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REVIE ARTICLE

REPRODUCTION IN GOATS: A REVIEW

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ABSTRACT

The ruminants are the most primitive animals to be domesticated by human being from the time unknown. They were not only domesticated by the ancient civilized man for the need of minimizing labor (in terms of tilling or pulling carts) but also for differential need of every day livelihood like meat, milk, skin and hair. The main reason behind goats' popularity is the low rearing cost of this animal and their higher adaptability to a number of harsh and unfavorable conditions without any physiological complication. The main physiological process which has made the goats successful survivors under stressful condition is the management of immunity and reproduction under variable environmental conditions. The first is needed for survival of the animals and the latter is of extreme use for perpetuation of species. However, the modulation of immunity in goats is a huge process and a matter of another review. The present review encompasses the process and describes about various factors which modulate goat reproduction.

INTRODUCTION

Goats are the most helpful friends to poor people because of their prominent role and contribution in the developing countries' economy. Goats contribute to the subsistence of small holders and landless rural poor. Goats are short day breeder ruminant and taxonomically belonging to the class mammalia order Artiodactyla, sub-order Ruminantia, family Bovidae and genus, *Capra*. Goats are cosmopolitan and found across all agro-ecological environments and nearly in all livestock production systems (Winrock International, 1983). Goats are suitable for very extensive to highly mechanized production system (Wilson, 1982). India is bestowed with 17% of total world's goat population comprised of 21 recognized and many non-descript local breeds (Fatima *et al.*, 2008). In the tropics and sub-tropics, the interest in goat production has grown only in recent years. In the bio-industry, goats are underutilized and poorly understood resource even more under estimated in terms of veterinary research. A fair understanding of goat physiology and its industrial capabilities and economic outputs will be helpful in increasing the overall productivity of tropical goat farming systems. Despite of the large goat population, diversity and their economic significance, the caprine research in India particularly to the indigenous goats has been neglected by ruminant researchers. Although small ruminants are a major component of the livestock sector in most parts of the world including India, yet the information about goats and its physiology is very limited and fragmented.

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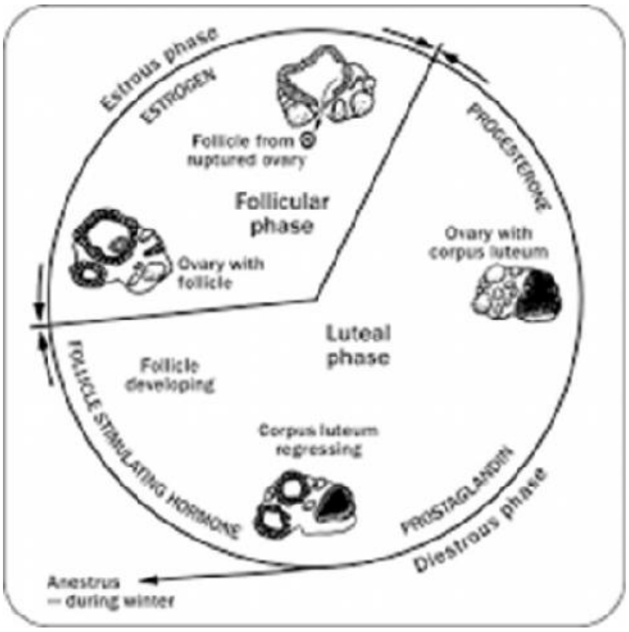
The importance of small ruminants for meat production in the tropics was well recognized by Payne (1990). However, small-ruminant production has some constraints and disease, which are associated with high mortality, decline in productivity and reproductive performance and even public health concerns (Nyange, 1984; Mbise, 1984).

Estrous cycle in goats: During the course of the breeding season, females can undergo several estrous cycles successively and the number of successive cycles is dependent on the length of the breeding season and the breed of goat. The length of estrous cycle is defined by the interval between two successive expressions of estrus or two successive ovulations. While the average duration of the goat estrous cycle is of 21 days, its length is highly variable. A study with Alpine goats during the breeding season recorded 77% cycles of normal in duration (17–25 days), 14% were short cycles (8 days in average) and 9% were long cycles (39 days in average; Baril *et al.*, 1993). The relative high frequency of short cycles is characteristic of goats and increases when ovulation is induced either just before or during breeding season. This proportion can be modulated by environmental factors such as photoperiod and nutrition.

