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REVIEW ARTICLE **OPEN ACCESS**

Technological Advances in Goat Reproduction

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ABSTRACT
Reproductive activity of the goat begins when the females reach puberty, which happens at 5 months of age. The estrous cycle is the period between two consecutive estrus. The goat is seasonal polyestrous animal, that is, during certain times of the year, it reproduces naturally. This varies according to hours of daylight and nutrition [4]. In domestic goats, reproductive season starts between the summer and fall and ends between the winter and spring. Reproductive seasonality limits the reproductive efficiency in goat production systems. On an average, the estrus cycle in goat is of 21 days. The high frequency of short estrual cycle is characteristic and tends to occur at the beginning of the reproductive season and in young animals [5]. The average duration of standing estrus is 36 hours but can range from 24 to 48 hours depending on age, breed, season, and presence of a male [8].
Key words: *estrus, goat, insemination, reproduction, synchronization*

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INTRODUCTION

The rearing of goat (*Capra hircus*) is a source of livelihood for small and marginal farmers including landless labourers. It provides steady and substantial regular income through milk, meat, hair and manure. The population of goat has been recorded to increase during the last couple of years, but majority of animals belongs to non-descript population. Therefore, it needs an immediate implementation of appropriate breeding strategies and improvement programme through conservation of potential animals. The goat keeping has been a traditional practice in India since its domestication around 9000-7000 B. C. The goat is also described as poor man's cow and is a choice of animal due to small size, ability to utilize a wide range of feed and fodder resources, low initial investment and good remuneration [19]. Goat has proved to be an excellent experimental animal for physiological, endocrinological and biochemical research. The factors which make it especially suitable experimental animal include its preference for clean and dry surroundings, relatively dry feaces, docile and intelligent animal and its resistance to many diseases. Therefore, the productive potential of goat needs to be exploited in view to amplify the economic returns to poor class of people and also to meet the requirements of researchers. Selective breeding and Artificial Insemination using semen of proven males are methods to augment the productive potential of poor producers, but the production of quality semen depends upon several factors. The season of the year and quality of semen are of concern. The dairy goats are similar to those of cattle in hormonal control of reproduction, the differences remain in several reproductive characters.

FOLLICULAR DEVELOPMENT

In mammals, germ cells originate from the extraembryonic endoderm and migrate by amoeboid movement into the coelomic cavity, to reach the urogenital mesodermal crest. Subsequently, the germ cell is transformed into oogonium, which should populate the gonad by mitotic processes. At the end of mitosis, the oogonium enters the meiotic cycle until prophase I, where it acquires the primary oocyte state [3]. Therefore, folliculogenesis begins when the primordial follicle is formed, due to the union of the primary oocyte and granulosa cells. In primordial follicles, the primary oocytes leave their state of latency spontaneously and continue to other phases of growth during which the differentiation and proliferation

of the oocyte coexist with the surrounding cells. These all events are independent of the gonadotropins by the effect of the growth factors synthesized in the ovarian microenvironment [2].
Different types of follicles are present during folliculogenesis. Primordial follicle: This follicle begins the process of follicular growth and maturation, to guarantee increasingly mature units that can lead the ovary toward ovulation or atresia. Primary follicle: It is characterized by a significant change occurring when the flattened cells surrounding the oocyte increase in size into a more cuboidal form, grow in diameter, and consolidate as a structure with oocytes having a diameter greater than 22.12 mm and a layer of 25–40 cuboidal cells called granulosa cells. It also increases the volume of the oocyte and the formation of the zona pellucida. Secondary follicle: The transition to this stage depends on the FSH stimulus. At this stage, granulosa cells develop the ability to synthesize growth factors and steroids [2].

