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Original

Progesterone concentrations during the estrous cycle in sheep in the Colombian tropics

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ABSTRACT

Objective. Efficiency in heat detection, determination of the duration and type of estrous cycle and progesterone concentration in sheep racial biotypes in the high tropics was evaluated. **Materials and methods.** In 32 adult ewes, biotype Criolla, Hampshire, Romney Marsh and Corriedale, during the postpartum period, Heat Detection Efficiency - EDC, cycle type: Short - CC, Regular - CR and Long - CL, Cycle Duration was determined. Oestrus – DCE and progesterone concentrations – CP_4. CP_4 were assessed by ELISA technique. Statistical analysis used a completely randomized model and repeated measures over time. **Results.** The average EDC was 64.88%, presenting 35.12% CC, 59.92% CR and 4.96% CL. The average of regular DCE was 16.9±0.89 days. The Criollo group presented the highest ranges of variation of CP_4, showing changes in its steroidogenic activity of the corpus luteum similar to that observed with the Hampshire group. Between days 4 and 12, the Romney Marsh group presented the lowest CP_4., being similar to the behavior of the Corriedale group. **Conclusions.** CP4 increases from days 2 to 6, remaining high and constant between days 10-12, gradually decreasing until day 18, progressively evidencing a possible functional luteolysis that leads to structural luteolysis. The CP_4 may be associated with adaptation phenomena of some racial groups, which affect the reproductive efficiency that is observed to be differentiated between them.

Keywords: Reproductive physiology; estrous cycle; oestrus detection; progesterone (*Sources: DeCS; TAC; AIMS*).

RESUMEN

Objetivo. Se evaluó la eficiencia en detección de calores, determinación de la duración y tipo de ciclo estral y concentración de progesterona en biotipos raciales ovinos, en el trópico alto. **Materiales y Métodos.** En 32 ovejas adultas, biotipo Criolla, Hampshire, Romney Marsh y Corriedale, durante el periodo posparto, se determinó la Eficiencia en Detección de Calores - EDC, tipo de ciclo: Corto – CC, Regular - CR y Largo - CL, Duración del Ciclo Estral – DCE y concentraciones de progesterona – CP_4. Las CP_4 se valoraron mediante técnica de ELISA. El análisis estadístico usó

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un modelo completamente al azar y medidas repetidas en el tiempo. **Resultados.** La EDC en promedio fue de 64.88%, presentándose 35.12% CC, 59.92% CR y 4.96% CL. El promedio de DCE regular fue de 16.9±0.89 días. El grupo Criollo presentó los mayores rangos de variación de la CP_4, evidenciando cambios en su actividad esteroidogénica del cuerpo luteo semejante a lo observado con el grupo Hampshire. Entre el día 4 y 12 el grupo Romney Marsh presentó los menores CP_4., siendo semejante al comportamiento del grupo Corriedale. **Conclusiones.** Las CP_4 incrementan los días 2 a 6, manteniéndose altos y constantes entre los días 10 - 12, disminuyendo gradualmente hasta el día 18, evidenciando progresivamente una posible luteolisis funcional que conduce a una luteolisis estructural. Las CP_4 pueden estar asociadas a fenómenos de adaptación de algunos grupos raciales, que afectan la eficiencia reproductiva que se observa es diferenciada entre ellos.

Palabras clave: Fisiología reproductiva; ciclo estral; detección del estro; progesterona (*Fuentes: DeCS, TAC, AIMS*).

INTRODUCTION

The oestrous cycle is defined as the period between the appearance of a physiological oestrus and the beginning of the next, constituting an important point to maximise fertility in sheep (1). This event is characterised by its rhythmic presentation, lasting an average of 17 days (2, 3). About 77% of cyclical adult female sheep have regular oestrous cycles (14 to 20 days in duration), 14% have short cycles (8 to 13 days) and 9% long cycles (>20 days) (3), showing differences by breed, seasonality and age (1,3).

Traditionally, the oestrous cycle is divided into two phases: the follicular phase of 2 to 3 days and the luteal phase of 12 to 14 days (4, 5). The follicular phase is the period that involves receptivity to the male until ovulation, characterised by an increase in the concentration of oestrogens (E2) (1). The luteal phase is the period in which the corpus luteum (CL) is formed, considered as a transitory endocrine gland that secretes progesterone (P4), and culminates in luteolysis (6).

