there were also changes in the circulating testosterone levels (Yagil and Etzion, 1980; Zeidan, 1999, 2001) and active poll glands (Yagil and Etzion, 1980; Tingari *et al.*, 1984; Agrawal and Khanna, 1990)**,** which were high from late December to the end of March. For the remainder of the year, it is generally thought that the male is sexually quiescent. However, some authors (Arthur *et al..,* 1985) believed that a stud male is capable of mating and fertilizing an estrous female at any time of the year. Abdel Raouf *et al.* (1975) and Osman *et al.* (1979) indicated that spermatogenesis continues through the year, but at a higher rate during the colder months of the breeding season (Tingari *et al.,* 1984)**.** In other words, spermatogenesis slows down, but not stop completely, when external signs of rut are not present. Azouz *et al*. (1992) claimed that Hyperprolactinaemic may cause reduced *libido* and fertility during the non-breeding season due to the suppressive effect of the high prolactin levels on the synthesis and secretion of FSH and LH. Treatment with GnRH was found to stimulate sexual activity outside the breeding season, in normal males (Moslah *et al.*, 1992).

In rutting**,** male camels have many behavioural and physiological peculiarities, but neither the physical nor the physiological attributes of the rut are as pronounced in dehydrated animals as in regularly watered ones (Charnot, 1965)**.**

Manifestation of the 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. 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. However, rutting males are more preoccupied with the 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 ridiculous. Sexual desire can be diminished or quelled, if sexually active males (rutting) are put to hard work.

The male in the rut extrudes off soft palate (gula) from its mouth by filling air from trachea (Arnautovic and Abdelmagid, 1974). Air is retained for about 5 to 10 seconds, after which it is expired with a gurgling sound, the pressure is released and gula collapses. A camel in rut stands with hind legs apart, flapping the tail up and down with frequent micturation and throwing urine over back again and again. As the season advances, males loose condition and tend to go off feed.

Physiologically, the onset of rut is marked by increase in activity in the *Alpha and Beta* secreting cells in the anterior pituitary which have a primary action on the gonads. Testicular weight increases due mainly to the increase in the amount of interstitial tissue and spermatogenesis and the growth of the soft palate that takes place (Charnot and Racadot, 1963; Charnot, 1964). Spermatogenesis continues through the year (Abdel Raouf *et al.*, 1975; Osman *et al.* 1979) with a high rate during the colder months of the breeding season (Tingari *et al.,* 1984) and slows down, but not stop completely, when external signs of rut are not present.

In rutting, the seminiferous tubules have a greater diameter (209-220 µ) than in the tubules of camels not in rut (190 – 203 µ). Spermatogonia, spermatids and spermatozoa also become numerous. 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). However, the highest of these figures is only about one-third the value for semen of cattle. Activity of the Leydig cells becomes maximal during the rutting season (Tingari *et al.*, 1984), but are less active in the non-breeding season with a resulting reduction in steroidogenic activity by the testes (El-Wishy, 1988). High testosterone levels have also been recorded during the rutting season (Yagil and Etzion, 1980; Agarwal and Khanna, 1990) when the poll glands become active and secrete dark brown material with a pungent odour that attracts females (Yagil and Etzion, 1980; Tingari *et al.,* 1984). The copious secretion from poll (occipital) gland (Charnot, 1963) is dark brown with acrid smell and androgens are present (Yagil and Etzion, 1980). Anatomical, histological, histochemical and morphological changes in poll gland during the breeding and non-breeding seasons were reported by Singh and Bharadwaj (1978). Tingari *et al.* (1984) reported that histologically the poll gland resembles endocrine glands.

An increase also occur in each of the accessory gland sizes and secretions, but such increase was striking in behaviour and quantity of the poll glands secretion (Merkt *et al.*, 1990). However, Leese (1927) reported that poll glands were present only in males, while Pocock (1910) reported that the poll glands are present in females.

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)**,** during the rutting. 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.*, 1986). The testis increased greatly in weight and size, during the rutting season (Owaida, 1973, Abdel-Raouf and Owaida, 1974; Ismail, 1982) due to the extensive development of interstitial tissues at this time (Ismail, 1982). The tunica albuginea of the camel testis is very thick. It constitutes on average, 17 to 20.6% of the testis weight (El-Wishy and Omar, 1975; Ismail, 1979, 1982) The seminiferous tubules have a small diameter which is significantly less when the camels are not in rut.