ENDOCRINOLOGY OF ESTRUS CYCLE:
The ovarian cycle is classically divided into two phases: follicular phase and luteal phase (Figure 1). The follicular phase corresponds to follicular waves development that will provide the ovulatory follicle and involves the maturation of follicles that are dependent on the gonadotropins until ovulation [1]. During the follicular phase, FSH secreted by the anterior pituitary stimulates follicular growth. A cohort of antral follicles, which are gonadotropin dependent and with a diameter of 2–3 mm, is recruited, and the follicles enter their terminal phase of growth [10]. Only two to three of these follicles reach a size of 4 mm in diameter and are selected to enter the dominance phase. Under the influence of LH, the follicles reach the preovulatory stage (6–9 mm), while the subordinate follicles degenerate (atresia). The increase in the peripheral concentrations of estradiol 17β causes a positive feedback effect on the hypophysis-gonadotropin axis, due to the follicular growth inducing the goat's estrus behavior [11]. The consequent increase in gonadotropin-releasing hormone (GnRH) secretion induces an increase in the preovulatory LH peak, which will induce ovulation between 20 and 26 hours later, and finally the luteinization of follicular cells will occur. The beginning phase, before the estrus behavior, is known as proestrus. The estrus phase includes the events of the sexual behavior of the goat until ovulation. During the estrus cycle, the ovaries undergo a series of morphological (follicular recruitment and growth), biochemical (follicle maturation) and physiological (endocrine regulation) changes, which lead to ovulation. These cyclic changes that take place in the gonads are known as ovarian cycles. A follicular wave is characterized by the sequence of three gonadotropin-dependent events: recruitment, selection, and dominance. There are two to six follicular waves development during the estrus cycle in goats, but usually three to four are evident.
The luteal phase begins after follicle luteinization (16 days) and corpus luteum is formed. During this phase, pulsatile LH release that is negatively correlated with progesterone. Luteolysis begins around day 16–17 of the estrus cycle, by uterine prostaglandins, influenced by oxytocin. With the above, the concentration of progesterone decreases, causing a strong increase in the frequency of pulses of LH and its amplitude, which causes ovulation [13]. Goat exhibits an estrus sign that involves uptailing, decrease appetite, increase vocalization, increased urination, mount on other goats, oedema of vulva and vaginal mucus discharge.

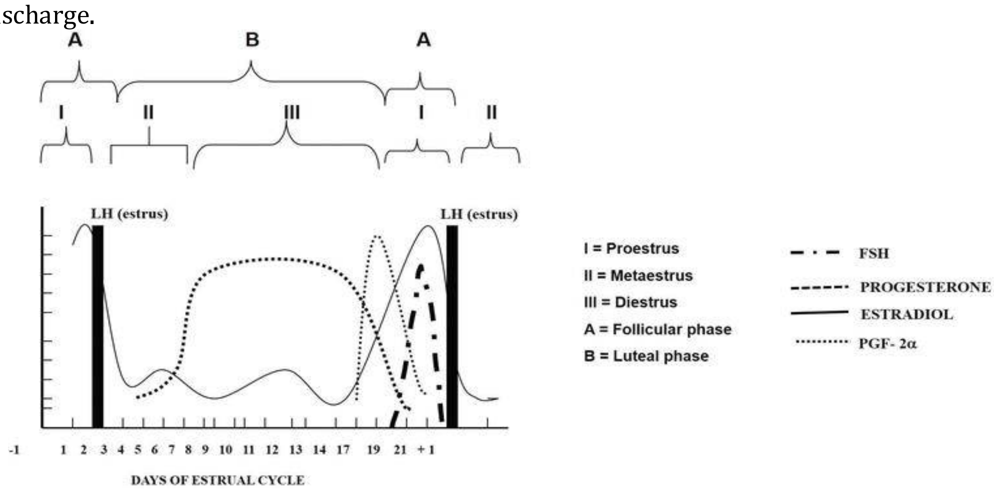

Figure 1. Schematic representation of the estrus cycle of the goat (modified by Fatet et al., 2011).

NUTRITION AND BODY CONDITION SCORE (BCS):

Various studies all over the world confirm that nutritional management significantly affects goat reproduction. The seasonal reproductive pattern in goats evolved in a manner that time of parturition and lactation coincides with season of the greatest feed availability and favorable temperatures. The body condition score negatively affects the presence of estrus and ovulation rate. If goats have a body condition below 2, ovulation rate is reduced by up to 16% compared with body condition above 3. Moreover, goats with low BCS shows a shorter breeding season and estrus cycles of abnormal duration [17]. However, recent research shows that goats with low body condition have a higher rate of ovulation (37.5%). Physiologically, folliculogenesis and ovulation rate can present a favorable response through good nutritional status and preferred BCS [20]. Malnourished goat shows defected ovulatory cycles, exhibit increased sensitivity of the pituitary to negative feedback of estradiol, which in turn causes an inhibition of GnRH release and therefore LH. For that, "flushing" strategies have been used, which consist of increasing the energy or protein levels of the goats before and during the breeding, to positively affect the rate of ovulation and prolificacy. It is also advisable to maintain such nutritional practice 10–15 days after the breeding to help the implantation of the embryo and reducing the early embryonic death.