Ovarian cycle and endocrine regulation: During the estrous cycle, ovaries undergo a number of morphological (follicular recruitment and growth), biochemical (follicle maturation) and physiological (endocrine regulations) changes leading to the ovulation. These cyclical changes in the gonads are referred to as the ovarian cycle. Follicular growth evolves in a wave-like manner throughout the cycle.

A follicular wave is characterized by the sequence of three gonadotropin-dependent events in follicular growth: recruitment, selection and dominance (Driancourt, 2001). The follicle development is under influence of follicular waves (generally 2-6 in number) amongst them 3-4 waves are most prevalent. The last wave provides the ovulatory follicle. When double ovulations occur they are usually of follicles derived from the same wave, but in a few cases they derive from two consecutive follicle waves (Ginther and Kot, 1994). The ovarian cycle is classically divided in two phases: the follicular phase and the luteal phase. The follicular phase corresponds to the wave of follicle development providing the ovulatory follicle and involves maturation of gonadotropin-dependant follicles until ovulation (terminal growth). During the follicular phase, FSH secreted by the pituitary gland stimulates follicular growth. A cohort of gonadotropin-dependant antral follicles of 2–3mm of diameter is recruited and follicles enter their terminal growth. Only 2–3 of these follicles reach 4mm diameter and are selected to enter the dominance phase. Under the influence of LH, they reach the pre-ovulatory stage (6–9 mm), while subordinate follicles degenerate (follicular atresia).



(Photo courtesy: www.google.co.in)

The increase in peripheral concentrations of 17β-oestradiol, secreted by bigger follicles, induces estrous behavior and acts as a positive retro-control on the gonadotropic axis. The consequent increase in GnRH secretion induces the pre-ovulatory LH surge which induces ovulation 20–26 h later and subsequently luteinization of follicular cells. The beginning of the follicular phase, before overt estrous behavior is observed, is also referred to as the proestrus. The estrous phase includes events from overt estrous behavior to ovulation. The luteal phase starts from the time of ovulation. About 5 days after the onset of estrus, cells of the ovulating follicle turn into luteal cells and form the corpus luteum (CL). They secrete progesterone causing its concentrations to increase and remain at a high level (>1 ng/ml) during 16 days. During this luteal phase, gonadotropin-dependant follicular growth continues in a wave-like manner but progesterone inhibits ovulation. At the end of the luteal phase, 16–18 days after estrus, prostaglandin F2α secreted by the non-gravid uterus induces the CL regression – called luteolysis – and the decrease of progesterone secretion.

The decrease of plasma concentrations of progesterone gradually removes the inhibition of gonadotropic hormones secretion and a new follicular phase then commences (Baril *et al.*, 1993). The luteal phase is also called the post-estrous period, which can be divided in met-estrus, when peripheral concentrations of progesterone begin to rise, and di-estrus, when peripheral concentrations of progesterone are high up to the start of luteolysis.

Cyclical changes in the cytology and secretions in the genital tract: During the estrous cycle, changes occur in the genital tract in order to facilitate sperm transport and fertilization and then to prepare for embryo implantation. Vaginal, cervical and uterine mucosa congests and become oedematous at the time of estrus due to high estrogen levels (Hamilton and Harrison, 1951). In addition, uterine, cervical and vaginal glands secrete important quantities of aqueous mucus, clear at the beginning of estrus then becoming more viscous and compact as the period of estrus continues. The cervical mucus plays a central role in cervical function by controlling and directing sperm migration. Estrogens stimulate the secretion of sialomucin by mucus cells located at the bottom of the large cervical folds within the cervix. Sulfomucins are also secreted in smaller quantities by mucus cells on the upper parts of the cervical folds (Heydon and Adams, 1979). At estrus, the cervical mucus becomes more watery and penetrable to sperm, allowing their migration through the cervix. Cervical secretion is inhibited by the post-ovulation rise in peripheral progesterone. Different studies have recorded cytological changes in the genital tract of the female goat during the estrous cycle. The relationships between vaginal exfoliated cells and ovarian steroids secretion cycle have been well established in goats. This pattern of exfoliation of vaginal cells could be used to determine the estrous cycle status.

