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Resumption of ovarian activity is modified by non-photoperiodic environmental cues in Criollo goats in tropical latitudes

Jorge Urrutia Morales[a], César A. Rosales Nieto[a,*], Héctor R.Vera Ávila[b], Eugenio Villagómez Amezcua Manjarres[b]

[a] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Campo Experimental San Luis, San Luis Potosí, San Luis Potosí 78431, Mexico
[b] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro Nacional de Investigación Disciplinaria Fisiología y Genética Animal, Ajuchitlán, Querétaro 76280, Mexico

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ABSTRACT

The reproductive activity of female goats under tropical latitude is modulated by photoperiod; however other non-photoperiodic cues may play a role in this modulation. We assessed the relationships among circulating concentrations of progesterone and environmental cues (photoperiod, atmospheric pressure, precipitation, absolute humidity, maximum environmental and soil temperatures, and wind speed). For two consecutive years, environmental data were collected every 10 min, while 8 female goats, separated from bucks, were individually fed a maintenance diet and were kept under natural conditions of photoperiod and climate (22°N). Female goats were weighed and body mass index (BMI) determined every week and were bled bi-weekly to monitor circulating patterns of progesterone. Environmental data was not similar in both years ($P < 0.001$). Live weight rose from 37.4 ± 1.3 kg (mean ± SEM) to 53.7 ± 2.2 kg, and BMI from 8.3 ± 0.3 to 12.2 ± 0.4 over the course of the experiment. The mean date when resumption of ovarian activity occurred differed between years (17 October vs. 27 September; $P < 0.001$) and it was negatively associated with live weight and BMI ($P < 0.01$). We observed that resumption of ovarian activity occurred when the ambient temperature averaged below 26° C. The concentration of progesterone was positively associated with live weight and BMI ($P < 0.05$), absolute humidity and atmospheric pressure ($P < 0.001$); but it was negatively associated with photoperiod, precipitation, and also maximum environmental and soil temperatures ($P < 0.001$). The concentration of progesterone was not associated with wind speed ($P > 0.05$). In conclusion, criollo goats from the semi-arid region of central-northern Mexico exhibited a clearly defined reproductive seasonality. This reproductive seasonality is not only modulated by photoperiod but also by non-photoperiodic environmental cues which may play an important role on this modulation. Temperature above 28 °C affects productivity by causing a decrease of the concentration of progesterone resulting in anoestrus. An understanding of the interactions between climatic variables and the seasonal reproductive activity in goats, may lead environmental manipulations that aid to their reproductive management.

1. Introduction

Reproductive seasonality is an adaptive mechanism developed in response to the change of climate and food availability throughout the year, which allows coupling from the time of birth to the most appropriate phase of the annual cycles of temperature and food availability (reviewed by Martin et al., 2004). In central-northern Mexico, goats (Nubia, Alpine and Criollo among others) adapted to this region present a clear reproductive seasonality (Duarte et al., 2008; De Santiago-Miramontes et al., 2009; Rivera Lozano et al., 2011). This reproductive seasonality is under photoperiodic control due to a combination of genetic factors and endogenous circannual rhythm driven and synchronized by light and melatonin (Amoah et al., 1996; Delgadillo et al., 2004).

In small ruminants, transition from the long days of summer to the short days of late autumn stimulates sexual activity and the breeding season ends because females become refractory to this stimulus (Chemineau et al., 1988; Malpaux et al., 1988). However, the differences in the timing of seasonality observed among years in animals from the same species and breed, suggests that other

* Corresponding author.
E-mail addresses: nieto_cesar@hotmail.com, rosales.cesar@inifap.gob.mx (C.A. Rosales Nieto).

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environmental cues apart of photoperiod are also involved; particularly in species under tropical or equatorial photoperiods, where variations in daylength across the year are minuscule (Robinson and Karsch, 1984; Jackson et al., 1990; Jansen and Jackson, 1993).

Thus, in these circumstances, it is possible that other non-photoperiodic environmental variables (eg. nutrition, social interactions and environmental temperature and humidity) are important complementary modulators, which together, with photoperiodic cues entrain the endogenous reproductive rhythm of the animals (Menassol et al., 2012). These observations could explain the reproductive seasonality observed in females maintained under constant photoperiod (Jackson et al., 1990; Chemineau et al., 1992, 2004). In dormouse and feral sheep, when the response to daylight is ablated, the other environmental cues still produce a well-defined reproductive cycle synchronized to the season (Jallageas et al., 1989; Lincoln et al., 1989). Therefore, environmental cues may play some role in the expression of the circannual reproductive rhythms in both the dormouse and feral sheep, as it has been suggested for other species (Barnes and York, 1990). In domesticated sheep, fluctuations *per se* in temperature cannot drive seasonal reproductive function under constant photoperiod; but, temperature can modulate the timing of the transition from anoestrus to breeding season and manipulate the duration of the breeding season (Dutt and Bush, 1955; Wodzicka-Tomaszweska et al., 1967; Legan and Karsch, 1980). Therefore, temperature fluctuations may serve to complete the series of stages necessary for full expression of a circannual rhythm of reproductive seasonality (Jansen and Jackson, 1993). Consequently, it is possible that changes in non-photoperiodic environmental cues play a permissive role in the expression of the circannual reproductive rhythm in goats (Gómez-Brunet et al., 2008).

