



## Out-of-season control of reproduction in subtropical goats without exogenous hormonal treatments<sup>☆</sup>



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### ABSTRACT

Some breeds of goats originating from or adapted to subtropical latitudes display seasonal variations of their annual rhythm of reproduction. The reproductive seasonality causes a seasonal production of goat-derived products affecting producers, goats' meat and milk industry and consumers. A good knowledge of the annual rhythm of reproduction, as well as the identification of the major environmental cues controlling this rhythm in both males and females, is necessary to draw new and sustainable techniques to induce a synchronized reproductive activity outside the natural breeding season and therefore to increase the out-of-season availability of the goat-derived products. This knowledge allows to control caprine reproduction without the use of exogenous hormones, and to develop techniques adapted to the environmental, economic and social characteristics of the breeding systems. Thus, in this review we will describe how photoperiodic treatments can be used to induce the sexual activity of male goats during the period of sexual rest. Then, we will describe how these photo-stimulated males were used to induce and synchronize the sexual activity of anestrus goats maintained in intensive or extensive management conditions by means of the male effect. In subtropical latitudes, the use of the male effect performed by using photo-stimulated bucks constitutes an original and sustainable way to control goats' reproduction.

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## 1. Introduction

Some breeds of goats originating from or adapted to subtropical latitudes (24–40°) show a reproductive seasonality with around 3–6 months of sexual rest (for a review, see [Delgadillo, 2011](#)). This reproductive seasonality causes a seasonal production of the goat-derived products affecting producers, goats' meat and milk industries and consumers. To avoid this reproductive seasonality, exogenous hormones (progestagens, eCG, prostaglandins, melatonin, etc.) have been used over a long time to

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<sup>1</sup> Deceased. This text is dedicated to her memory.

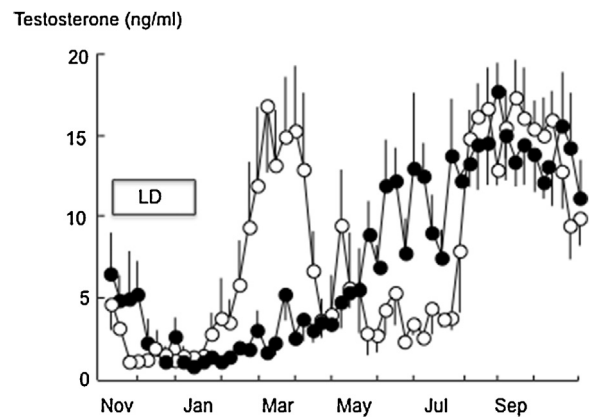
induce a reproductive activity during the sexual rest (Fateh et al., 2011; Leboeuf et al., 2008). However, consumers are now demanding natural methods to manipulate animal reproduction in both intensive and extensive management systems. For example, several countries belonging to the European Union have adopted restrictions on the use of synthetic hormones on livestock, and it is expected that these prohibitions shall be increased in future. To allow the reduction of the use of hormonal treatments, a good knowledge of the annual rhythm of reproduction, as well as the identification of the major environmental cues controlling this annual rhythm of reproduction in both males and females, is necessary to induce a synchronous reproductive activity outside the natural breeding season. In this context, the use of natural treatments as photoperiod, coupled to socio-sexual relationships, as the male effect (=synchronous ovulations occurring after introduction of males into a group of anovulatory females, see below), could represent interesting methods to stimulate the sexual activity of male and female goats outside the natural breeding season (Chemineau et al., 2006; Delgadillo, 2011). Thus, in this review we will describe how the photoperiodic treatments were useful to induce the sexual activity of male goats during the sexual rest. Then, we will describe how these photo-stimulated males can be used to induce and synchronize the sexual activity of anestrus goats maintained in intensive or extensive management conditions.

## 2. Annual rhythm of reproduction in male and female goats from subtropical latitudes

In Cashmere and local Mexican male goats, breeding season lasts from late spring to late autumn (Delgadillo et al., 2002; Walkden-Brown et al., 1994). In contrast, in Maure Tunisian and local Mexican female goats, breeding season lasts from early autumn to late winter (Lassoued and Rekik, 2001; Duarte et al., 2008). In the subtropics, it was suggested that the reproductive seasonality of goats was due to reduction of food availability (Walkden-Brown et al., 1994; Zarazaga et al., 2005). However, well-nourished animals also displayed seasonal variations of their sexual activity (Delgadillo et al., 2002; Duarte et al., 2008). Interestingly, the seasonal variations of sexual activity in Mexican goats are similar in length and timing of those described in males and females from Murciano-Granadina and Payoya breeds raised at Mediterranean latitudes (36–40° N; Fálagan et al., 1989; Zarazaga et al., 2005, 2009). These results suggest that in these types of goats, nutrition is a modulator of the reproductive seasonality, but is not the main cue that times the reproductive and endocrine changes. Consequently, we further look at photoperiod to better precise its role in controlling the seasonality of reproduction.

## 3. Photoperiodic control of the annual rhythm of reproduction in male and female goats raised under subtropical latitudes

On the contrary to what could be expected, in some subtropical breeds, photoperiod times their annual breeding season. In local Mexican goats, for example, artificially



**Fig. 1.** Plasma testosterone concentrations (mean  $\pm$  SEM) in two groups of local male goats from subtropical Mexico (26° N) subjected either to artificially long days (16 h of light per day) between November 1 and January 15, followed by natural photoperiod ( $\circ$ ) or to natural changes in photoperiod ( $\bullet$ ). LD: period of long days. Adapted from Delgadillo et al. (2002).

short days (SD) stimulate the sexual activity of males and females, while artificially long days (LD) have an inhibitory influence (Delgadillo et al., 2004; Duarte et al., 2010). Similar results were reported in the Spanish Payoya goats (Zarazaga et al., 2011). Therefore, these results suggest that photoperiod is the main external cue entraining the reproductive cycle over the year. In addition, for practical purposes in farms, these results also suggest that the sexual activity in male and female goats can be induced during the non-breeding season by photoperiodic treatments alternating LD and SD.

## 4. Out-of-season induction of reproduction in male and female goats raised under subtropical latitudes

Since the sexual activity can be induced during the sexual rest using alternations between LD and SD, we presumed that LD provided to goats kept in open pens and using extra-light during autumn and winter, followed by a return to natural light, would be able to mimic the alternation between LD and SD. This is the treatment that we used to control the sexual activity in male goats.

### 4.1. Male goats

To induce their sexual activity, bucks were exposed to LD (16 h of light by day) from November 1st to January 15th, then returned to natural photoperiodic variations. Control males remained under natural photoperiod throughout the experiment. In these latter males, plasma testosterone concentrations were low between December and May. By contrast, in the light-treated bucks, the plasma testosterone concentrations, the intensity of odor and the sexual behavior were much greater than in controls from February to April (Fig. 1; Delgadillo et al., 2002; Rivas-Muñoz et al., 2007). Similar results were reported in Payoya male goats exposed to 3 months of LD followed by the natural photoperiodic variations (Zarazaga et al., 2010). These results showed that 2.5 months of long followed by natural pho-

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