Camel semen in the breeding and non-breeding seasons

The lack of a reliable semen collection technique has been one of the limiting factors for studies on semen characteristics and the use of artificial insemination. Several methods have been tried to collect camel semen, but without much success. The methods used were intravaginal pessaries or sacs (San-Martin *et al.*, 1968), artificial vagina mounted inside a dummy (Sumar and Garcia, 1986; Lichtenwalnes *et al.*, 1996; Bravo *et al.*, 1997), artificial vagina sleeves (Magrovijo, 1952) and electro-ejaculation (Fernandez-Buca, 1993). Recently, ejaculate volume collected by using artificial vagina was 0.4 to 4.3 ml and 0.8 to 3.1 ml in alpaca (Garnica *el al.*, 1993) and 4.0 to 6.0 ml in dromedary camel (after copulation time from 14 to 36 minutes; Zeidan and Abbas, 2003). Sperm concentrations in such collections were 82- to 250 x 10^3 / ml which were very few than in rams (2000-6000 x 10^6 / ml) and bulls (1500-2500 x 10^6 / ml; Salamon, 1976). Particularly, semen has to be collected during the breeding season.

Semen physical characteristics

Semen characteristics of the dromedary camel vary considerably (Billah and Skidmore, 1992) and semen quality has been found to be correlated with the general health and the nutritional status of the males.

Semen colour depends on the ratio of the gelatinous fraction which is grey, to the sperm fraction which is white. The colour becomes slightly yellow if the sample is contaminated by urine. Particularly, such information can give a prelimimary evaluation when inspection of semen visually. In the male dromedary camels semen varies according to concentration of spermatozoa and semen consistency, as well as, to age and season. Semen colour is yellowish white, creamish white or milky white at 2.5 to 5, over 5 to 10 and over 10 to 20 years of age, respectively (Zeidan, 1999; Zeidan *et al.*, 2001)**.** During the seasons of the year, semen was found to be yellowish white during winter and spring and greyish white during summer and autumn (Khan, 1994; Abd El-Azim, 1996, Zeidan, 1999; Ahmadi, 2001)**.** However, Rai *et al.* (1997) reported that the colour was milky white creamish in breeding and non-breeding seasons.

The camels' semen is highly viscous and forms coagulum soon after copulation (Lichtenwalnes *et al.*, 1996; Bravo *et al.*, 1997; Zeidan *et al.*, 2001) which presents difficulties in separating sperm cells from seminal plasma by conventional methods to assess sperm concentration. Moreover, the high viscosity results in oscillatory movement of the spermatozoa (Sumar and Garcia, 1986; Garnica *et al.*, 1993; Bravo *et al.*, 1997; Zeidan *et al.*, 2001; Zeidan and Abbas, 2003) and not the progressive sperm motility as occurs in ejaculates from other domestic animals. The high viscosity may be important in maintaining the viability of sperm within the uterus (Mattner, 1969). The proportions of live morphologically normal spermatozoa range from 58 to 83% in alpaca semen (Bravo *et al.*, 1997) and 71 to 84% in dromedary camel (Zeidan *et al.*, 2001). Semen consistency of the male dromedary camels is semi-viscous at 2.5 to 5 years of age and viscous at over 5 to 10 or over 10 to 20 years of age (Zeidan, 1999; Ahmadi, 2001)**.** During the breeding and non-breeding seasons, Rai *et al.* (1997) found that semen consistency was medium – thick jelly. Vescosity of the camel semen is usually attributed to the presence of mucopolysaccharides (Mann, 1964)**,** of which identification, isolation and source remain to be unknown. Immediately after semen collection, the ejaculate becomes aqueous in consistency. Abdel-Raouf and El-Naggar (1976) found that liquifaction time was 4.5-9.6 min, while Garnica *et al.* (1993) found that it occurred after 8-48 h. This property may be necessary to present the backflow of the ejaculate from the easly dilated cervix of the she-camel (Abdel-Raouf and El-Naggar, 1964, 1976; Chen *et al.*, 1980)**.**

Semen – ejaculate volume was found to be 7.82, 8.12 and 7.94 ml at ages of 2.5 to 5, over 5 to 10 and over 10 to 20 years, respectively (Zeidan, 1999; Ahmadi, 2001; Zeidan *et al.,* 2001) and varied between 5 and 22 ml (Wilson, 1984) and from 5.3 ml in the breeding season to 3.5 ml in the non-breeding season (Rai *et al.,* 1997). In addition, semen-ejaculate volume values were 3.92 and 8.47 ml when semen was collected by artificial vagina and electro – ejaculation, respectively (Alfuraiji, 1999)**.**