In this respect, superficial cells appear to be associated with the pro-estrus, estrus and early met-estrus (Hulet and Shelton, 1980). Intermediate and parabasal cells are observed in larger quantities during the progesterone dominated luteal phase. Exfoliated cells in the vaginal lumen are the result of rising peripheral estrogen which causes the vaginal wall to thicken. As the outermost layer moves further from the vascular supply, the cells keratinise and detach from the wall (Pérez-Martinez *et al.*, 1999). Distribution of mast cells also varies depending on physiological changes during the estrous cycle in the goat reproductive tract and ovarian tissues. The numbers of mast cells in the ovary, uterus, uterine cervix and uterine tubes are highest on pro-estrus and lowest on met-estrus (Karaca *et al.*, 2008). Mastocytes are derived from haematopoietic precursors and represent critical effector-cells in allergic diseases. It is assumed that these cells might operate as sentinel cells to help mediate the uterine host defense systems and might have a role in the uterus with regard to the embryo implantation.

Estrous behavior in goats: Estrous behavior includes two phases: proceptivity and receptivity. Proceptivity consists in seeking out and stimulating the male partner. Receptivity consists in the expression of the immobilization reflex in response to male nudges, inducing serial mounting and copulation. At the beginning of estrus, proceptivity always precede receptivity, then both behavior components are expressed simultaneously the duration of estrous behavior is about 36 h but varies from 24 h to 48 h depending on age, individuals and breeds, season and the presence of a male.

Angora goats and Mossi goats are known to have a short estrus lasting only 22 h and 20 h, respectively (Shelton, 1978; Tamboura *et al*., 1998). Creole goats exhibit 27 h of estrous behavior and French Alpine goats are reported to experience a 31 h estrus (Baril *et al*., 1993). In Boer goats, the mean duration of estrous period is about 37 h (Greyling, 2000) and it is of about 58 h in Matou goats in Central China (Moaeen-ud-Din *et al*., 2008). Continuous presence of a male and service during the estrous period may reduce the duration of estrus although it did not affect ovulation times or ovulation rates in Nubian dairy goats (Romano and Fernandez Abella, 1997).

Recognizing heat periods in goats: If a buck is in an adjoining pen, it is usually easy to recognize heat period in the doe, as she will attempt to get in with the buck. If there is no buck in the adjoining pen, then it is more difficult to recognize the signs of heat. However, experienced goat men will recognize heat periods because the does tend to decrease in milk yield, their appetite is less and they show a characteristic nervousness and frequent bleating. There will be much wagging of the tail from side to side; the external genital organs (vulva) will be swollen and red. If heat recurs in 18 to 21 days, the doe did not conceive and mating should be repeated. The normal period of gestation in goats varies from 145 to 152 days. The application of laws of animal health and reproduction genetics has contributed towards increase in milk and meat productivity. The increase in egg production brought about the Silver revolution in the area of animal husbandry. The methods being widely used are artificial insemination and embryo transplant.

