DOI: 10.21451/1809-3000.RBRA2021.046

Anais do XXIV Congresso Brasileiro de Reprodução Animal (CBRA-2021) e VIII International Symposium on Animal Biology of Reproduction – Joint Meeting, Belo Horizonte, MG, 19 a 22 de outubro de 2021.

Interação entre fotoperíodo e nutrição e reprodução caprina

Interaction between photoperiod and nutrition on goat reproduction

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Resumo

A reprodução é um processo fisiológico complexo que visa perpetuar as espécies. Esse processo é regulado por um grande número de fatores, entre os quais se destacam o fotoperíodo e o nível nutricional dos animais. O fotoperíodo é o principal fator ambiental que controla a atividade reprodutiva em caprinos e suas informações são transduzidas pela secreção de melatonina. As cabras apresentam um padrão sazonal na atividade reprodutiva relacionado às variações anuais do fotoperíodo. Dias curtos estimulam a atividade reprodutiva e dias longos inibem. O fato de sua atividade reprodutiva ser sazonal afeta a distribuição de sua produção ao longo do ano e isso é um problema tanto nos sistemas de produção de leite como de carne que buscam uma produção constante durante todo o ano. Dessa forma, as técnicas de controle da reprodução caprina permitem uma melhor distribuição de suas produções, leite e carne, ao longo do ano. Os tratamentos fotoperiódicos baseiam-se na alternância entre dias longos e curtos. Por outro lado, o nível nutricional que os animais recebem também é essencial para que eles apresentem atividade reprodutiva, de forma que uma melhora na alimentação permita um período mais longo de atividade e maiores desempenhos reprodutivos. Nesse sentido, a cabra é uma espécie que costuma ser criada em sistemas agrícolas com condições de alimentação flutuantes, que devem ser levadas em consideração para que a reprodução não seja comprometida.

Palavras-chave: cabra, sazonalidade, fotoperíodo, nutrição.

Abstract

Reproduction is a complex physiological process that aims to perpetuate species. This process is regulated by a large number of factors, among which the photoperiod and the nutritional level of the animals should be highlighted. The photoperiod is the main environmental factor that controls reproductive activity in goats and their information is transduced by the melatonin secretion. Goats show a seasonal patter in reproductive activity related to the annual variations of photoperiod. Short days stimulate the reproductive activity and long days inhibit. The fact that their reproductive activity is seasonal, affects the distribution of their production over the year and this is a problem both in dairy and meat production systems which attempt to have a constant production year-round. In this way, goat reproduction control techniques allow a better distribution of their productions, milk and meat, throughout the year. Photoperiodic treatments are based on the alternation between long and short days. On the other hand, the nutritional level that the animals receive is also essential for them to show reproductive activity, so that an improvement in feeding allows a longer period of activity and greater reproductive performances. In this regard, the goat is a species that is usually raised in farming systems with fluctuating feeding conditions, which must be taken into account so that reproduction is not compromised.

Key words*: goat, seasonality, photoperiod, nutrition.*

Introduction

The photoperiod is the main environmental factor that allows to different seasonal species, to identify the most favourable moment for birthing in terms of climatic conditions and food and water availability along the year (Malpaux et al., 1999). The repeatibility of the photoperidic changes along the years, as the different intensity and duration of the seasonal anoestrous depending on the latitude,

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Recebido: 17 de setembro de 2021
Aceito: 28 de dezembro de 2021

demonstrates the important role of the variations of the number of light hours on the regulation of the reproductive seasonality (Rivera et al., 2003). Domestication has nearly abolished seasonal reproduction in cattle and pigs but it is still seen in most breeds of sheep and goat originating from higher latitudes (Chemineau et al., 1992a; Zarazaga et al., 2005, 2011a,b). This photoperiodic information, is conveyed to a hormonal signal into a circadian rhythm through the secretion of melatonin from the pineal gland that allows to the animal to read this photoperiodic information (Karsch et al., 1984).