Percentage of sperm motility varies according to age and season. Zeidan (1999) and Zeidan *et al.,* (2001) found that sperm motility values were 48.26, 64.62 and 56.45% at ages of 2.5 to 5, over 5 to 10 and over 10 to 20 years, respectively, similar to that recorded by Abd El-Azim (1996) and Ahmadi (2001)**.** During seasons of the year, Zeidan *et al.* (2001) found that sperm motility values were 73.5, 70.1, 61.6 and 65.0% during winter, spring, summer and autumn, respectively**.** From another point of view, Musa *et al.* (1992) found that sperm motility values of the male dromedary camels were 50.5 and 49.7% when semen was collected by artificial vagina and electro-ejaculation, respectively. Individual spermatozoal motility was detected as an oscillatory motion of the flagellum, but not progressive due to the viscous materials.

The morphological studies showed that the camel spermatozoa were smaller than in the other animals. The head is short and narrow and the total length of the tail is shorter than in the other animals (El-Sharief, 1997; Zeidan *et al.,* 2001)**.** The shape of the head of the camel spermatozoa, generally, appears to be elleptical and the whole head appears to have a cylinderical form with slight constriction at the base and bearing a short acrosome piece. Zeidan *et al.* (2001) observed that the head length, head width, head breadth, tail length, tail width and total length of the dromedary camels were 6.21, 2.86, 3.76, 45.18, 1.09 and 51.39µ, respectively. The camel sperm is smaller than that of the bull or the buffalo (Tayeb, 1945).

Percentages of each of dead spermatozoa, sperm abnormalities and acrosomal damage were recorded in the male dromedary camels at ages of 2.5 to 5, over 5 to 10 and over 10 to 20 years, respectively (Zeidan, 1999; Zeidan *et al.,* 2000, 2001). During the seasons of the year, the highest percentages of dead spermatozoa and sperm abnormalities were recorded during summer and the lowest during winter (Abd El-Azim, 1996; Rai *et al.,* 1997).

Sperm-cell concentration varies with age and season. The highest values (336.60×10^6/ml) were recorded at the ages of over 5 to 10 years of age and the lowest (312.36×10^6/ml) at 2.5 to 5 years of age (Zeidan, 1999; Zeidan *et al.,* 2001)**.** Sperm-cell concentration was the highest (5.7×10^8/ml) during the breeding season,, while it was the lowest (4.7×10^8/ml) during the non – breeding season (Rai *et al.,* 1997). However, although the season affects the spermatozoa number, but it has not any effect on the size.

Semen chemical characteristics

Hydrogen-ion concentration (pH) of camel semen is alkaline (7.2 - 8.8) averaging 7.8 (Khan and Kohli, 1973; Bravo *et al.,* 1997; Zeidan *et al.,* 2000, 2001; Ahmadi, 2001). The highest (8.12) values of pH were recorded at over 5 to 10 and the lowest (7.82) at 2.5 to 5 years of age (Zeidan *et al.,* 2001)**.** pH was found to be 8.2 during the breeding and 7.7 during the non – breeding seasons (Rai *et al.,* 1997).

Citric acid and fructose concentrations in seminal plasma were found to be 4.3 and 5.0mg/dI, respectively, in alpaca camels (Garnica *et al*., 1995). Citric acid and fructose concentrations were far lower than concentrations in any other livestock species (bulls 720 and 540, rams 247 and 137 and stallion 26.1 and 2.1 mg/100 ml, respectively; Mann, 1964).

The seminal plasma was found to contain an average of 64.8 King Armstrong units of the acid phosphatase and 313.6 for the alkaline phosphatase, indicating that the camel seminal plasma has a comparatively low acid phosphatase and a considerable high level of alkaline phosphatase. High enzymatic activity of both acid and alkaline enzymes were seen in February, while the lowest values were observed in March, in Egypt (El-Naggar and Abdel-Raouf, 1976; Ahmadi, 2001)**.**

Protein fractions isolated from the camel seminal plasma by paper electrophoresis ranged between 10 and 14 in number. However, the camel seminal plasma proteins varied in its electrophoresis behaviour, since it was found patterns with only 10 fractions, others with 14 fractions and the majority showed 12 fractions. It was also noticed that 3 to 4 major components were always present in addition to other 7 or 8 minor ones (El-Naggar and Abdel-Raouf, 1976).

