INTERESTING FEATURES OF FEMALE DROMEDARY (CAMELUS DROMEDARIUS) REPRODUCTION

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ABSTRACT

Inormation on the reproduction in camel continues to be poorly known and scattered. Some interesting features include seasonality of breeding, delayed puberty, peculiar anatomy of the reproductive structures, poorly defined estrus and estrous cycle and induced nature of the ovulation. Other interesting features include exclusive left uterine horn pregnancy, faster demise of the corpus luteum in the absence of pregnancy, an early maternal recognition of pregnancy, upward curling of tail (tail cocking) by Day 15 of pregnancy, diffuse placenta and a longer gestation period of 12-13 months. This review collates scientific data on the above interesting features of female camel reproduction

Key words: *Camel, Endocrinology, Estrus, Physiology, Pregnancy, Parturition.*

INTRODUCTION

Reproduction in the camel is different from other domestic species due to delayed puberty (Skidmore, 2011), seasonality of breeding (El-Wishy, 1987), induced nature of ovulation (Marie and Annouassi, 1986), poor definition of the estrous cycle (Mahla *et al.,* 2015), poor estrus signs (Joshi *et al.,* 1978, Musa and Abusineina, 1978a; Padalino *et al.,* 2016), exclusive left uterine horn pregnancies (El-Wishy, 1988), presence of an extra fetal membrane (Musa, 1977) a longer gestation period (Nagy and Juhasz, 2019) and prolonged anestrus following parturition (Derar *et al.,* 2014). As per census of 2019 In India, Rajasthan has the highest population of camels but a downfall in camel population has been recorded over the past decade. Purohit and Pareek (2000) have previously mentioned that the low reproductive performance in camels is a major obstacle to growth of camel population. Camel is considered a sturdy desert animal with a low disease incidence (Nagpal and Purohit, 2001) however, a recent study in Ethiopia found high reproductive disease in camels (Belina *et al.,* 2021). Information on the mechanisms of reproduction in the camel is poorly understood and lesser known. This review collates the scientific data on the reproduction peculiarities of female camel.

Seasonality

Camels are seasonally polyestrous animals with maximum breeding occurring during the time of the year when days are short (Khan and Kohli, 1972; Sghiri and Driancourt, 1999; El-Harairy *et al.,* 2010). The breeding months for camels in India and Pakistan extend from December to March (Matharu, 1966; Khanna *et al.,* 1990; Ali *et al.,* 2007) whereas they vary for different geographical locations (Reviewed Merkt *et al.,* 1990; Ainani *et al.,* 2018). The dromedary camel exhibits reproductive cycles during the short photoperiod but enters into anestrus during the long photoperiods (Musa *et al.,* 1993). Only a small proportion of camels evidenced a follicle between September to October months (Quzy *et al.,* 2013). The nycthemeral rhythm of melatonin secretion was documented in camel (Vyas *et al.,* 1997).Application of a mask over eyes for six hours daily (Vyas *et al.,* 2008) or subcutaneous placement of commercial implants (1 implant per 28 Kg) induced ovulatory activity in camels (Dholpuria *et al.,* 2012) ahead of the breeding season.

Similarly another study noticed that subcutaneous placement of melatonin implants in camels advanced the breeding season in camels by 2.5 months (El-Allali *et al.,* 2018). A study on camels in Morocco showed that treatment with melatonin implants advanced the onset of follicular growth activity by 3.5 months compared to untreated animals. Plasma estradiol-17β increased gradually from the second week after the beginning of treatment to reach significantly ($P < 0.01$) higher concentrations (39.2 ± 6.2 to 46.4 ± 4.5 pg/ml) between the third and the fifth week post insertion of melatonin implants and melatonin implants also suppressed the plasma prolactin levels (Khalid *et al.,* 2018). Availability of fodder, rainfall and temperature has more effects on the onset of breeding in camels located near the equator where day lengths do not vary (Bono *et al.,* 1989; Merkt

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et al., 1990). A recent review mentioned that besides the photoperiod the environmental temperature, humidity, rainfall and food availability has the impact on onset of breeding season in camels in different parts of the world (Ainani *et al.,* 2018).