Short days stimulate the reproductive activity (breeding activity) and long days inhibit it (seasonal anoestrous). This reproductive model, however, determines seasonal variations in the market availability of small ruminant fresh products (meat, milk and cheese) variations that lead to fluctuations in price. Reproductive seasonality showed at middle (>25º) and high (>40º) latitudes by the males and females, can therefore be a problem for farmers. It can, however, be overcome by photoperiod manipulation. Different studies in goats (Chemineau et al., 1992a; Duarte et al., 2010; Delgadillo et al., 2011; Zarazaga et al., 2011a,b,c) have demonstrated that the manipulation of the photoperiod could modify the reproduction of the animals allowing it to show reproductive activity during the deep seasonal anoestrous. Specific treatments could adjust the breeding season to farmers' needs, e.g., making days longer by providing extra illumination during naturally short days, and making days shorter during naturally long days by the administration of exogenous melatonin. Currently, however, light-only treatments enjoy greater producer support since they require no use of synthetic hormone treatments, something of particular concern to organic farmers. These treatments have demonstrated a very high efficacy to improve the reproductive results of the "male effect" (introduction of bucks on a group of anovulatory does, that have previously been isolated from males, induces the females to ovulate, to display oestrus and become pregnant) (Chemineau, 1987), because this practice is carried out during the seasonal anoestrous and the males and females show a reduction of their reproductive activity.

However, there are other factors that could modulate the reproduction, being the nutrition one of the most important (Scaramuzzi y Martin, 2008). The goats, usually are distributed around the world, on areas with important fluctuations on the availability of food along the year (Silanikove, 2000), inducing variations on the quantity and quality of the nutrition intake modifying their body weight and their body condition. Thus, from a neuroendocrine point of view, in the goat, low nutritional levels can affect plasma LH concentrations by inducing changes in the hypothalamic release of GnRH, which reduces the pulsatile secretion of both GnRH and LH, leading to a reproductive arrest (Kile et al., 1991).

This paper describes the basic principles of the action of the photoperiod in the control of reproductive seasonality and treatments used in photoperiod- based control of reproductive activity and their interaction with nutrition as modulator of the response to the photoperiod mainly in goats.

Role of photoperiod in the regulation of seasonal reproduction

General principles

The photoperiod, defined as the seasonal variation of the duration of the daily number of light hours, is the environmental factor most repeatable along the years (Chemineau et al., 1992b; Malpaux, 2006; Chemineau et al., 2010). The photoperiod is the main environmental factor responsible for the seasonality of reproduction in sheep and goats – both in males (Zarazaga et al., 2009a) and females (Zarazaga et al., 2005; Duarte et al., 2010). This assertion is based on two observations: the number of hours of light per day at different times of year varies strongly as one moves away from the equator, and, the higher the latitude, the stronger seasonality becomes. Further, unlike temperature, food availability or social factors, the photoperiod is reliably repeatable from one year to the next, and is therefore, the best indicator that the reproductive season has arrived.

Several models based on the modification of the natural light/dark cycle (with no changes in other environmental variables) have been proposed to demonstrate the regulation of the reproductive season by the photoperiod. The reversal of the photoperiodic cycle causes the breeding season to shift phase by six months (Thimonier and Mauléon, 1969). Similarly, reproductive activity can be controlled by alternating periods of three months of long days (16 h light) with three months of short days (8 h light). In goats subjected to such a regimen, Zarazaga et al. (2011a) showed that, pituitary activity started after 46 days of short days, while pituitary rest started after 30 days of long days. In males, testicular growth begins after exposure to 30-40 short days, while the inhibition of reproductive activity occurs after 20-30 long days (Zarazaga et al., 2010a). The alternation of one month of long and one month of short days prevents seasonal changes in the activity of the male hypothalamo-pituitary axis (Delgadillo et al.,

1992).

Together the above data indicate that, in small ruminants, the onset of reproductive activity occurs after animals are exposed to short days, while reproductive rest occurs after the onset of long days.