The camel seminal plasma cystine, cystathionine, ornithine, histidine, lysine, arginine, asparagine, serine, glycine, glutamic acid, alanine, threonine, proline, tyrosine, tryptophan, methionine, valine, phenylalanine, isoleucine and leucine amino acids were identified by the application of thin layer chromatography. Histidine, arginine and lysine were found with relatively high concentrations (El-Naggar and Abdel-Raouf, 1977).

The concentrations of chloride, calcium, inorganic phosphate, phospholipids, total nitrogen, total protein and albumin were found to be in close agreement with those of other animal species (Garnica *et al.*, 1993).

Semen used in an AI programme should have a sperm concentration greater than 325 x 10^6 / ml and pecentages of motile sperm, dead sperm and abnormal sperm higher than 50.5%, lower than 18.0%, and lower than 27.7%, respectively (Tingari *et al.*, 1986; Merkt *et al.*, 1990; Musa *et al.*, 1992, 1993).

Ovarian activity

The breeding season sexual activity of the female coincides with the males rutting and it seems that both respond to the same environmental conditions.

The ovarian activity changes show highly significant differences between months, as well as, between seasons (Sghiri and Driencourt, 1999). Most of the ovarian activity occurs form December to March and during July and August (rainy season) in India (Rai *et al.*, 1995) and from December to May, in Egypt (Shalash, 1965)**.**

During the breeding season, follicular growth occurs constantly in both ovaries in regular waves (Musa *et al.*, 1993). Such waves include follicular growth, maturation and atresia (Musa, 1969; El-Wishy and Hemeida, 1984).

Ovulation seems to be induced by copulation in the dromedary, since the estous cycle is restricted only to a follicular development and absence of luteinization (Noseir *et al.*, 1980, cited by Iamail, 1998). Induction of ovulation could be achieved in the camel by mating with an intact or vasectomised male (Marie and Anouassi, 1987), although this is not a practical method because of the risk of the transmission of venereal and other diseases. Stimulation of the release of sufficient LH from the pituitary to cause ovulation could be carried out by manual stimulation of the cervix, the intrauterine injection of whole semen, seminal plasma, water or prostaglandin (Musa and Abusineina, 1978a; Sheldrick *et al.*, 1992). Ovulation can occur within 48 h following mating or intramuscular injection of luteinizing hormone. The left and right ovaries function alternatively. The optimal time to mate or attempt to induce ovulation is when the growing follicle measures 0.9-1.9 cm in diameter (Skidmore *et al*., 1996). Receptivity may disappear after 3 days if copulation occurs on the first day of estrus. Follicular regression occurs in 3 days, with copulation (Yagil and Etzion, 1984; Yagil and van Creveld, 1990; Musa *et al.*, 1993).

Induction of ovulation without the need for coitus by deposition of camel semen in the female's uterus (Chen *et al.*, 1985; Musa *et al.*, 1990) makes AI an attractive tool for genetic improvement (Musa *et al.*, 1993), although a major difficulty with camel AI in this case is ensuring that the inseminated females ovulate (Chaudhary, 1995). Following AI, ovulation has been induced with either 3000 IU hCG or 20 ug of the GnRH analogue, Buserelin (Mckinnon and Tinson, 1992). A single treatment with GnRH or hCG (Marie and Anouassi, 1987; Anouassi *et al.*, 1992; Mckinnon and Tinson, 1992; Sheldrick *et al.*, 1992; Skidmore *et al.*, 1996), could be used to induce ovulation. Particularly, the ovulatory response in the camel could be a result to a combination of stimuli including a chemical factor in the seminal plasma, neurohormonal responses to the chemical stimuli of the coitus and the male effect (Marie and Anouassi, 1987; Anouassi *et al.*, 1992; Moslah *et al.*, 1992; Sheldrick *et al.*, 1992), since the mechanical stimulation of the cervix which triggers ovulation in the cat and rabbit species were not useful in induction of ovulation in the camel (Musa and Abusineina, 1978a; Elias *et al.*, 1984; Musa *et al.*, 1990). Ovulation rates and pregnancy were found to be significantly higher in inseminated camels that had been mated by vasectomised male (Anouassi *et al.*, 1992).

Generally, ovulation rates reached 85% in natural mating, 81% with 20 ug GnRH analogue and 67% with 3000 IU hCG when the dominant follicle measured 0.9-1.9 cm in diameter. A marked reduction in the effectiveness of natural mating and these hormones to induce ovulation has been observed when the diameter of the dominant follicle exceeded 2.0 cm in diameter (Skidmore *et al.*, 1996).