Puberty

Puberty in dromedary camels commonly occurs at 3 to 4 years of age (Matharu 1966; Yagil 1985; Khan *et al.,* 2003). Sexual activity may start earlier at 2-3 years but under most managemental systems camels are not bred until they are 4 years (Williamson and Payne, 1978; Khanna *et al.,* 1990) with resultant age at first calving being 5 years (Beniwal and Chaudhary, 1984). Female camels usually attain a body weight of 400 kg at 2 years and 513 kg at 3 years (Al-Metiery and Al-Hashemy 1986). In Kenya however, under traditional management systems camels attained the mature body weight at a later age of 7 to 8 years(Schwartz *et al.,* 1983). Attempts to enhance pubertal estrus have yielded moderate success and have included the IM administration of 1000-2000 IU of eCG for 3 days (Yagil, 1985; Rai *et al.,* 1991) or IM administration of 250 mg of hydroxyprogesterone for 2 days followed by eCG (Agarwal *et al.,* 1996).

Anatomy of the Reproductive Tract

The ovaries in the non-pregnant dromedary camel are oval or furrowed, and are dorso-ventrally flattened (Purohit *et al.,* 1999). The size and shape of the ovaries (Table 1) vary with their content of follicles and corpora lutea (Abdalla, 1960; Musa, 1969; Wilson, 1984; Yagil, 1985). No differences were observed in the dimensions of the left and right ovaries (Heidari and Mohammadpour, 2010). The ovarian bursa is well developed and is important as this is the frequent site for accumulation of fluid (hydrobursitis) in camels (Ali *et al.,* 2012) confusing with early pregnancy. The ovaries of non-pregnant camels are situated in the caudal part of the lumbar region, i.e. just in front of the pelvic brim (Abdalla, 1960) or may be inside the pelvic cavity (Musa, 1969). In all cases examination of the ovaries is an important part of the gynaecological examination but they are often difficult to find. On many occasions they were found hidden beneath the uterus, so unless the uterus is retracted and rolled from side to side the ovaries would be missed (Higgins, 1986). An interesting recent finding was the identification of interstitial glands in the ovaries of camel (Awad *et al.,* 2018) which have steroid secretion activity in ovaries of cat, rabbits and rat.

The oviduct of the camel has a less coiled isthmus compared to the ampulla and the ovarian part of the fallopian tube (Abdalla, 1967; Musa, 1969; Wilson, 1984; Srikandakumar *et al.,* 2003).

The uterus of the camel (Table 1) is bicornuate and is large enough to occupy a position which is partly abdominal and partly pelvic. It has a well-developed uterine body from which the two horns diverge and taper anteriorly to give a uterine shape intermediate between that of the letters T and Y. The endometrium shows irregularly raised mainly longitudinal folds and internally there is a clear median septum (Shalash, 1965; Novoa, 1970; Wilson, 1984; Yagil, 1985). The left uterine horn is bigger than the right. The cervix of camel is short and has 4-5 annular mucosal folds (Srikandakumar *et al.,* 2003). In addition to the longitudinal folds, the cervix contains five rows of annular or transverse folds and protrudes caudally about 1 cm into the vaginal lumen, forming a dorsal and ventral fossa (Ismail, 1987). The endometrial

TABLE 1 SIZE OF THE GENITAL STRUCTURES IN CAMEL

Structure	Size(cm)	Weight (gm)	Reference
Ovary	Length 3.0-4.0 Width 2.0-3.0 Thickness 0.5-1.5	4.0-5.0	Abdalla, 1965; Wilson, 1984; Yagil, 1985; Heidari and Mohammadpor, 2010
Oviducts	14.0 – 30.0	-	Abdalla, 1967; Wilson, 1984; Srikandakumar *et al.,* 2003
Uterus	13.0 – 22.0 5.9 (right), 7.77 (left horn)	284.06	Musa, 1969 Srikandakumar *et al.,* 2003
Cervix	5.3 – 5.9	-	Shalash, 1965
Vagina	30.0 – 32.0		Wilson, 1985; Srikandakumar *et al.,* 2003
Vestibule	8.0	-	Merkt *et al.,* 1990