Breeding and gestation in goats: Copulation occurs during estrus, therefore usually before ovulation. Hence, sperm progressing through the female genital tract may be present in the oviduct by the time of ovulation. Meanwhile, other sperm is retained in the cervix where preservation conditions are good (up to 3 days) and released continuously in the uterus where survival is limited to about 30 h (Hulet and Shelton, 1980). The primary mode of sperm transport is by contractility of the female reproductive tract, though sperm motility might be important in the cervix for migration through the cervical mucus (Cox *et al*., 2006). Ova may remain viable for 10–25 h. Fertilization occurs in the ampullae of the oviduct a few hours after ovulation. The fertilized ovum migrates down the oviduct while undergoing successive divisions. The embryo reaches the uterus 4–5 days after estrus at an early morula stage. Migration of the ovum is the result of combined movements of ciliated epithelial cells in the oviduct, peristaltic activity of muscular layers and a liquid current from the infundibulum to the uterus. Implantation of the embryo is observed 18–22 days after the onset of estrus. In goats, the presence of a functional corpus luteum is indispensable throughout gestation. The placental production of progesterone in goats is unable to maintain pregnancy after ovariectomy or lutectomy (Sheldrick *et al*., 1981). Parturition in goats is preceded by a drastic decline in progesterone 12–24 h before the beginning of labor. Gestation length averages about 149 days but it may vary a little between breeds. Breed of dam, litter weight, breeding season and parity effects on gestation length have been observed by Mellado *et al*. (2000). The number of kids born and gender of kids were not a significant source of variation affecting this trait. Granadina goats had the shortest gestation (149.0±0.31 days), whereas Toggenburg (151.7 ± 0.28 days) and Alpine (151.4 ± 0.46 days) had the longest. Boer goats also have a short gestation period of 148.2 ± 3.7 days (Greyling, 2000). Gestation of goats bred in summer was 1 day longer than those mated in autumn and there was a progressive reduction of gestation length as parity increased.

Seasonality in sexual behavior: Reproduction in goats is commonly described as seasonal with differences in seasonality between breeds and locations. The onset and length of the breeding season in goats is dependent on a number of factors: latitude and climate, breed, physiological stage, presence of a male, breeding system but mainly photoperiod. The main environmental factor affecting seasonal breeding in small ruminants is the annual change in day length. Photoperiodic control of reproductive patterns is mediated through circadian rhythmic secretions of melatonin by the pineal gland during darkness, which influences the gonadotropin-releasing hormone pulse generation and the hypothalamic–pituitary–gonadal feedback loop. Animals bred in tropical and equatorial regions subjected to less change in photoperiod and temperature, display a longer breeding season than those bred in temperate and Polar Regions which exhibit more distinct seasonal effects.

A.**Seasonality at higher latitudes:** The sexual activity in female goats can be assessed by their spontaneous ovulatory activity and demonstration of sexual behavior. Two distinct periods are observed throughout the year in temperate latitudes: a period of deep anoestrus, when neither estrous behavior nor ovulations are noted, and the breeding period, with both estrous behavior and cyclic ovarian activity observed. During the transition periods, anovulatory estrus or silent ovulations (ovulation not accompanied by estrous behavior) can also be observed. Seasonal breeding is observed in most breeds of goats originating from high latitudes (>35^0) and in some local breeds from subtropical latitudes (25–35^0). In temperate regions the breeding period is observed in the fall and winter. In France (45^0 North Latitude), the breeding season starts in September, when day length is declining, and persists until March (Bodin *et al*., 2007). In Australia (10–39◦ South Latitude), goats have a brief period of spontaneous ovulatory activity, from April to August, centered on the winter solstice with a peak in June (Restall, 1992). In the Alpine and local goats bred in subtropical Mexico, the breeding season begins in the early autumn and ends in the late winter (Delgadillo *et al*., 1997). With increasing latitude, for example in Swedish Landrace goat, the breeding season tends to be restricted to the autumn months and most kids are born in spring.

Seasonality in lower latitudes: In equatorial, tropical and subtropical regions, changes in day length are less pronounced. Seasonality in reproduction is therefore less marked and most local goats in the tropics have the ability to breed all year-round and have a relatively short post-partum anoestrus. However, environmental factors (forage availability and temperature changes) have a strong influence which often does not allow these potentials to be fully expressed. In particular insufficient nutrition is often responsible for the appearance of prolonged anoestrous and anovulatory periods, a reduction in fertility and prolificacy and also causes an elevated spring mortality rate (Delgadillo *et al*., 1997). The most suitable times for mating and kidding are determined by climatic or management factors. For example, in some regions estrus is thought to be induced by monsoon rains so as to delay kidding until after the monsoon is over (Lassoued and Rekik, 2005; Moaeen-ud- Din *et al*., 2008). Year-round kidding potential has been observed in tropical goats, like Creole goats bred in

Guadeloupe, though not homogenously distributed throughout the year: a peak period still occurs in spring with few kidding recorded in autumn.