An understanding of such interactions may lead to environmental manipulations that aid reproductive management in goats. Therefore, we hypothesized that, in female goats under tropical photoperiod, seasonal resumption of ovarian activity is modulated by changes in non-photoperiodic environmental cues. To test this hypothesis, we analyzed statistical relationships among the circulating concentrations of progesterone, daylength, maximum environmental and soil temperatures, absolute humidity, precipitation, wind speed and atmospheric pressure.

2. Materials and methods

2.1. Experimental location and animals

The study was conducted at San Luis Potosi research station of INIFAP (Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias). The research station is located in Soledad de Graciano Sanchez, San Luis Potosí, Mexico (22°14′03″N, 100° 53′11″O and 1835 MASL). At this location, climate is considered desert dry and cold BsKw (wi) according to Köppen as modified by García (1973). The average annual temperature is 18 °C and with a precipitation of about 341 mm per year. The driest month is March (average of 6 mm) and most precipitation falls in June (average of 67 mm; Medina et al., 2005).

Criollo goats used (n = 8) in this experiment were obtained from representative local flocks. In brief, these criollo goats are derived from the Spanish Granadina, Murciana and Malaguena breeds and nowadays are variable from a phenotypic viewpoint because of repeated crosses with Alpine, Saanen, Anglo-Nubian and Boer breeds. Hence, the selection criteria of goats were: some Nubia breed influence, three years old, non-pregnant, non-lactating and healthy. This experiment was undertaken in accordance with the Code of Practice for the Care and Use of Animals for Scientific Purposes (NHMRC, 2004).

2.2. Animal management and feeding

The experiment was conducted from January 2005 (Year one) to November 2006 (Year two). Female goats were separated and kept away from males and were under natural climate and photoperiod (22°N). A diet was formulated to meet the daily nutritional requirements for maintenance and was based on alfalfa hay, sorghum stubble, sorghum grain, soy meal, molasses, vitamins and regular salt which provided 12% protein and 2.02 Mcal/kg of metabolizable energy (NRC, 1998). Females were acclimatized for 14 days, before blood sampling regimen, to diet and facilities. Feed amount was offered individually every day (0900 h) and adjusted every 14 d as per live weight in order to provide maintenance for crude protein and metabolizable energy requirements. For this purpose, goats were placed in individual pens (1.0 × 1.78 × 0.78 m), no more than 1 h and half, until total feed disappearance. Female goats spent the rest of the day in a common pen where clean water and minerals *ad libitum* were provided. Once a week, live weight and body mass index (BMI) of goats was recorded before feed amount was provided. The BMI was estimated as described in Tanaka et al. (2002).

2.3. Environmental data

Environmental data were provided by the department of Meteorology from the University of San Luis Potosi; which is located within 500 m from the goat unit of the research station. Data were recorded every 10 min for twenty-three months including: daylength (photoperiod), maximum environmental and soil temperatures, atmospheric pressure, wind speed, absolute humidity and precipitation.

The date for each year of the summer solstice, the first, the highest and the last temperatures above 32 °C and the precipitation above 30 ml were recorded. These data helped us to generate the intervals among these variables and the date when resumption of ovarian activity occurred for each goat in each year.

2.4. Blood sampling and immunoassay

Ovarian activity was monitored by progesterone concentration (ng/mL) in serum. Blood samples were collected bi-weekly from all female goats by jugular venipuncture before feeding for 23 months (January 2005 to November 2006). Blood was sampled into sterile vacuum tubes (6 ml; BD Vacutainer; Frankling Lakes, NJ, USA), allowed to clot at room temperature for 3 h and then serum was separated by centrifugation at 2000 × g for 20 min, decanted and collected in duplicate in polypropylen microtubes (Axygen Scientific, Union City, CA, USA) and stored at −20 °C until hormone analysis.

For hormonal quantification, solid-phase radioimmunoassay kits were used to determine serum concentrations of progesterone (Co at-a-Count, DPC, Los Angeles CA, USA). Sensitivity for assays was 0.03 ng/mL, whereas intraassay and interassay coefficients of variation were 4.8% and 8.2%, respectively. Female goats were considered as ovulating when progesterone levels were >1.0 ng/mL for at least two consecutive blood samples. The ovulation period was deemed from the first to the last sample with elevated concentration of progesterone. Within the samples with elevated progesterone, the lowest was considered the sample closer to the ovulation timing.

2.5. Data analysis

The data were analyzed using SAS version 9.3 (2010).

Hormone concentration (progesterone) was analyzed using mixed models (PROC MIXED) allowing for repeated-measures, and included as fixed effects: day, month and year. Daylength