PHYSIOLOGIC FEATURES OF FEMALE CAMELS

Ovarian Follicular growth

Ovarian follicular growth in camels is generally considered to be initiated during the breeding season although small follicles could be identified also during the non-breeding season (Vyas *et al.,* 2004; Ali *et al.,* 2007; Hussein *et al.,* 2008). The number of small, medium, large and the total number of ovarian follicles were higher (P<0.01) during the breeding than non-breeding season (Abdoon, 2001). Follicular growth in camels two months ahead (transition phase) of the breeding season is limited to appearance of small follicles (below 4 mm) appearing at the periphery of the ovaries sometimes referred as “black periphery” (Dholpuria *et al*., 2012). Follicle can grow over the entire surface of camel ovaries. Age had a significant effect on the presence of follicles over ovaries in camels with 6-10 year camels having the maximum number of follicles (Ashour *et al.,* 2017). In non-pregnant camels (*Camelus dromedarius*) follicle waves emerge approximately every 11–20 days (Adams *et al.,* 1990; Skidmore *et al.,* 1996a). In camel’s follicle develop to a maximum diameter of approximately 20 mm or grow to become over-sized follicles reaching an average of approximately 40 mm (Skidmore *et al.,* 1996a) in diameter. It is not clear as to what triggers the growth of follicles in camel. A non-significant rise of FSH was recorded 3-4 days after mating (Anouassi *et al.,* 1987). Ovarian follicular growth waves similar to cattle are not seen in camels. All the more since ovulation is induced hence a well grown follicle may not ovulate and follicle growth can still continue. The presence of an active corpus luteum does not prevent the development of new follicles (Merkt *et al.,* 1990). The presence of an oversized follicle (30-40 mm) does not interfere in the growth of follicles. The time taken by the follicle to reach its full mature size varies considerably among individuals (Manjunatha *et al.,* 2012). Studies have described the occurrence of follicular growth waves in camels (Skidmore *et al.,* 1996a; Manjunatha *et al.,* 2012) and accordingly have been divided into three phases: namely: i) the growth phase of 10.5 ±0.5 days, ii) the mature phase of 7.6±0.8 day and a regression phase of 11.9±0.8 days (Skidmore *et al.,* 1996a). In the absence of mating there is a succession of overlapping follicular waves with variable rhythm (Anouassi and Tibary, 2013). In the absence of ovulation, the mature follicle continues to grow and reach sizes varying from 25 mm to 75 mm in 40–50% of the follicular waves. About one third of these anovulatory follicles become hemorrhagic and even undergoes partial luteinization (Anouassi and Tibary, 2013). On Day 14 postovulation, over 85% of the females have a mature follicle and are ready to ovulate again if mated (Anouassi and Tibary, 2013). Many of the physiologic events in camel for example the primordial follicle numbers their growth during puberty and antral follicle pool during breeding season etc. continue to be poorly known. Mature dominant follicles can ovulate in response to mating and in the absence of mating the fate of anovulatory follicles in camel can be development of hemorrhagic follicle (Anouassi *et al.,* 1994).

Estrous cycle, estrus signs and duration

On account of less reliable estrus signs (Tibary and Anouassi, 1997), lack of rhythmic estrus expression (Skidmore, 2011) and poor correlation of the presence of a mature follicle with the estrus expression (Skidmore *et al.,* 1996a; Mahla *et al.,* 2015) estrous cycle is difficult to be defined and seems inappropriate. The length of estrus cycle and estrus period has been mentioned in the past to vary from 22-30 days and 3-6 days (Joshi *et al.,* 1978; Musa and Abusineina, 1978a; Al-Eknah *et al.,* 1993; Alfuraji, 1999). Such evaluations have however not considered whether or not the camels were mated because the presence of a CL in camel would depend on mating and the demise of a mated non-pregnant camel occurs rapidly (9-10 days). Camel breeders randomly mate the camels with male camels during the breeding season assuming that a follicle is always present during the entire breeding season (Purohit and Pareek, 2000). However, such an assumption is not always correct as the follicle might not be of an ovulatory size or it may be oversized (Vyas and Sahani, 2000). In the absence of a male, estrus may last for about 2 weeks, whereas if copulation occurs on the first day of estrus, receptivity may disappear after 3 days (El-Wishy, 1987).