Camels as induced ovulators offer great prospects of natural synchronization of estrus solving problems of estrous detection and has made artificial insemination more convenient and attractive (Helmy, 1991; Minoia *et al.*, 1992). Synchronization of estrus in the dromdary could be successfully carried out by Progestin injections (Mckinnon and Tinson, 1992). The use of progesterone-releasing intraviginal device (PRID) alone was not satisfactory for controlling ovarian function (Cooper *et al.*, 1992). Equine chorionic gonadotrophin (*e*CG) in doses ranging between 1000 to 8000 IU resulted in a very low number of pregnancies (Yagil and Etzion, 1984; Rai *et al.*, 1990).

Stimulation of the ovaries for production of multiple follicles has been carried out successfully in camels by the use of *e*CG at various doses between 1500 and 6000 IU (Anouassi and Ali, 1990; Mckinnon and Tinson, 1992; Skidmore *et al.*, 1992). Superovulation can be carried out by the use of 1-3 mg ovine FSH in a split dose regime over 3-6 days (Cooper *et al.*, 1990, 1992; Mckinnon and Tinson, 1992; Skidmore *et al.*, 1992).

Pregnancy occurs mostly in the left uterine horn, although both ovaries equally produce ova (Shalash and Nawito, 1964; Musa and Absineina, 1976). Embryos that are produced in the right horn may migrate to the left horn for unknown reasons, although migration of the ova is not a frequent occurrence. Pregnancy can be detected by feeling large corpus luteum and presence of high level above 1 ng / ml progesterone beginning of the second week of pregnancy (Elias *et al.*, 1984) and / or by using ultrasound technique after the third month of pregnancy (Schels and Mostafawi, 1978). Sealing of the external cervical os during pregnancy by a plug, is one of the unique properties for the she-camel (Guyton, 1991), and it is an indication of pregnancy. The physiochemical properties of the cervical mucus of pregnant camels, showed parallel increases in plasma progesterone and protein concentrations, alkaline and acid phosphatase (Al-Eknah, 1997 a,b). The low elasticity of the mucus is affected by the decrease of hydration under the influence of progesterone which leads to concentration or alteration and arrangements of mucus (Prasad *et al.*, 1981). Plasma progesterone concentrations in camels are constantly low (Homeida *et al.*, 1988). At least one corpus leuteum is formed following mating, that secretes a significant amount of progesterone. During pregnancy, a value of more than 2 ng / ml was recorded (Al-Eknah, 2000). Oestrogens are continuously secreted during pregnancy in the she-camel (Agrawal *et al.*, 1987b), but their concentrations rise at mid-gestation, suggesting continued follicular development during pregnancy (El-Wishy *et al.*, 1981; Wilson, 1984). On the day of parturition, high concentrations of oestrogens in the allantoic fluid have also been recorded, suggesting that the placenta could be a probable source of oestrogens (Elias *et al.*, 1984). Gestation length averaged 373-393 days with longer or shorter periods (Musa and Abusineina, 1976; Yagil and Etzion, 1984; Hermans and Shareha, 1990; Abdel-Raouf, 1993; Al-Bisher, 1998). Such variation may be due to differences in the methods of husbandry, number of matings over the entire period of estrus (Novoa, 1970), number of pregnancies, sex of the foetus (Arthur *et al.*, 1982; Agrawal *et al.*, 1987b), level of feeding (Yagil and Etzion, 1984) or season of conception (Elias *et al.*, 1991).

Signs of approaching parturition include segregation from the herd, restlessness, increasing humming and relaxation of the sacroisciatic ligaments (Musa, 1983; Al-Bisher, 1998). Presence of colostrum in the udder (Arthur *et al.*, 1985; Elias and Cohen, 1986) and dilation of the cervix during the peri-parturition period (Al-Eknah, 1996) are the best signs of approaching parturition.

Expulsion of the foetus is preceded by the attainment of a minimum level of plasma progesterone and high levels of oestrogen (Elias *et al.*, 1984, 1986; Al-Bisher, 1998).

FERTILITY

The camels reproductive life length varies according to plane of nutrition, management, health and genetic factors. However, the high level of reproductive efficiency is essential for profitable production and imperative to efficiency of selection and rapid herd growth.