However, assessment of BCS is a simple indicator of body fat reserves. The body condition values have been determined from 1 to 5, where 1 is skinny and 5 is obese. It has been evaluated that the goats must maintain a BCS of 3, in which, the backbone is not prominent, ribs are barely discernible and an even layer of fat covers them, so that the reproduction is not affected negatively.

BUCK EFFECT

The buck effect is an interaction between a male and a group of females at the time of starting mating. The presence of buck creates an olfactory, behavioral, and visual stimulus which increases the secretion of luteinizing hormone which stimulates folliculogenesis and ovulation [13]. Although, it was believed initially that pheromones played a pivotal role in the buck effect, subsequent work has proved that visual and behavioral stimuli are equally important as the smell [15]. Physiologically, the contact of buck with goats in anestrous induces an increase in the circulating LH level, which gives rise to a preovulatory peak and consequently ovulation before 48 hours. Delgadillo and Martin [4] reported that after the introduction of the buck, this phenomenon occurs with only 4 hours of contact. Bucks can also be treated with the testosterone 1 month before male introduction (@10 mg/day, for 3 weeks). In nut shell, for the goat to respond, complete contact of both sexes is necessary and not only by the smell of the male [15]. Recent studies have shown that malnourished goats present a delayed ovulation up to 7 days compared to those steaming up with balanced ration during the breeding season. Moreover, the male response will be better on goats having body condition score of 2 compared to those with above 3 score.

ESTRUS SYNCHRONIZATION AND INDUCTION OF OVULATION:

Synchronization of estrus involves the development of a luteal phase by means of exogenous hormones (devices with natural or synthetic progesterone) for a specific period and not exceeding the luteal phase of the normal estrus cycle [16]. These hormones are used to modify the physiological chain of events of the sexual cycle, while the non-hormonal methods of estrous synchronization involve the use of light control or exposure to a male [14].

In goats, estrous synchronization protocols are currently based on the use of vaginal devices (sponges) impregnated with 20–40 mg of fluorogestone acetate or 50–60 mg of medroxyprogesterone. The controlled internal drug releasing (CIDR) device is an inert silicone elastomer containing 0.3 g of natural progesterone [12]. These devices are inserted intravaginally for a period of 5–14 days (Figure 2) to create a luteal phase and then accompany it with a luteolytic agent, as well as the application of a hormone that synchronizes ovulation (equine chorionic gonadotropin (eCG), estradiol benzoate (EB), gonadotropin-releasing hormone (GnRH)), which have been applied at the time, 24 and 36 hours to remove the device, respectively [9].

The use of repeated eCG treatment after progestogen to promote follicular growth and ovulation is debated as it affect pregnancy rate in goats [15]. It can also be done using 50 mg of GnRH 36 hours after the removal of the device or 200 μg of estradiol benzoate 24 hours after short-term protocol [15].

Estrous synchronization protocols have been improved to more frequently use fixed-time artificial insemination as well as more effectively implementing third-generation reproductive techniques. These are in vitro oocyte production, intracytoplasmic sperm injection, nuclear somatic cell transfer and pronuclear microinjection of zygotes. At present, further research is required to lead to an economical and efficient synchronization program to establish efficient protocols for controlled breeding, massive use AI and embryo transfer by nonsurgical methods [18].