The behavioral signs of estrus in the female camel are less marked compared to changes in the male camel (Merkt*et al.,* 1990). The signs of estrus described for the female include restlessness, bleating, vulval swelling and mucous vaginal discharge. The tail is moved up and down in rapid succession on the approach of the male or when hearing its gurgling voice (Merkt*et al.,* 1990). The vagina at this stage is moist and pink coloured although the degree of wetness decreases as heat progresses. The cervix is relaxed and moist. Trans-rectal palpation reveals that the uterine horns are turgid (Musa and Abusineina, 1978b; Wilson, 1984; Yagil, 1985).One study evaluated the behavioral signs of estrus in female camels before and at mating and found that the behavioral signs had a weak intensity and could not be used as a reliable indicator for selecting female camels for mating (Mahla *et al.,* 2015). Receptive behavior of female camels when approached by a male is generally used as an indicator for mating however; some females (30%) remain indifferent and suddenly become receptive (Mahla *et al.,* 2015). Breeding camels on the ultrasonographic finding of a follicle between 1.0 to 2.0 cm has been suggested (Skidmore *et al.,* 1996a; Quzy *et al.,* 2013) however; a few of the camels might not be receptive. Use of vaginal

electrical resistance for estrus detection and its relationship with ovarian follicle detected by ultrasound yielded unreliable results (Vyas *et al.,* 2009; Dholpuria *et al.,* 2014). Attempts to time estrus (follicular) phase in camels on the basis of exfoliative vaginal cytology have yielded inconclusive results (Majama *et al.,* 2018). Thus human approaches to select estrus females suitable for mating appear to be far from perfect.

Endocrinology

The levels of progesterone and estradiol were low during the non-breeding season (1.15 ± 0.09 ng/mL and 45.86 ± 3.1pg/mL) in camels compared to values during the breeding season (1.97±0.14 ng/mL and 53.66+2.46 pg/mL) (Amal *et al.,* 2019) and similar observations were recorded in another previous study (Elias *et al.,* 1984). A previous study also recorded higher in vitro oestradiol concentration with increasing follicle size and was larger in follicles obtained during peak breeding season (Sghiri and Driancourt, 1999).

Peripheral concentrations of estradiol increase with increasing follicle diameter until the follicle reaches 1.7 cm in diameter at which time they start to decrease even if the follicle continues to grow (Skidmore *et al.,* 1996a). In the absence of mating also the estradiol concentrations decline after the follicle has attained an ovulatory size (Skidmore *et al.,* 1996a; Basiouni, 1997; Basiouni, 2007). In mated camels estradiol concentrations decline sharply whereas in non mated camels the decline was slow (Elias *et al.,* 1984) and estradiol concentrations rose again in a few days concomitant to the presence of a new mature follicle(Elias *et al.,* 1984). High serum estrogen and testosterone concentrations during the 5 days of follicular development are probably the stimulus to behavioral estrus (Homeida *et al.,* 1988). Regression of the follicles on the other hand was followed by low estrogen and testosterone concentrations (Khalil, 1989). Measurement of estradiol concentrations in the follicular fluids also revealed that estradiol levels were found to be higher in large follicles and minimal in small sized, cystic and atretic follicles (Salem *et al*., 1997; Afaleq *et al*., 2003). Estradiol concentrations remained low throughout the non breeding season in camels (Elias *et al.,* 1984).

The cyclic changes in the levels of circulating estrogens and progesterone revealed that in mated dromedaries the progesterone concentration was low (0.5 ng/ml) on the day of estrus (Day 0) when the levels of estrogens (E2) achieved their peak of 66-110 pg/ml (mean 74.7 + 6.61 pg/ml) (El-Wishy, 1987). The concentrations of progesterone remains low in non-mated animals but in mated camels it increases 3-4 days after ovulation (day of ovulation=Day 0) to reach maximum concentrations on Days 8-9 before decreasing rapidly on Days 10-11 in the non-pregnant animal (Skidmore, 2011).

The concentrations of Luteinizing Hormone (LH) were found to be higher during the breeding season compared to the non-breeding season (Bono *et al*., 1990). Since camels are induced ovulators, mating in camels is the stimulus for an LH surge needed for the completion of the final stages of follicular maturation and subsequent ovulation. In the dromedary female plasma LH concentrations were found to increase gradually to reach maximum concentrations of 3-19 ng/mL at about 2-3 h after mating and then start to decrease 6 h later (Marie and Anouassi, 1987).