Control of sexual activity

Role of hormonal treatment: Hormonal regimens based on progestagens, eCG (equine chorionic gonadotropin) and/or prostaglandins have been established for over four decades allowing estrous and ovulation synchronization during both the breeding and non-breeding seasons. In France, the treatment consists of the deposition of a vaginal sponge impregnated with a progestagen (20–45mg fluorogestone acetate) for 11 days. An intramuscular injection of a PGF2α analogue (50µg cloprostenol) and 250–600 IU of eCG (dosage is dependent on parity, season and milk production level) is made 48 h before sponge removal. Artificial insemination is carried out 43–45 h after sponge removal. For out-of-season AI with frozen-thawed semen, this treatment allows a conception rate of about 60–65% (Leboeuf *et al*., 2000). It is currently used on 95% of inseminated dairy goats in France, but is also used to facilitate natural mating (in combination with photoperiodic treatment when used out of the breeding season). This treatment can be used at any time of the year, independently of the strength of seasonality. Other progestagens and other progestagen dispensers have been used in different countries including vaginal sponge impregnated with 60mg medroxyprogesterone acetate, subcutaneous implants containing 3–6mg Norgestomet and controlled internal drug releasing device (CIDR) containing 330mg progesterone.

Photoperiodic treatment: Seasonality of reproduction in goats is strongly dependant on photoperiod. In temperate and subtropical regions, out-of-breeding season breeding can be achieved using strategies based on manipulation of the photoperiod (Chemineau *et al*., 2006; Delgadillo *et al*., 1997). Following extended exposure to decreasing day length, animals become photo-refractory to the short day stimulus and will cease cyclic activity, unless a period of long day photo-stimulation is supplied. Photoperiod treatments are based on alternation of long and short days. First, the animals are subjected to long days (provided by artificial lighting in winter or by natural days in spring and summer) in order to prepare them to respond to the stimulatory effects of subsequently administered short days (Chemineau *et al*., 2004, 2008). Under field conditions, short day effects are easily provided by melatonin implants. These photoperiodic treatments can induce sexual activity in males and females similarly to hormonal treatment in females (Chemineau *et al*., 1999). Photoperiod treatments can induce ovulation over several weeks but cannot synchronize ovulation sufficiently to facilitate AI. Photo-periodic treatments are generally combined with hormonal treatments or the buck effect for synchronizing ovulations.

Melatonin treatment: The control of seasonal reproductive activity in sheep and goats in open sheds, needs extra-light (E) during the photosensitive phase (equivalent to long days, LD), followed by treatment with melatonin (equivalent to short days, SD). Melatonin, synthesized by the pineal gland, is the chemical messenger which allows seasonally reproductive animals to perceive day length changes. In the ewe, the neural message, transformed into a hormonal one, triggers pulsatile activity of the LHRH neurons. About 40 days are necessary for melatonin to centrally stimulate the pulsatile LHRH activity. Its sites and mode of action are not yet known completely, but a precise hypothalamic zone has been defined in which radioactive melatonin binds specifically and where cold melatonin delivered locally stimulates LHRH activity. In the veterinary clinic, the most frequent mode of distribution is a sub-cutaneous implant, which induces an advancement of the cyclical ovulatory activity of ewes and goats. The date of fertilization is advanced and fecundity of females is improved. It can be used alone, or in association with other hormonal treatments, or after an artificial photoperiodic treatment. Under these conditions, it allows a quantitative and qualitative increase in out-of-season sperm production in rams and billy-goats. Such an implant is registered and marketed in France, the UK, Greece, Australia and New Zealand (Chemineau *et al*., 2004). In autumn-born Ile-de-France or Lacaune ram lambs, 2 months of E followed by decreasing day length for 90 days, advanced onset of the first breeding season by allowing males to reach their maximum testis volume and sperm production earlier than for untreated ram lambs. Substitution of decreasing day length with melatonin implants allowed a transient increase in testis volume. Adult Ile-de-France rams maintained under short light rhythms with 2 month-period, demonstrated, during at least 2 consecutive years, a testis volume equivalent to that observed during the normal breeding season. These light-treated rams produced, during non-breeding season, spermatozoa in the same quantity and quality as during the normal breeding season. In anovulatory out-of-season dairy goats, E treatment was demonstrated to be necessary before melatonin treatment and melatonin to be necessary after E treatment to stimulate estrous and ovulatory activities. Stimulation of the anovulatory females by the introduction of treated males ("male effect"), appeared to be necessary to obtain maximum stimulation of the treated females. Two months of E, followed by melatonin treatment (daily injection or drenching or subcutaneous implants) allowed cycles with ovulation to be maintained for more than 2 months. Although effective for control of out-of-season reproductive activity, melatonin slightly decreased milk production when applied soon after kidding. So, total control of reproduction in sheep and goats by manipulation of photoperiod in open sheds and melatonin treatments appears feasible in both sexes (Cheminieu *et al*., 2006).