P4 is the most important ovarian steroid during the productive life of the sheep and is essential to regulate the oestrous cycle (2,5). The presence of high concentrations of P4 reduces GnRH pulses at the hypothalamic level (3). During the follicular phase, a decrease in P4 concentrations begins, characterised by an increase in gonadotropins and oestrogen secretion (7).

The increase in the circulation of E2 during proestrus induces the preovulatory surge of luteinising hormone (LH) (5), caused by the continuous and frequent increase in gonadotropin-releasing hormone (GnRH). P4 has been shown to have regulatory effects on LH surge and pulse frequency (2), possibly having long-term central effects (3), linked to sexual behaviour, via a pre-exposure system for expression. of oestrogens. Sexual behaviour lasts between 24 to 36 hours (8) and heat detection efficiency is within the range of 60 to 90% in cyclic sheep (9). Oestrus expression is influenced by environmental and nutritional factors, social interactions, stress, genetics, and P4 concentrations (10,11).

The oestrous cycle in female sheep is dependent on the uterus. Thus, the exposure of the endometrium to P4 during dioestrus not only prepares the uterus for the establishment of pregnancy (12), but also activates the mechanism for the endometrial production of luteolytic PgF2α at the time that pregnancy is not established (14 days of the oestrous cycle) (12,13). PGF2α initiates functional luteolysis, which consists of the loss of the ability to synthesise P4, followed by structural luteolysis that is completed with CL involution (3,4).

The objective of this study was to evaluate the efficiency in heat detection, determine the type and duration of the oestrous cycle and progesterone levels in four sheep breeds, under conditions of the Colombian high tropics from the resumption of postpartum cyclicity.

MATERIALS AND METHODS

Study site and conditions. It was carried out at the Centre for Ovine Research, Technological Development, and Extension (CIDTEO), located at the Marengo Agricultural Centre, National University of Colombia, in Mosquera, Cundinamarca, at 4°42' north latitude and 74°12' west longitude, altitude of 2650 metres above sea level, variable temperature between 6.4°C and 20.9°C, relative humidity of 80% to 87% and precipitation ranging between 21.5 mm and 104 mm (in dry or rainy season, respectively), during a period of eight months, corresponding to the calving season.

Selection and management of animals. A follow-up of 32 adult ewes, between 2 to 3 calvings, clinically healthy, was conducted. Eight (8) females for each of four breed biotypes: Colombian Creole - wool, Corriedale, Hampshire, and Romney Marsh were monitored from parturition to the resumption of postpartum ovarian cyclicity by assessing the first oestrus observed, and from this moment, monitoring was performed every two days on average during the first three consecutive complete oestrous cycles, confirmed with the P4 profiles. Heat detection was performed with the help of a vasectomised adult male provided with a harness and marking chalk. Mounts were recorded daily to obtain an estimated date of oestrus or heat by observation. The animals were managed in paddocks with a free-range system and meadows composed mainly of Kikuyo (*Cenchrus clandestinum*) and Italian Ray-grass (*L. multiflorum*) in a 70/30 ratio, respectively. The females were supplemented with 500 grams of concentrate, 300 g of corn silage, 6 ml of glycerol, 10 g of salt and water available to maintain the coverage of the nutritional needs of the animals and to ensure throughout the evaluation period a normal physiological behaviour.

Obtaining samples and hormonal assay. From day 5-7 postpartum and throughout the follow-up, blood samples were taken every two days on average, using the jugular venepuncture technique (5 ml) in vacutainer tubes with heparin (Becton Dickinson® Rutherford, NJ, USA) to assess serum levels of P4. Blood plasma was obtained from the samples, in which P4 concentrations were measured using the commercial ELISA immunoassay kit DSI-EIA-STEROID-PROGESTERONE®RH/351-Italy. Experimental samples were analysed in duplicate using a linear calibration curve with calibrators ranging from 0.1 to 3.5 ng/ml P4 in plasma. Calibrator 4 of the kit and calibrator 0 were used as positive and negative control, respectively. The assay had 95% certainty, a lower sensitivity limit of 0.1 ng/mL, and an inter-assay coefficient of variation of 4.2% and an intra-assay coefficient of variation of 3.6%. The work was carried out under the approval concept of the Bioethics Committee of the School of Veterinary Medicine and Animal Science - UNAL Bogotá issued on 1 November 2012 (Minute 10).