The FSH secretion in relation to follicle recruitment is poorly known in camels (Basiouni, 2007). Follicle stimulating hormone in the female dromedary camel tend to increase 3-4 days after mating compared to pre-mating values. However, this increase is not significant (Anouassi *et al*., 1987). It is possible that this little rise in FSH secretion maybe needed for the development of the next wave of follicles if the previous mating did not end up with conception. In one study utilizing abattoir derived ovaries FSH levels were higher in follicles parallel to the diameter of follicles up to those of 9-19 mm, but FSH concentrations in larger follicles groups (20-24 and 25-30 mm) were lower (Hussein *et al.,* 2008).

Ovulation

Ovulation in the camel is mating induced (Agarwal and Rai, 1995) as LH concentrations started to rise within an hour of mating and peaked within 2-3 h (Marie and Anouassi, 1986; Agarwal and Khanna, 1997) and started declining 6 h after mating (Marie and Anouassi, 1986). Mating may not essentially result in ovulation as a few matings have been found to be non-ovulatory (Vyas *et al.,* 2010) and in one study the number of non-ovulating camels in response to mating was 35.6% when the copulation time was less than 1.5 min compared to only 8.5% when the copulation time was more than 6 min (Anouassi and Tibary, 2013). Although a few workers mention that the ovulation induction factor is present in the seminal plasma (Chen *et al.,* 1985; El-Allali *et al.,* 2017) however, this is not widely accepted. Manual stimulation of the cervix for 15 minutes did not induce ovulation, although luteinization of the mature follicle occurred (Musa and Abusina, 1978a). Spontaneous ovulation has also been reported in camels in one study (Nagy *et al.,* 2005). The induced nature of ovulation poses serious problems in artificial insemination (Purohit, 1999a) and suggestions for ovulation induction during AI include administration of GnRH or hCG as the administration of both of these can induce ovulation in camel (Skidmore *et al.,* 1996a) when follicle is 1.0 – 1.9 cm. However one report mentioned no effect of administration of 40 micro gm of buserelin acetate on ovulation in camel (Vyas. 2011). Oversized follicles

beyond 3.0 cm do not ovulate in response to mating or hCG (Skidmore *et al.,* 1996a). Twins in camels are rare (Purohit, 1999b).

Corpus luteum formation and regression

Cyclic formation of corpus luteum as it occurs in cattle is not seen in camels. The corpus luteum formation in the camel depends upon mating. Mating occurs in camels in a sitting position (El-Wishy, 1987; Dholpuria *et al.,* 2012). In the non-mated camels no corpus luteum is formed. If the camel is mated, ovulation occurs 24-36 h later but progesterone concentrations in peripheral serum remain low (<1 ng/ml) for the first 3 days after mating. Progesterone concentrations increase to reach maximum values of about 3 ng/ ml by Day 8 or day 9 after mating before decreasing rapidly to basal concentrations of <1 ng/ml again, in the non-pregnant camel, by Day 11 or Day 12 (Marie and Anouassi, 1987). The corpus luteum in non pregnant mated camels has a very short lifespan of 10 days compared with other domestic species. The luteolytic cascade of PGF2-alpha originates from the endometrium in the mated non-pregnant camel on Day 10 (Skidmore *et al.,* 1998). However, the release of endometrial PGF2alpha in the non-pregnant camel may not be controlled by the release of oxytocin (Skidmore *et al.,* 1998). Interesting features of PGF2-alpha in the camel have been described elucidating that the PG released from the right uterine endometrium is luteolytic only for the CL on the right ovary whereas PGF2-alpha released from the left uterine horn is luteolytic for CL on both right and left ovaries (Tibary and Anouassi, 1997).In pregnant camels corpus luteum is maintained throughout gestation (El-Wishy *et al.,* 1981), and thus is the principal source of progesterone for pregnancy maintenance throughout gestation (Musa *et al.,* 1976; Al-Eknah *et al.,* 2001). The corpus luteum of pregnancy is spherical, elongated or oval and a large part of its bulk protrudes from the ovary and shows clearly branched blood vessels on its surface (Musa, 1969; Yagil, 1985).The size of CL increases from 1.5 cm during early pregnancy to 2.0 cm at 60 days of gestation (El-Wishy, 1988).