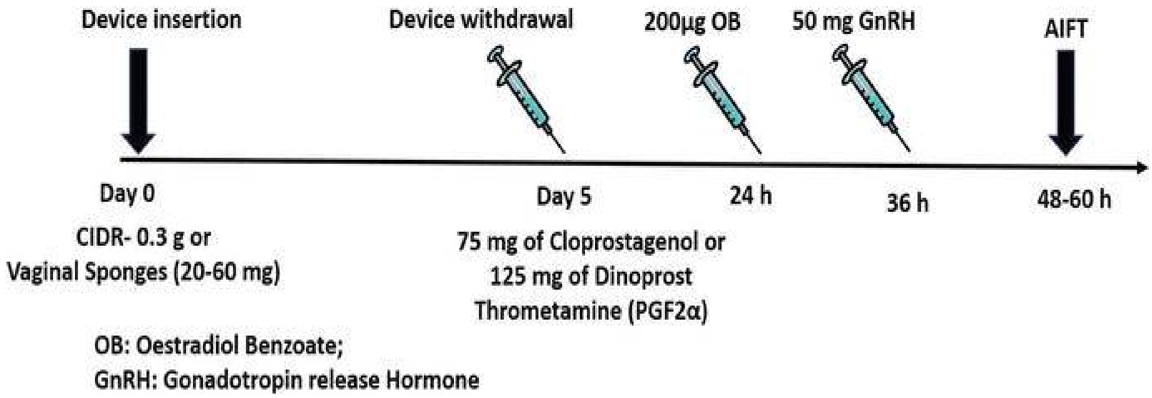

Figure 2. Short protocol at 5 days and ovulation synchronization with GnRH.

Prostaglandin-Based Synchronization Protocols:

Prostaglandin F2α (PGF2α) and its analogues have also been used to synchronize estrus by controlling luteal function. The PGF2α is secreted by the non-pregnant uterus up to 16 days after estrus [2]. Administration of PGF2α after removal of a CIDR mimics the secretion of PGF2α by the uterus, causing lysis of the CL and the onset of a new follicular phase [9]. A single administration of PGF2α can induce luteolysis, and two PGF2α injections at an interval of 10–12 days have been used to synchronize estrus. These treatment can be used on cycling goats only, limiting its application with nonfunctional corpora lutea [6].

Progesterone-Based Synchronization Protocols:

Intravaginal sponges impregnated with progestogens have been extensively used in sheep and goats to control estrus and ovulation during the breeding and non-breeding season. The use of medroxyprogesterone acetate (MAP) or fluorogestone acetate (FGA) or melengestrole acetate (MGA) sponges has been used in many advanced countries. Most commonly, progestogen/progesterone-impregnated vaginal devices and subcutaneous progestogen implants followed by an injection of eCG, were used for estrous synchronization [21]. However, a prolonged progestagen treatment is also associated to reduced fertility that may due to an impairment of sperm transport [23].

Combined CIDR and PGF Synchronization Protocols:

The CIDR focused on short-term (5–7 days) and long-term (12–19 days) protocols in small ruminants. The short-term protocols (Figure 3) synchronize females in a short period. Short-term protocols typically combine the use of progesterone with multiple follicle-controlling hormones, such as FSH, LH, a combination of eCG, hCG, and PGF2α which facilitate increased ability to control luteal and follicular dynamics [13].

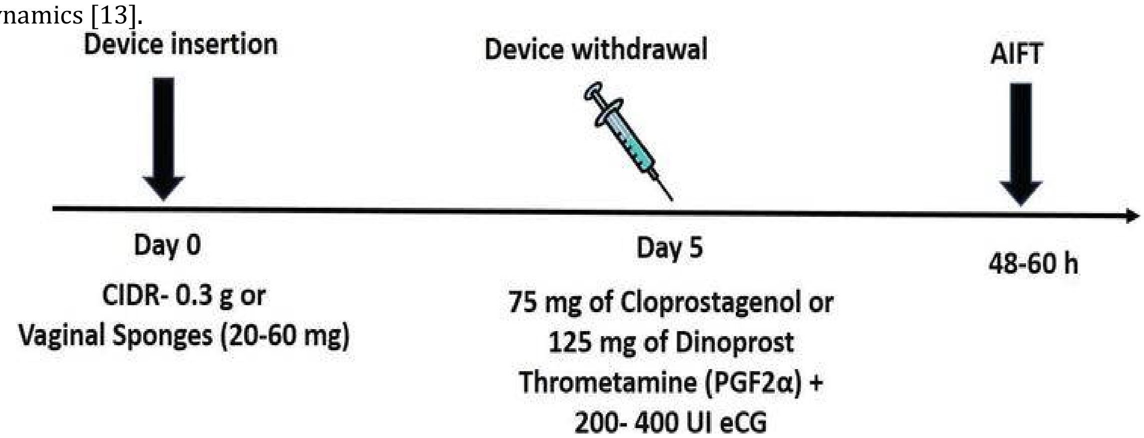

Figure 3. Short-term protocol of 5 days and artificial insemination at fixed time (AIFT).