Criteria for handling response variables. The response variables were: heat detection efficiency (HDE); classification of the types of oestrous cycle according to length: short cycle (CC) from 8 to 13 days, regular (CR) from 14 to 20 days, long (CL) greater than 21 days (3), oestrous cycle duration (ECD), and levels of progesterone (NP4) during the oestrous cycle. An oestrous cycle was considered to have started when P4 levels were below 1 ng/ml with or without manifestation of heat observed, subsequently supported by luteal function based on maintenance of P4 above 1 ng/ml for at least three consecutive samples (3).

Analysis of results. Using an ANOVA presenting descriptive statistics, the behaviour of the variables within and between breed biotypes was analysed. Quantitative variables were expressed as means (±SEM) and were tested with univariate analysis (4 breed biotypes) using the ANOVA procedure; t-test was used to compare means. Means were compared using Tukey's method. P4 profiles during the oestrous cycle were analysed according to breed group; data were normalised by ovulation (day 0) and subsequently analysed using the repeated measures General Linear Model (PROC GLM) SAS procedure (2011).

RESULTS

The average efficiency in the detection of heat or oestrus (HDE) by observation was 64.05%. In Hampshire females, heat detection efficiency was 72.52% and in Creoles, 70.24%. The lowest value corresponds to the Romney Marsh group with 55.01% and the intermediate Corriedale group with 61.78% (Figure 1). Statistically significant differences were not evidenced by breed biotype ($p>0.115$).

The percentage and number of oestrous cycles classified according to length are listed in Table 1. The statistical analysis showed differences in the presentation of regular cycles (CR) with respect to breed types ($p<0.016$), presenting the highest proportion of the biotype Creole, without differences with the Hampshire group;

Corriedale and Romney Marsh being the lowest proportion, which have no difference with the Hampshire group, but with the Creoles. The CC and CL, without presenting significant differences between groups, were shown in greater proportion for the females of the Romney Marsh group.

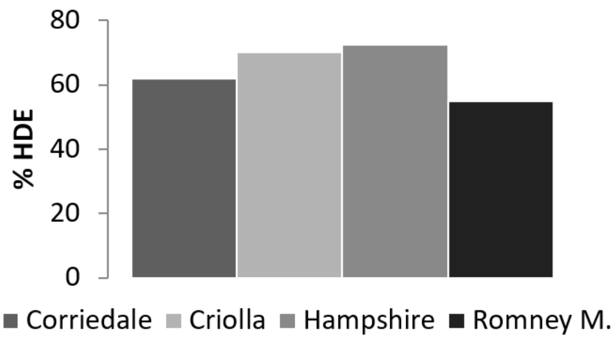

Figure 1. Oestrus detected by observation according to breed type.

Table 1. Oestrus cycle type classification

Breed biotype	Oestrus	Cycle types (duration)					
		Short – CC		Regular – CR		Long – CL	
	N	%	N	%	N	%	N
Creole	60	21.67	13	76.67[a]	46	1.66	1
Corriedale	62	43.55	27	53.23[b]	33	3.22	2
Hampshire	61	31.15	19	63.93[ab]	39	4.92	3
Romney Marsh	59	44.07	26	45.76[b]	27	10.17	6
Total	242	35.12	85	59.92	145	4.96	12

Oestrus cycle type classification according to length: Short (8 to 13 days), regular (14 to 20 days), long (> to 21). a,b Differences ($p<0.05$) between breed biotype.

The average duration of the oestrous cycle (ECD) in high tropical conditions was 16.8±0.9 days. Regarding each one of the biotypes, the Creoles had a cycle length of 17.4±0.9 days, the Corriedale 16.7±0.8 days, Hampshire 16.7±0.3 days and Romney Marsh 16.3±1.1 days. Statistically significant differences were not evidenced ($p=0.129$).