Generally, the fertility rate in camels is extremely low (50%) when compared to other domestic animals (Novoa, 1970). The fertility rates showed no significant differences with differences in age of the male camels either at 2.5 to 5 (46.67%), over 5 to 10 (52.17%) or over 10 to 20 (47.37%) years of age (Zeidan, 1999), . Fertility rates were estimated as 34.00 and 52.25% (Bremaud, 1969), 37-47% (Yuzlikaev and Akhmediev, 1965) and 70% (Wilson, 1984), in dromedary camels. The low fertility rate in camels may be due to non-developing follicles, embryonic mortality and abnormal anatomical features of genital tract of the she-camel (Shalash, 1965;Yuzilikaev and Akhmediev 1965; Novoa, 1970), failure of females to ovulate when mating (Novoa, 1970) and poor semen quality (Hemeida *et al.*, 1985). Improvement of management conditions are very likely to increase the fertility rate above 50% in camels (Dahl and Hjort, 1976), since Cossin (1971) obtained better fertility rates with improved management practices. Percentage of 80 of the animals have a calving interval of at least 2 years and 73 do not rebreed within 12 months of calving.

Calving rate averaged only 40% in a Soviet camel ranch (Keikin, 1976), 41% in Egyptian camels (Zeidan, 1999), 9.82 - 60% (average 39.2 during 1959 to 1984 and 35.38 and 51.47% during 1985 and 1986, respectively) in Indian Bikaneri camel (Ismail, 1987) and 39.1% in dromedary camel in Libya (El-Azab *et al.*, 1997). The wide year to year variations were due to inconsistent management in the different years. Unplanned breeding, malnutrition and poor management practices result in low calving rate (Ismail, 1987). The maximum calving was during January, followed by February March, December, April, May and November, respectively.

Ratios of male to females during the breeding season were stated to be 1 male to 5-7 females (Watson, 1969) and 1 male to 50-80 females (Singh, 1963, Leupold, 1968; Williamson and Payne, 1978). Leese (1927) reported that a male camel can serve up to 50 females in a season and 70 females when it is very well fed. Burgemeister (1975) reported that one camel stallion can breed three females per day at the peak of the breeding season depending on levels of management and health. The recommended ratio is 1 male to 20-25 females. Keeping extra males is desirable to provide genetic diversity and to check inbreeding and for wider and efficient selection (Mukasa-Mugerwa, 1981)**.**

Herd growth in camels is affected by late age at first calving, limited breeding season and opportunity, prolonged calving interval, low plane of nutrition, poor management practices, diseases and frequent prenatal losses (Mukasa-Mugerwa, 1981)**.**

Improvement of the reproductive efficiency of the camel could be very acceptable if a calf per each she-camel is produced every 2 years. Maintaining adequate nutritional level, advancing puberty, achieving conception outside the breeding season and shortening the days open, may be beneficial, in that respect. The use of A.I. may realize that level of the reproductive efficiency.

PHYSIOLOGICAL BACKGROUND

The literature showed that rectal, skin and coat temperatures and respiration rate of camels increased significantly in the non-breeding season (summer) than in the breeding season (winter), in the dromedary male camel. The increase in rectal temperature to 41.1^{o}C during the mid summer day, minimized temperature gradient between the body and the environment (Ibrahim, 2001). Schmidt Nielson *et al.* (1957) and Chawdhary-Brahman (1981) reported that diurnal variation in camels rectal temperature ranged between 2.9 and 6.0^{o}C, while such variation was found to be about 2^{o}C only in other animals (sheep, goats, cattle and buffaloes (Abdel-Samee, 1991, 1992; Abdel-Samee *et al.*, 1992, 1996). Particularly, the highly significant increase (P<0.05) in respiration rate and rectal temperature during summer may be a reaction to the stored heat in camels body, since Bornstein (1988**)** reported that camel, although it has sweat glands and can sweat efficiently stores some of the heat that allows its body temperature to rise as high as 40.7^{o}C, in spite of dissipating most of the excess heat load through the loss of water by sweating during the hot part of the day. The camel also saves a quantity of water estimated by Bornstein (1988) to be nearly 5 litres in a camel of 500 kg body weight. In such a camel, body temperature decreases 6^{o}C (from 40.7^{o} C by day to 34.5^{o} C by night) which is equivalent to approximately 3000 kcal. Chawdhary-Brahman (1981) reported that a camels' high body temperature is dissipated to the environment through conduction, convection and radiation during nights.

Blood cortisol as an indicator of adrenal function, did not change significantly due to heat stress (Abdel–Samee and Marai, 1997). Sheep behave similarly (Abdel-Samee, 1991). However, other studies on sheep and cattle showed that cortisol level either decrease significantly (Abilay *et al.*, 1975) or increase significantly (Wise *et al.*, 1988) or do not consistently change. The low values were found to follow the initial values before exposure to heat stress (Jhani, 1988). Such contradictions may be attributed to the high variation in the basal cortisol concentration and to differences in duration of exposure to high environmental temperature (Hundson *et al.*, 1975).