CIDR devices offer advantageous low natural doses of progesterone, and do not absorb or obstruct drainage of vaginal secretions, resulting in less foul-smelling discharge upon removal as compared to vaginal sponges. However, CIDRs are expensive compared to vaginal sponges.

ARTIFICIAL INSEMINATION (AI)

Currently, the techniques of artificial insemination in goats have been limited worldwide, due to the lack of resources and trained technicians. Artificial insemination (AI) is an important technology as herd genetics can be upgraded by its consistent use at a rapid rate. AI needs careful doe management and is most effective if used in conjunction with estrus synchronization programme. Artificial insemination in goats is more difficult than cattle because of the small animal size and complex anatomy of the cervix, making insemination difficult into the uterus. The success of AI depends on sound management that involves seasonality, efficient semen collection and cryopreservation as well as appropriate timing of AI. Currently, for every 10 cows inseminated, only 2 goats and 3 sheep are inseminated. This low percentage of insemination has caused that the genetic progress is limited in the caprine species.

The primiparous does with small reproductive tract and tightness of the cervical rings can make transcervical AI difficult. However, several methods have been developed, which are similar to nonsurgical embryo transfer in goats [7]. The simplest transcervical AI method is the use of a tube-like speculum and a standard French-style AI gun. The speculum, with a detachable light, is inserted into the vagina and used to visualize the external os of cervix. Frozen semen is available in 0.25 ml or 0.5 ml straws and must be properly thawed prior to use. The insemination gun is introduced through the speculum into the cervix and the semen deposited into the uterine body. The pregnancy rates following the use of the standard techniques are low, typically in the range of 20–30% [22].

Artificial Insemination by Laparoscopy:

Laparoscopy is another technique for AI that has been used to increase the rate of conception, in which the semen is directly deposited inside the uterine horns, avoiding the natural barrier of the cervix. In this technique, pregnancy rates of 80% with diluted fresh semen and 50–80% with frozen semen are achieved. Endoscope is introduced in the abdomen under the local anesthesia followed by the insemination gun insertion through the second puncture and reached into the wall of the uterus into the lumen releasing the semen. Usually, the semen is deposited in both uterine horns to achieve better conception rates.

Deep Cornual Insemination (Catheter-Within-Catheter) Method:

In 2005, the development of a novel method for transcervical insemination of goats has been reported [22]. In this method, semen is deposited deep into the uterine horn by means of a catheter-within-catheter technique. With trained personal, the entire procedure takes about 5–10 min and does not require any surgery or anesthesia. A soft, small diameter pediatric urinary catheter is fixed with an insemination gun stylet to enter the uterine horn through uterine body. To facilitate this, a Pozzi Tenaculum Forceps are used to grasp the cervix and align the cervical rings. Once the catheter is positioned into the uterine horn, the stylet is removed, and small diameter insemination tube is threaded through the urinary catheter and used to deposit fresh or frozen-thawed semen into the upper portion of the uterine horn. The urinary catheter is then repositioned into the opposite uterine horn, and the second half of the semen sample is deposited deep into that horn to complete the insemination. The pregnancy rates following deep cornual insemination were greater than those for laparoscopic insemination [22].

CONCLUSIONS

Goat production as well as demands globally has increased in recent years. The goats with a body condition less than 3 respond better than others with greater body condition score. Therefore, proper nutrition and appropriate and feasible breeding strategies are to be applied by goat keepers, such as estrus and ovulation synchronization and artificial inseminations. Laparoscopic AI is an important tool to improve the reproductive efficiency in goats but requires deep technical knowhow to perform.

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