Maternal recognition of pregnancy, implantation and placentation

Little is known about pregnancy recognition signals, and implantation in camel. Due to a short life span of the CL the camel conceptus must migrate to the left uterine horn and send an anti-luteolytic signal to the endometrium by day 7 or 8 to maintain CL (Skidmore *et al.,* 1994). After fertile mating, the camel embryo enters the uterus between Day 6 and Day 6.5 post ovulation many times at early hatched blastocyst stage (Mc Kinnon *et al.,* 1994). The hatched camel blastocyst remains spherical, grows rapidly, and then starts elongating at Day 10 post ovulation (Tibary and Anouassi, 1997).Maternal recognition of pregnancy (MRP) takes place before Day 10 post ovulation(Trassoras *et al.,* 2010) and coincides with the migration of the elongated embryo towards the left uterine horn that always hosts pregnancy (Picha *et al.,* 2013). In camels, the embryo signal for MRP has been suggested to be oestradiol 17-beta (Skidmore *et al.,* 1994) as described in pig. During pregnancy, oestrogen concentration in peripheral blood increases up to 100 pg/mL (Skidmore *et al.,* 1996b). In addition, aromatase, a key steroidogenic enzyme converting cholesterol to oestrogens was found in trophoblast cells of the camel conceptus between days 14 and 30 and is predominant in trophoblast giant cells by day 30 after ovulation until term (Wooding *et al.,* 2003). A recent study confirmed that (i) conceptus implantation is not associated with an IFN response in the pregnant uterine horn (ii) when regulation of classical interferon-stimulated genes (ISG) occurs, it takes place during the formation of the feto-placental unit, and (iii) gene expression can differ between the left and right uterine horns during implantation and early placentation phase (Salah Abdoon *et al.,* 2017).

Some insights on implantation of camel embryos were derived from study by (Skidmore *et al.,* 1996b). By day 14 the majority of the trophoblast had become closely apposed to the luminal epithelium of the endometrium to form the start of an epitheliochorial placenta with microvillar interdigitation initiated in some places. By day 25 a well-developed microvillar junction had formed between the fetal and maternal tissues. The fetus was situated in the middle of the left uterine horn in the day 35 and 56 specimens and, histologically, large multinucleate giant trophoblast cells had developed at frequent but irregular intervals along the, otherwise single-cell, trophoblast (Skidmore *et al.,* 1996b).

Based on the distribution type of the chorionic villi, and the formation of layers between the maternal and fetal structures the camel placenta was found to be diffuse and epitheliochorial (Ghazi *et al.,* 1994). An interesting feature of camel placenta is the presence of an extra fetal membrane termed the epidermal membrane (Musa, 1977). In dromedaries it can be identified at 03 month of gestation (Hussein *et al.,* 1991) however, the precise function of this membrane is not clear.

Pregnancy diagnosis

Pregnancy occurs exclusively in the left uterine horn. Approaches for pregnancy diagnosis in camels include the visual observation of tail cocking, transrectal palpation (Purohit, 2010a) and trans-rectal ultrasonography (Skidmore, 2000).

The pregnant female dromedary camels exhibit a characteristic behavior when approached by a male or a person. The female assumes a stiffened posture with the head held high and tail curled upwards (Banerjee,

1974; Banerjee *et al.,* 1981; Yagil, 2006; Abusammad *et al.,* 2011). This is known as cocking of the tail. This behavior appears 14 to 15 days after fertile mating, persists till advanced pregnancy and known to be 95% reliable for pregnancy diagnosis in quiet and calm dromedary female camels (Purohit, 2010a). However, many false positives can be obtained in agitated females if the observer is untrained and camels with ovarian cysts may exhibit tail cocking (Quzy *et al.,*2013).

For transrectal palpation female camels are restrained in a sitting position with both hind, and forelegs tied together separately with ropes. An assistant holds the head tightly. Vicious females often require pressure on the back by legs of persons standing on both sides to prevent side wise movements (Purohit, 2010a). More vicious animals may require the administration of xylazine (0.25 - 2.2 mg/Kg IM or IV) (Purohit, 2012). The most appropriate time for detection of pregnancy using transrectal palpation appears to be 60-70 when left enlarged uterine horn can be easily palpated (Purohit, 2010a) although palpations can be done at an earlier time of 40-45 days. The fetal membrane slip is not palpable. The uterus descends in the abdomen by 4 months and between 4-7 months it is difficult to palpate either the fetus or uterus due to the large size of the animal and the uterine location, but after 7 months fetal parts become palpable (Purohit, 2010a).