Plasma T4 and T3 levels were lower (P<0.01) in the hot summer climate than in spring by 24 and 28%, respectively. Such decline may help the camel to reduce its endogenous heat production during summer (Abdel–Samee and Marai, 1997; Ibrahim, 2001). Gauly *et al.* (1997) confirmed that thyroid hormone concentrations changed seasonally and the lowest concentration was during summer and the highest was during winter, in male llama (*Lama glama*), under middle European conditions. The same authors added that serum T3 and T4 concentrations were positively correlated with the number of spermatozoa (P<0.05) and T4 and free T4 concentrations were negatively correlated with average ambient temperature (the maximum and minimum temperatures) and with the hours of sunlight per day..

Blood haemoglobin, haematocrit and the red blood cells (RBC's) count did not change appreciably from spring to summer, while the white blood cells (WBC's) count was higher (P<0.05) by 15% in summer than in spring. This latter change may enhance the camels resistance to disease.

Blood glucose, total lipids, cholesterol and triglycerides were lower (P<0.05) by 22, 12, 17 and 18%, respectively, in summer than in spring, while blood total solids, total proteins, albumin and globulin levels did not show significant changes between the two seasons. These results may reflect the greater ability of camels to adapt to heat stress than in the other farm animals (Abdel- Samee and Marai, 1997). The results of Abdel-Samee and Marai (1997) showed nonsignificant differences between spring and summer in serum urea, creatinine, uric acid, bilirubins, Ca, P, Na and K, indicating that the camels' kidney function was not affected by exposure to the hot climate.

From another point of view, the camels can conserve and recycle urea for microbial protein synthesis in the forestomach to avoid the negative protein balance that occurs (as in the other farm animals) during heat stress, since the kidneys of the camel not only excrete small amounts of urine but the animal can also produce urine with extremely low concentration of urea (Schmidt- Nielsen *et al.*, 1957). The urea formed during protein metabolism in the camel is not necessarily excreted, but it may pass back into the forestomach from the blood plasma via the saliva and through the rumen wall. In addition, camel kidneys can conserve and correct negative mineral balance occurred when heat stressed. In other words, camels may be able to avoid the disturbances of protein and mineral metabolism that occur in many species of farm animals due to heat stress through adaptation of its kidney and liver function. These phenomena may be supported by the observations of Bornstein (1988) who found that the metabolic rate of camels in the arid lands of Australia was about half of that of cattle in the same environments.

Serum glutamic oxaloacetic transaminases (SGOT) and serum glutamic purovic transaminases (SGPT) levels did not differ significantly between spring and summer, while alkaline phospotases (ALP) and acid phospotases (ACP) decreased significantly by 21 and 15%, respectively, in the hot summer. This suggests that liver function may be partially affected by heat stress (Abdel–Samee and Marai, 1997). However, Kataria and Bhatia (1991) found that ALP and ACP were significantly higher during extremely hot (May-June) than in extreme cold (December-January) conditions, in India.

From above, it is clearly seen that during the non-breeding season which occurs during summer, the physiological activities of the camel which is the most tolerant farm animal to hot climate conditions (although it may be exposed to freezing conditions during some nights of the winter), are affected adversely by heat stress due to their disturbance as a function of the elevated temperature. The studies of Habeeb *et al.* (1992), Marai and Habeeb (1998) and Marai *et al.* (2002a, 2007) on the other farm animals showed that such disturbances result in impairment of reproduction including reduced semen quality or fertility in the male and failure to exhibit estrus, failure of the ova to be fertilized, loss of the fertilized ova shortly after mating and fetal dwarfing in the female.

This may indicate that the polyestrous nature, i.e. sexual activity of the camel (male and female) is quiescent during the summer, although the male is capable to mate and fertilize an estrous female at any time of the year (Abdel-Raouf *et al.*, 1975) and the female pregnancy can occur at any season of the year (Nawito *et al.*, 1967). In other words, elevation of the ambient temperature during summer which is closely correlated and may be a result of the increase in daylight, plays the main role in affecting the camel reproductive activities through disturbance of the physiological activities, similar to that reported by Marai *et al.* (2002b) regarding other induced ovulators (the rabbit).