The values obtained in the serum quantification of P4 (NP4) through the regular oestrous cycle appear in Figure 2. The CP4 readings ranged from a minimum value of 0.36 ng/ml for day 18, corresponding to the period of ovulation; and up to a maximum value of 3.33 ng/ml on day 10, within the mid-luteal phase, with the Creole group being the one that showed the highest ranges of variation in NP4, with a minimum value on day 0 of 0.04 ng/ml and a maximum value on day 12 of 3.57 ng/ml, showing an important variation in steroidogenic activity in the corpus luteum. Between days 4 and 12 of the oestrous cycle, CP4 were on average higher than 2 ng/ml, except for the Romney Marsh group, which showed the lowest average values in general. The results show an increase in behaviour between days 2 to 6 of the oestrous cycle, metestrus stage or early luteal phase, remaining at high and constant levels between days 10 - 12, with an average concentration of P4, which reaches a maximum value of 2.75±0.57ng/ml. Then a clear decrease in luteal activity is evident, which by day 14 shows an average of 1.517±0.89 ng/ml when the right-handed, late luteal phase ends, falling to CP4 of 0.833±0.40 ng/ml on day 16, and finally reaching 0.755±0.4 ng/ml on day 18. No significant differences were found in progesterone concentration between days 6 to 8 and between days 8 to 12, respectively ($p>0.05$).

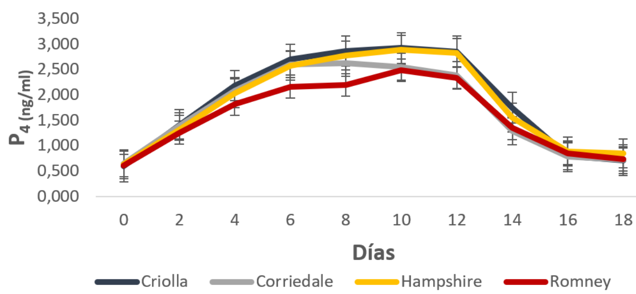

Figure 2. Progesterone concentration during the oestrous cycle in the evaluated biotypes. Day 0 represents the start of oestrus (ovulation).

Regarding the behaviour of CP4, no significant differences were found between breed groups ($p>0.05$); When analysing them, expressed in the punctual times evaluated (day 0, 2, 4, 6, 8, 10, 12, 14, 16 and 18), differences were found between day 10 (2,750±0.58 ng/ml) and day 0 (0.622±0.22 ng/ml) ($p>0.006$), evidently being the days with the highest and lowest concentration of P4, respectively. The values observed between days 8 and 12 show differences with respect to the values observed on days 0, 2, 4, 6, and days 14, 16 and 18 ($p<0.002$).

The Romney Marsh group showed the lowest luteal steroidogenic activity for days 2 to 14, having lower CP4 in all phases observed, early luteal phase (days 2 to 6), middle (days 6 to 12) and late (days 12 to 14) with respect to the other breed groups, this behaviour being similar to what was observed for the Corriedale group, in contrast to what was observed in the Creole and Hampshire females (Table 2). On the contrary, for days 0 and 18, corresponding to the follicular or ovulatory phase, NP4 were similar between all groups.

Table 2. Plasma concentrations of progesterone during the oestrous cycle in the four breed types evaluated.

Day	Creole		Corriedale		Hampshire		Romney Marsh		Total		Pr > F
	CP4	DS	CP4	DS	CP4	DS	CP4	DS	CP4	DS	
0	0.596	0.226	0.65	0.230	0.634	0.203	0.612	0.233	0.622[f]	0.219	0.9134
2	1.410	0.395	1.392	0.350	1.317	0.535	1.258	0.437	1.346[d]	0.440	0.5210
4	2.185	0.551	2.086	0.590	2.037	0.624	1.823**	0.585	2.046[c]	0.595	0.0650
6	2.698	0.486	2.604	0.554	2.575	0.591	2.163	0.613	2.538[b]	0.584	0.0013
8	2.865	0.446	2.630	0.762	2.772	0.529	2.198	0.541	2.650[ab]	0.616	0.0002
10	2.923	0.422	2.554	0.752	2.887	0.488	2.487	0.587	2.750[a]	0.577	0.0060
12	2.857	0.712	2.389	0.888	2.832	0.586	2.338	0.835	2.651[ab]	0.776	0.0002
14	1.747	1.059	1.289	0.708	1.558	0.839	1.349	0.802	1.517[d]	0.892	0.0115
16	0.796	0.380	0.792	0.358	0.887	0.396	0.856	0.518	0.833[e]	0.408	0.7929
18	0.713	0.674	0.719	0.328	0.855	0.441	0.733	0.115	0.755[ef]	0.397	0.1244

Progesterone concentration CP_4 (ng/ml) during regular oestrus cycle of adult ewes in high tropics. Day 0 represents ovulation. a,b Differences ($p<0.05$) between breed type.