Biological methods of pregnancy diagnosis have been tested in camels such as the Cuboni test (Fedorova *et al.,* 2015) and the Ascheim zondek test (El-Azab and Musa, 1976) with limited success. A common approach of pregnancy diagnosis prevailing in some countries is the assay of plasma progesterone (Vyas *et al.,* 1998; Vyas *et al.,* 2010) at Day 20 and 30 of mating (Quzy *et al.,* 2013). Camels with plasma progesterone values above 2ng/mL are considered pregnant and at Day 30 the values must increase above the values on Day 20 for confirmation (Quzy *et al.,* 2013) however, camels with luteal cysts can constantly reveal elevated progesterone concentrations although they are not pregnant. In few studies progesterone concentrations above 1 ng/mL were considered to be a positive sign for pregnancy (Agarwal *et al.,* 1987; Vyas *et al.,* 2004).

Transrectal ultrasonography have become an easier tool to identify the early (Vyas *et al.,* 2002; Al-Rawi, 2014) and late (Mostafa *et al.,* 2018) features of camel pregnancy. The embryonic vesicle and embryo proper within the vesicle were first visible on Days 18 and 23 post-mating, respectively. Theheart-beat of the embryo proper could be detected on Day 30. The allantois and amnion were first identified on day 40 (Vyas *et al.,* 2002). Although pregnancy could be diagnosed as early as Day 20 (Vyas *et al.,* 2002) a second evaluation at Day 30 is suggested due to the possible early embryonic death (Quzy *et al.,* 2013).The efficiency of pregnancy diagnosis by tail cocking, trans-rectal ultrasonography and serum progesterone was high at day 20 post mating but accurate at day 30 post mating because of 9.21% early embryonic deaths that occurred between day 20 and 30 post mating (Quzy *et al.,* 2013).

Gestation and Parturition

Gestation period in camel varies from 12 to 13 months (Abusammad *et al.,* 2011). The mean gestation length in camel was 384.5 ± 0.17 days (Nagy and Juhasz, 2019) but reports mention gestation lengths varying from354 to 407 days (El-Wishy, 1987; Al-Bisher, 1998; Almutairi *et al*., 2010). The mean gestation lengths in Indian camels varied from 380-386 days (Mehta and Sahani, 2009). The month of conception, parity, month of parturition and live/dead status of the calf affected the gestation lengths in camel (Nagy and Juhasz, 2019).

The mechanisms of parturition induction in camels are poorly known. The plasma progesterone concentration increased during the first 10 weeks of gestation in camels whereas the estradiol increased upto 8 weeks and was undetectable by 10th week (Ayoub *et al.,* 2003). Plasma concentrations of progesterone remained elevated but unchanged from Day 20 till Day 120 but significant increase was recorded between 150-180 days of gestation (Abdulkareem *et al.,* 2015). A three-fold rise occurred in the plasma estradiol concentrations in camels on Day 6 prepartum compared to concentrations on 18 days prepartum was recorded whereas plasma progesterone concentrations fell precipitously on the day of parturition (Ayoub *et al.,* 2003). Significant prepartum increase in the plasma cortisol levels were recorded with a peak on the Day of parturition in camel (Howida *et al.,* 2017).Also concomitant to estrogen rise and progesterone decrease one study recorded a 10 fold increase in plasma concentrations of 13,14- dihydro-15-keto-prostaglandin F2 alpha (PGFM) between days -10 and -1, showing a sudden and large increase during the 5 h prior to delivery (El-Belely, 1994). One study also recorded ruminant like relaxin in the ovary and utero-placental tissue of camels. Starting from Day 93 the expression of relaxin was maximal at 380 days of gestation (Homasch-Klonisch *et al.,* 2000).