Endogenous rhythm and photorefractoriness

However the mechanisms by the photoperiod regulates the seasonal reproductive activity, are more complex than the stimulatory effect of the short days and inhibitory effect of the long days. Firstly, the goat, as the most part of the seasonal species, shows an endogenous rhythm of reproduction, being the annual variations of the photoperiod involved on the synchronization of this rhythm to a period of 365 days (Malpaux et al., 1989).

Secondly, this endogenous rhythm is manifested due to a photorefractoriness mechanism. This mechanism consists that a prolonged exposure to a constant photoperiod, short or long days, induces a spontaneous reversion of the physiologic condition form reproductive activity to inactivity or viceversaa (Lincoln et al., 2005). This photorefractoriness in goats has an important central role on the regulation of the transition from a reproductive season to another (Gómez-Brunet et al., 2010).

The existence of this endogenous rhythm and the mechanism of photorefractoriness have two different consequences: firstly, the animals cannot be maintained in permanent activity submitting the animals to constant short days photoperiod and secondly to avoid the establishment of refractoriness, animals must perceive alternations between long and short days (Chemineau et al., 1992a).

Transduction of photoperiodic information

The light-dark cycle and melatonin

The pineal gland is the main melatonin-secreting organ, although in vertebrates, including humans, it is also synthesized in the retina, skin, gastrointestinal tract and ovary. Melatonin synthesis starts only after the onset of darkness. Melatonin secretion, however, depends on the photoperiod regime. This marked day–night rhythm is characterized by low or undetectable concentrations (around 4 pg/mL) during the day, increasing to 30-140 pg/mL in goats (Zarazaga et al., 2010b). Under continuous darkness, the period of melatonin secretion is almost 24 h per day, although wide inter-animal variability appears after several weeks (Lincoln et al., 1985). When animals are maintained under constant light, the rhythm of melatonin release disappears and secretion occurs erratically (Ebling et al., 1988).

The exposure to extra light or the provision of a pulse of light during the night produces a decline in melatonin secretion in sheep and goats. However, depending on the exact time during the night when this pulse is given, normal melatonin release may (early or mid-night pulse) or may not (late pulse) manage to recover (Lincoln et al., 1985; Earl et al., 1985).

Control of reproduction with photoperiod

Manipulation of the photoperiod is one of the most useful practices that allows to regulate the reproductive activity of the goats. As mentioned, to be effective is necessary an alternation between long days (LD) and short days (SD), being during this last period when the reproductive activity is stimulated. To induce long days is easy during the period of the year when the days are short (for example, three months between November and January), and thereafter to benefit of the natural short days (NSD) (January of February). This photoperiodic treatment of tree months of long days has been demonstrated to be very efficient to induce reproductive activity during the seasonal anoestrous (March-April) in females (Zarazaga et al., 2011d). Moreover, the period of short days effect can be induced through the use of exogenous melatonin (MEL) implants to produce a short-day-like response (Chemineau et al., 1992a; Zarazaga et al., 2009b, 2010a). When those treatments: artificial LD+NSD, LD+MEL or MEL implanted around the spring equinox has been applied to females and associated to the male effect the reproductive response is similar (Zarazaga et al., 2012). This fact has important practical implications since photoperiod treatments are likely to be increasingly used in more sustainable animal production systems when applied to females.

Moreover, the photoperiodic treatment of 2.5-3 months of long days and thereafter natural photoperiod is very effective on stimulation of the reproductive activity in bucks inducing an increase on the testosterone concentrations, sperm concentrations and sperm production in spring, precisely during

the seasonal anoestrous, when usually is performed the "male effect" (Delgadillo et al., 2002; Zarazaga et al., 2010a). Similarly to females, when the effectiveness of the male effect has been compared using bucks treated with LD+NSD, or MEL implanted around the spring equinox the reproductive results of the male effect were similar indicating that the melatonin treatment is not necessary (Zarazaga et al., 2019). The photoperiod treatments of bucks represent a reliable alternative for farmers when there is prohibition of the use of hormonal treatments.