DISCUSSION

Based on the CP4, 242 oestrous cycles were totalled, of which 155 were confirmed by observation, which corresponds to a heat detection efficiency (HDE) of 64.05% in accordance with values reported by Moonmanee T y Yammuen-art S (10) (Figure 1). No differences were found ($p<0.05$) between the groups, although it is worth highlighting a better expression of oestrus in sheep from the Creole and Hampshire group in contrast to the Romney Marsh and Corriedale types that expressed their sexual behaviour to a lesser extent, representing low intensity and short duration, making their behaviour very mild and the vasectomised male not noticing the event and failing to detect it (15). Authors such as Rodríguez et al (3) reported a proportion of heat detection efficiency of 82.1% in the Corriedale breed, being consistently high compared to the results obtained although the trial used synchronisation of oestrus. In contrast, in Ethiopia they indicate an HDE of 87% in animals of the Bonga breed (16).

On the other hand, in Pelibuey ewes in Mexico, sexual behaviour was evaluated for 105 days postpartum, finding a percentage of heat detection efficiency of 64.7% (17); results that match those obtained in this research, despite the difficulty of detecting heats in this species, especially in natural mating conditions (18). Additionally, stress can have important implications in sexual behaviour, since the female sheep is highly influenced by the psychosocial phenomenon (18, 19).

The importance of heat detection efficiency for maintaining adequate reproductive efficiency (mounting control or insemination at the exact time) is recognised and should be implemented as a key indicator to evaluate oestrous cyclicity at certain times and environmental conditions (9, 20), since successful reproduction requires the expression of sexual behaviour within a short timeframe, which is evident as long as there is an appropriate endocrine rhythm (19). Estradiol is recognised as the main hormone that stimulates GnRH secretion and the subsequent events caused by the increased frequency of LH secretion during the follicular phase of the oestrous cycle (22). However, Stouffer et al (5) emphasise that P4 acts with a facilitating effect on the secretion of E2 – GnRH and/or the expression of hypothalamic GnRH receptors, demonstrating the importance of prior exposure to P4 in adequate concentrations (3.5), which allows a large increase in the magnitude of E2 and GnRH, which could be related to the greater expression of oestrus in the Hampshire and Creole biotypes. With the above, it is suggested that a higher concentration of P4 in the late luteal phase, corresponding to days 12 to 16 approximately (Figure 2), could be representing a better reproductive success, allowing a clearer or more evident expression of sexual behaviour in outstanding biotypes.

Based on the data, which generally indicate that 35.12% of the observed cycles correspond to short cycles (CC), 59.92% to regular cycles (CR) and 4.96% to long cycles (CL) (Table 1), it is evident that the regular cycles represent the highest proportion, as is characteristic in cyclical adult sheep (1), and additionally, significant differences between the breed types were evidenced ($p<0.016$). The greatest presentation of irregular cycles corresponds to the females of the Romney Marsh and Corriedale breed types, which suggests adaptation problems, including "thermal stress" given the enormous range of temperature variation during the day, which can induce early luteolysis that would affect hormonal dynamics (2). In contrast, the results of the Creole and Hampshire types show a greater tendency to normality with respect to the duration of the oestrous cycle, demonstrating a better regularity and possible conditioning and adaptation to the tropics. The results obtained are comparable to those reviewed in a free-rearing system, which report 14% in short cycles, 77% regular and 9% long (1). Additionally, the work of Rodríguez et al (3) highlights that there is a higher percentage of regular luteal phases (14-20 days duration) in groups with the same production system.

The duration of the regular oestrous cycle (ECD) found (16.8±0.9 days) aligns with the average of 17 days reported by Bartlewski et al (1) and Cox et al (22) in the reproductive season, demonstrating that the regular oestrous cycle in sheep is relatively constant between and within breeds, with only a slight variation of 1-2 days (8,24).

The results of hormonal quantification (CP4) are within the range of the P4 profiles reported by other investigations in sheep (2)(25)(26) and it is confirmed that the P4 hormonal quantification technique (ELISA) used allowed evaluating correct luteal steroidogenic function. The moment in which the concentrations of P4 are basal coincide in most cases with the detection of oestrus (5) and correspond to the estimated time of ovulation (day 0, 18 of the oestrous cycle) showing average values of P4 of 0.76 ±0.4ng/ml (Figure 2). Similarly, the research by Tera Dolebo (16) reported levels of P4, which coincide with those of this study. Studies in autochthonous breeds reveal that P4 concentrations were 0.82 ± 0.02 ng/mL at the beginning of the oestrous cycle (27).