One week before expected date of calving, the vulva and udder of camels begin to enlarge. When the udder is distended with milk, the teats point down and forward. The sacrosciatic ligaments relax, forming two grooves on each side of the tail head, and the superficial mammary veins become tense and tortuous (Prakash and Singh, 1962). In camels the relaxation may be visible some weeks before parturition (Purohit, 2010b). With the onset of parturition camel's evidence signs of uneasiness,

aggressiveness, scraping the ground with the hind feet, looking at the flank, and repeated lying down and standing up (Sharma and Vyas, 1970). It has also been reported (Sharma and Vyas, 1971a) that unrestrained animals have a tendency to run away, probably clue to pain. Sometimes the females lay on their sides and rolled over one or two times (Elias and Cohen, 1986). In addition, as each uterine contraction begins, the female camel raises her tail and arches and slightly flexes her back (Sharma and Vyas, 1971b). Calving can occur in a sitting or standing position with or without any vocalization. The dam does not lick the calf after delivery but may sniff it extensively.

The total time taken by camels in parturition varied from 281.8 ± 79.6 to 373.9 ± 38.2 min (Prakash and Singh, 1962; Sharma and Vyas, 1970; Elias and Cohen, 1986). For primiparous and pluriparous camels means of 281.8 ± 79.6 and 355.9 ± 79.3 min respectively were recorded by Sharma and Vyas (1970). The duration of the first, second and third stage of labor in camels required 275.0 ± 25, 33.9 ±9.0 and 65.0 ± 4.2 min respectively (Elias and Cohen, 1986). Mid-morning births were previously reported (Abdunazarov, 1971). However, in a large study evaluating 4204 births in most intensively managed camel farms over a 10 year period in United Arab Emirates reported maximum deliveries (74%) to occur from sunrise to sunset with a peak between 2.0 to 3.0 pm (Nagy and Juhasz, 2019). The calves stand within 20 minutes of birth and in a short while start suckling. Parturition can be successfully induced in camels within 24 -72 h by the IM administration of a combination of 500 µg cloprostenol and dexamethasone (Purohit *et al.,* 2011) or 25 mg of dinoprost tromethamine (Vyas *et al.,*1999).

Uterine involution and Post partum resumption of ovarian cyclicity

Uterine involution is considered to be rapid in camels as the micro-cotyledonary and diffuse nature of the placentation in these species does not cause a great loss of uterine tissue (Tibary and Anouassi, 1997).In the past evaluation of uterine involution was based on transrectal palpation and such evaluation recorded the uterine involution to be completed by 40 + 2.1 days (Sharma and Vyas, 1972). However, ultrasonographic evaluation revealed that the mean intervals for complete involution of the previously-gravid horn, non-gravid horn, and cervix were 34.33 ± 3.9, 42 29.01 ± 0.81, and 28.71 ± 1.51 d, respectively (Derar *et al.,* 2014). Reduction in the mean diameter of the previously gravid horn was significant 158 (P=0.0001) between Day 3 and Day 24 postpartum, and non-significant from Day 17 onwards (Derar *et al.,* 2014). Similar findings of uterine involution being completed by Day 25-30 were recorded in a previous study in camels (Vyas and Sahani, 2000).

Camels have been traditionally been known to have calving intervals of 22- 36 months (Tibary *et al.,* 2005*;* Gherissi *et al.,* 2020). The large variability of these reproductive parameters suggests the implication of several other factors such as nutritional level, breed differences and health (Tibary *et al.,* 2005; Ali *et al.,* 2018). Previous evaluations have considered that that post-partum estrus is normally delayed for about 1 year (Yasin and Wahid, 1957; Williamson and Payne, 1978). However, well fed females may show estrus within 1 month after parturition.A study evaluating the appearance of follicles over camel ovaries by transrectal ultrasonography found that 57% of the 17 parturating female camels evidenced a follicle above 1.0 cm and when these camels were mated and 57% conceived (Vyas and Sahani, 2000). The same group also recorded follicles above 1.0 cm in 50% (8/16) camels during the non-breeding season and when mated half of them (4/8) conceived (Vyas *et al.,* 2004). Follicular growth has been recorded in 50% of camels during the non-breeding season in another study at the same center (Sahani *et al.,* 2003). These studies point out that although camels have follicular growth during the post partum period and non-breeding season and can conceive if mated but are not mated routinely due to poor male camel libido and poor estrus phenomenon in camels. In a large survey involving 7122 dromedary camels in 115 herds in Saudi Arabia the mean calving interval was shorter (p =0.008) in camels mated within 3 months of parturition (15.25 ± 2.8 months) than in those mated after that time (24.33 ±6.5 months) (Ali *et al.,* 2018).

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