One of the most relevant implication of the use of this kind of males is that, it has been recently demonstrated that the continuous presence of sexually active males could prevent seasonal anoestrus. The use of bucks sexually active using LD+NSD led most does to ovulate from April to July (86%), during their seasonal anoestrous. By contrast, the presence of buck showing springtime sexual activity led to less than 15% females ovulating from April to June (Delgadillo et al., 2015). As consequence could be an efficient tool, as photoperiod to manipulate reproductive seasonality.

Interaction nutrition and reproduction

The nutrition is one of the most important modulator of the reproduction because it influences, among others: the onset of puberty, ovulation rate, fertility, prolificacy and duration of the seasonal anoestrous or even the semen production. In this way it has been demonstrated that the expression of the annual seasonal pattern of reproduction is modified by the nutritional environment. Zarazaga et al. (2005) working with Payoya goats receiving a level of nutrition of 1.5 times maintenance requirements, observed an earlier onset and later offset of the ovarian activity in comparison to females receiving their maintenance requirements. This fact determined that females overfeed showed a longer duration of the ovulatory season of around 1 month. This result could be due, because nutritional cues interact with the photoperiodic cycle to modulate the seasonal patterns of reproductive activities. The main effect of nutrition is observed on seasonal transitions of ovarian activity, with no effect on the midpoint of the seasons of ovarian activity and ovarian quiescence. This interaction between nutrition and photoperiod takes place mainly in central pathways that determine the seasonal patterns of the neurosecretion of GnRH (Menassol et al., 2012). Similarly, in bucks a higher feeding level allowed a better sexual behaviour in bucks in late spring, precisely when "male effect" is used on the local livestock to breed females (Zarazaga et al., 2009a). In this way, Delgadillo et al. (2021) demonstrated that under semiextensive management, the pregnancy rate of does joined by bucks treated with LD+NSD and a nutritional supplementation was greater than in those from the control group. Moreover, low levels of food intake or poor body condition are associated with an enhanced hypothalamic sensitivity to oestradiol (Rhind, 1992). Zarazaga et al. (2011a,b) observed how a lower level of nutrition induced a decrease in the mean LH concentrations both during short and long days photoperiod. Similarly, in bucks, Walkden-Brown et al. (1994) observed that the effect of a low-quality diet in bucks induced a reduction of LH concentrations during the entire experimental period compared with bucks with a high-quality diet. The reason could be due because the role of the different neural systems involved on the regulation of LH secretion are modified by the level of nutrition (Zarazaga et al., 2011b).

Moreover, the nutrition clearly influences the results of the response to the male effect". Under Mediterranean extensive or semiextensive systems, food availability in spring–when the male effect is practiced– can vary widely, and animals may experience increases or reductions in body weight (BW) and body condition (BC) that can modify the "male effect" results. Certainly, it is greater when female BW is higher (Veliz et al., 2006). Poor BCS has also been associated with reduced reproductive performance responses to the male effect in goats (Urrutia etal., 2003). Similarly, the reproductive performances of does subjected to the male effect in spring are poorer in those with a decreasing BW and BCS and better in those with increasing scores, even using sexually active bucks (Gallego-Calvo et al., 2015).

Concluding remarks

The photoperiod is the main environmental factor that controls reproductive activity in small ruminants, melatonin being the hormone that transduces photoperiodic information.

To induce reproductive activity, a transition from long to short days is necessary; long days treatment is feasible under field conditions supplementing natural sunlight with artificial photoperiod. To induce short days, it can be taking advantage of natural short days or using exogenous melatonin implants.

Nutrition is an important way to modulate reproductive activity. The level of food seems to be an important modulator of the control that the photoperiod exerts on the secretion of LH.

The manipulation of photoperiod and the improvement of nutrition could be an interesting tool to increase the reproductive results of some practices used at livestock, as the male effect.

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