The P4 profiles shown in (Figure 2) begin to increase on day two after ovulation, just as the new corpus luteum initiates P4-secreting activity (metestrus), gradually increasing levels from day 2 to day 12 of the oestrous cycle (2.26), showing the greatest variability. Likewise, the data obtained were similar to those reported by Valasi et al (26), which describe a gradual increase from day 3, and then the levels remain high and constant during days 6-12. This is physiologically explained by changes in luteal steroidogenic activity, which leads to differences in the fertilisation rate when there are low concentrations of endogenous P4 (28).

The maximums in CP4, found for day 12, of 2.75±0.57 ng/ml on average, are comparable with reports from countries such as Turkey, which refer to P4 values of 3.50±1.50 ng/ml around day 15 in Karaman females (29). In the mid-luteal phase, which is assumed to occur between days 6 and 12, the corpus luteum is made up of mature luteal cells, so P4 secretion tends to show lesser variations, maintaining high levels, in constant growth. Towards the end of the estrous cycle, in the late luteal phase, between days 12 to 16, P4 concentrations may begin to decrease, as a consequence of a possible functional luteolysis that leads to a subsequent structural luteolysis, reaching concentrations below 1 ng/ml for days 16 to 18, leading to ovulation (2.29).

The P4 profiles had the same behaviour in the four breed groups evaluated (Table 2) and it matches that reported in recent research with analyses in different genotypes (2). Particularly, the Romney Marsh females showed less steroidogenic activity of the corpus luteum, both for metestrus and for dioestrus in general, corresponding to the period between days 2 to 14 of the oestrous cycle, being very similar to those observed for the Corriedale group, having as reference the values seen in the Creole and Hampshire group, showing a greater variation of P4 secretion for the first two groups. With the foregoing, it is suggested that Creole and Hampshire females may have a better relationship with ovarian steroids in terms of the moment, time and duration of their action and the coordinated effects that must regulate the expression of receptors of both the same P4, and of oestrogen and oxytocin receptors in these phases, which modulate the luteolytic pulses of PgF2α by the endometrium (30) and forms the convenient mechanism that allows it to perform with better reproductive efficiency. On the contrary, the results of the Romney Marsh and Corriedale females conform with those referenced by Fierro et al (25) specific to the breed, indicating that the variations in P4 concentration during days 6 to 12 (middle luteal phase) and 12 – 16 (late luteal phase) of the oestrous cycle lead to changes in follicular dynamics and oocyte maturation, which translates to poor reproductive performance (20), evident in reduced fertility (21). This is associated with a poorer reproductive performance of Romney Marsh and Corriedale females and is related to P4 profiles. In contrast, and based on the study by Bartlewski et al (2), increased P4 concentration beyond dioestrus (day 14 of the oestrous cycle) result in follicular regression and decreased ovulation rate due to altered FSH and E2 levels (4), direct effects on the ovary involving alterations in follicular development and responsiveness to gonadotropic effects and/or biosynthesis of local promoters for antral follicular development.

Serum P4 concentrations are positively correlated with total luteal tissue volume (3) and vary between prolific and non-prolific breeds of sheep (31). In this sense, Laghrour et al (32) analysed the effect of supplementation on reproductive parameters, showing values similar to those found in this research.

In conclusion, the heat detection efficiency was 64.05%, finding 59.92% regular oestrous cycles and 35.12% short cycles, showing significant differences between breed types, which are possibly related to reproductive performance.

The average duration of the regular oestrous cycle was 16.8±0.9 days, observing that the occurrence of regular cycles with respect to the breed types had a higher proportion for the Creole biotype and the lowest for the Corriedale and Romney Marsh.

The Romney Marsh and Corriedale groups had the lowest progesterone concentrations in the mid (6 to 12 days) and late (12 to 16 days) luteal phases compared to the Creole and Hampshire groups, suggesting less luteal steroidogenic activity, which may be a factor that modulates the oestrous cycle, follicular development and the endocrine model, possibly related to the difference in reproductive efficiency that one or the other shows, respectively.

Conflict of interests

The authors declare that they have no conflict of interest. The funders played no role in the study design; in the collection, analysis, or interpretation of data, nor in the writing of the manuscript or in the decision to publish the results.

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