Buck Effect: The "Ram effect" is when non-cycling (anestrous) ewes are stimulated to ovulate by the sudden introduction of a ram or "teaser" ram. Rams produce a chemical substance called a pheromone, the smell of which stimulates the onset of estrus. When ewes and rams are in constant contact (sight or smell), the pheromones are much less effective at inducing estrus. Likewise, does and bucks are sensitive to their social environment, which can be used to manage their reproductive cycle. The so-called male effect is a technique to stimulate the sexual activity in seasonally anovulatory goats (Pellicer-Rubio *et al*., 2007). Most female goats have a short ovarian cycle of 5–7 day-length following the introduction of bucks, followed by a second ovulation associated with estrous behavior and a normal luteal phase (Chemineau *et al*., 2006). One of the major factors affecting the efficacy of response to the male effect depends on the strength of seasonality of the female and male goats. In this respect, the response to the male effect varies within breeds through the seasonal anoestrous period, and among breeds from different latitude origins (Walkden-Brown *et al*., 1999). For example, in breeds exhibiting moderate seasonality, such as the Creole goats of Guadeloupe Island, introduction of the male may induce highly fertile ovarian activity in anovulatory goats throughout the year. In contrast, when used alone in highly seasonal breeds, the male effect can only advance the onset of the breeding season by a few weeks; it does not satisfactorily induce full sexual activity in the middle of the anoestrous period (Walkden-Brown *et al*., 1999). Depending on breed and/or on anoestrous period, the pre-treatment of females and/or males with photoperiod may be necessary to optimize the response to the male effect (Flores *et al*., 2000). For instance, in Alpine and Saanen breeds in France, the treatment of males and females with artificial photoperiod is necessary to improve the response to the male effect. Under these conditions, most does exposed to males ovulated (99%) and 81% kidded (Pellicer-Rubio *et al*., 2007).

Adapted nutrition: Most characteristics of the reproductive cycle can be modulated through adapted nutrition. Nutritional strategies have recently been developed based on knowledge of precise nutritional needs for each stage of the reproductive process and interaction between metabolic status and reproductive performance. Both in sheep and goats, a long-term increase in body weight as well as a timed supplementation are known to affect folliculogenesis (Blache and Martin, 2009). Targeted nutrition can thus increase potential litter size by optimizing ovulation rate. The total number of offspring produced per doe can also be increased with planned nutrition to advance puberty. This was observed in Savannah Brown goats and seemed independent of their body weight (Fasanya *et al*., 1992). During pregnancy, nutrition can also affect both embryo survival and foetal programming of adult performance. Nevertheless, these tools can only increase reproductive performance within biological limits and should be adjusted to the considered breed and environment.

Conclusion

In conclusion of the review it may be suggested that there are various factors which can regulate goat reproduction. It may be due to their adaptive variation (since goat species are ranging from high altitude to low altitude as their habitat), ecological variation (belonging to different ecological niches) and hormonal regulation. But studies on the cumulative effects of all of those factors are lacking and in depth molecular works are arrested in this direction.

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