Generally, variation in timing and length of the breeding season of the camel may be due to local environment which includes geographic, climatic and / or nutritional factors (Schmidt, 1973; Sghiri and Driencourt, 1999). In other words, managerial and nutritional effects, environmental factors such as temperature, humidity and light, as well as visual or olfactory cues, are likely to influence the system centres controlling reproductive activity and may be considered as factors to trigger off or the start of increase in sexual activity. Referring to the studies of Wodzicka-Tomaszewska *et al.,* (1967), Karsch *et al.* (1984), Gallegos-Sánchez *et al.* (1997), Arendt (1998), Malpaux *et al.* (2002), Arroyo *et al.* (2007) may throw more light on the the role of the mentioned factors in affecting the camel reproductive activities.

ROLE OF THE SUPRACHIASMATIC NUCLEUS (CNS) IN REGULATION OF TEMPERATURE RHYTHMS IN THE CAMEL

Although the showed that environmental variations have a strong influence on the onset of the breeding season, yet there is some evidence suggesting that the suprachiasmatic nucleus (SCN) may be sensitive to changes in ambient temperature, with some cells being more responsive to cold and others more responsive to heat, in rodents (Burgoon and Boulant, 2001). Furthermore, the molecular mechanisms that regulate rhythmicity, such as the cyclic changes in the expression of clock proteins, can be altered by temperature changes in *Drosophila* (Majercak *et al.*, 1999).

In this respect, there is a vast amount of information suggesting that the SCN, is an important structure regulating circadian and seasonal rhythms of most biological functions in mammals (Pando and Sassone-Corsi, 2001), particularly reproductive function and behaviour, including the phasic and tonic release of hormones, reproductive heat and in some cases gonadal size (Buijis *et al.*, 2003)

It is a fact that most studies concerning the function of the SCN in response to changes in ambient temperature have been conducted on hibernating animals, or on animals whose reproductive patterns are heavily influenced by photoperiodic information (Ruby *et al.*, 2002 and Tournier *et al.*, 2003). Thus, much is known about the SCN of ground squirrels and the Siberian hamsters, but little is known about the role of the SCN in species of animals that live in environments that vary little in their duration of light dark cycles, but vary drastically in temperature across seasons.

Nevertheless, if the camel SCN is hypersensitive to environmental changes in temperature, it would be expected that temperature changes can easily entrain rhythms in camels regardless of photoperiod. It would also be expected that reproductive function would be enhanced if the camel is kept in conditions of constant temperate conditions regardless of changes in environmental light. In short, the SCN is highly sensitive to temperature changes and this would be expressed in temperature-induced gene expression of clock proteins within this nucleus.

Within the SCN of most mammals studied, there are two groups of cells that appear to be important in the coordination and timing of reproductive fluctuations in concert with the environment. The retino-recipient SCN is primarily composed of cells that secrete vasointestinal polypeptide (VIP) and this peptide has been implicated in the coordination of gonadotropin and prolactin secretion (Van Der Beek *et al.,* 1997; Gerhold *et al.*, 2001). A second group of cells on the dorsal portion of the SCN primarily secretes aginine vassopresin (AVP), a peptide implicated not only in the regulation of water balance, but also in the mechanisms that underlie social behaviours including reproductive behaviours (De Vries *et al.,* 1994; Insel *et al.,* 1998).

In the camel, the AVP pathways originating from the SCN may contain heat and/or cold sensitive cells. Activation of these cells by changes in temperature may in turn regulate neuroendocrine function and sexual behaviour in the camel and other species living in regions exposed to extreme heat. It could be predicted that in these species, the interaction between the AVP pathways that regulate osmotic balance and those regulate social behaviour are more extensive so that reproductive behaviours are harmonized with the time of the year in which water (and therefore food) is more readily available.

CONCLUSIONS

Due to the polyestrous nature of the camel, the male is capable of mating and fertilizing an estrous female at any time of the year and the female pregnancy can occur at any season of the year, although the breeding season of the camel occurs during the mild conditions and the non-breeding season during the summer hot conditions of the year. Elevation of the ambient temperature during summer which is closely correlated and may be a result of the increase in daylight length, seems to play the main role in affecting the camel reproductive activities through disturbance of the physiological activities. However, although environmental variations have a strong influence, yet there is some evidence suggesting that the SCN may be sensitive to changes in ambient temperature, with some cells being more responsive to cold and others more responsive to heat. Furthermore, the molecular mechanisms that regulate rhythmicity, such as the cyclic changes in the expression of clock proteins, can be altered by temperature changes. Particularly, further studies on the importance of SCN in reproductive functions of the camel, are needed.

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