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Productive and Reproductive Efficiency of Ewes Kept on Tropical Pastures as a Function of the Suckling Lamb Treatments

K. L. S. M. Ferelli[a], C. C. B. F. Ítavo[a], L. C. V. Ítavo[a,*], G. T. dos Santos[a], M. I. L. Souza[a], G. K. A. de Melo[a], M. de M. S. Peres[b], N. da S. Heimbach[b], T. F. F. de S. Arco[a], E. S. de M. Soares[a], J. A. da Silva[a], P. C. G. da Silva[a], C. de Godoy[a], P. B. de Andrade[a], & A. A. da S. Miguel[a]
[a]Faculdade de Medicina Veterinaria e Zootecnia - Universidade Federal de Mato Grosso do Sul
Campo Grande - MS 79070-900, Brazil
[b]Universidade Católica Dom Bosco
Campo Grande – MS 79117-900, Brazil
*Corresponding author: luis.itavo@ufms.br
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ABSTRACT

The aim of the research was to evaluate the productive and reproductive performances of ewes as a function of the supplementation offered to suckling lambs. The lambs were divided into two experimental treatments. Treatment (1) suckling lambs kept in pastures of Brachiaria-grass receiving mineral supplementation; and treatment (2) suckling lambs kept in pastures of Brachiaria-grass receiving concentrate supplementation in creep-feeding. Regardless of the nutritional treatment offered to the lambs, all matrices (female lambs and ewes) received 350 g of supplementation daily. Ewes from treatment-1 presented average 49 days to return to estrus. Ewes from treatment-2 presented, on average, 36 days to return to estrus. The body condition score (BCS) at weaning showed a significant difference between treatments. Ewes from treatment-1 presented a mean BCS of 1.75. Ewes from treatment-2 presented a mean BCS of 2.39. The other productive variables of lambs, such as weaning weight (kg), age at weaning (days), total weight gain (kg), and average daily gain of lambs, presented a significant difference between the nutritional treatments. Variables such as return to estrus and BCS were positively influenced by supplementation offered to lambs, which directly impacts the production efficiency and profitability of the production system. The lamb supplementation promotes indirect gains in the body condition score of ewes at weaning and, consequently, in the time to return of estrus in 13 days. Protein-energy supplementation in creep feeding to suckling lambs is recommended to improve the body condition score at weaning and decrease the return to estrus (days) of ewes. This nutritional tool is recommended to improve the supply of leaves and provide the best conditions for the selection and use of nutrients present in the leaves.

***Keywords:** body condition score; ewe's milk; lactation; lambs; physicochemical composition*

INTRODUCTION

The sheep production system in tropical regions, where the animals are kept in pastures, demands efficient food management strategies, especially when the objective is the production of lambs intended for meat production. Currently, the main nutritional strategies used for the production of lambs in tropical pastures are the different forms of protein-energy supplementation (Heimbach *et al.*, 2019; Melo *et al.*, 2019; Melo *et al.*, 2022). In the central region of the Brazilian Cerrado, it has already been proven that protein-energy supplementation in creep-feeding for suckling lambs kept on *Brachiaria* spp. is essential for the best productive and sanitary performance of this category (Melo *et al.*, 2019). In addition, protein-energy supplementation for lambs finished in these same pastures efficiently reduced the age at slaughter and ensured high carcass and meat quality with productivity close to that observed in feedlots (Silva *et al.*, 2020; Silva *et al.*, 2022).

To intensify the production of lambs in pastures, supplementation for ewes is an efficient way (Arco *et al.*, 2021; Campos *et al.*, 2022). This is because the birth weight of lambs is related not only to the genetic factors of the parents (rams and ewes) but also to the good nutritional conditions of the ewes in the final third of gestation (Heimbach *et al.*, 2020; Poli *et al.*, 2020).

Maternal nutrition can influence milk production and composition, and this production is important in the first weeks of life for lambs, as the development of lambs largely depends on lactation (Campos *et al.*, 2019; Freitas-de-Melo *et al.*, 2017). Knowledge about the chemical composition of milk from ewes kept on tropical pastures is important for balancing food intake and consumption, as it is the main source of nutrients in the first weeks of lambs' life (Freitas-de-Melo *et al.*, 2017).

For lambs to present positive responses to supplementation, it is necessary to adopt nutritional management strategies aimed at the matrices during pregnancy and lactation (Arco *et al.,* 2021) because the nutritional requirement of the ewe increase due to the physiological and metabolic changes that occur. In the suckling phase, the adoption of creep-feeding reduces the wear of the matrices, especially the female lambs, which are still in the growth phase, in addition to shortening the interval between parturition and leading to higher meat production per hectare (Heimbach *et al.,* 2019).

In this sense, the focus is the balance between the nutrition of the different categories and their productive performance using protein-energy supplementation. Previous research showed that the ewes are influenced directly by the supplementation they receive or indirectly by the supplementation offered to the lambs (Oliveira *et al.,* 2014). However, there are still few studies relating to the effects of the supplementation of lambs on the productive and reproductive performance of ewes kept in tropical pastures.

The estrus activity of ewes can occur all year round or seasonally, according to the greater or lesser photoperiod influence. The Brazilian Cerrado is characterized by its tropical climate and high incidence of light, and therefore, estrous activity is related to the other environmental factors, such as nutritional variations of pastures and, consequently, to the nutritional contribution to animals (Biehl *et al.,* 2019).

The central nervous system by the action of GnRH stimulates the anterior pituitary gland to synthesize and secrete gonadotropic hormones, FSH and LH, which stimulate, in the gonads (ovaries) steroidogenesis or gonadal steroid synthesis, peptide synthesis, and folliculogenesis, therefore, the development of ovarian follicles and ovulation. On the other hand, the hormone secreted by the anterior pituitary, prolactin, also intervenes in reproductive phenomena, inhibiting the hypothalamic-pituitary-gonadal axis in periods of anestrus to stimulate milk production during lactation (Lopes *et al.,* 2019)

It is known that lactation is one of the factors that cause postpartum anestrus in ruminants. Milk sucking and the presence of offspring generate neural, sensory, olfactory, and physiological metabolic messages that inhibit LH synthesis or prevent the pituitary from responding appropriately to GnRH stimuli (Risques *et al.,* 2020).

Lamb supplementation can also be used as a management alternative to increase the reproductive efficiency of ewes during lactation periods (Arco *et al.,* 2021; Campos *et al.,* 2022). The main objective would be to decrease the sucking of milk by the lambs and, consequently, increase the LH pulses, and increase the concentrations of receptors for LH and FSH in the follicles, generating ovulation a few days after delivery (Buso *et al.,* 2018).

The beneficial effects of supplementation on the performance of animals that receive it directly are known. But few studies describe the effects of supplementation on different categories that interrelate, as in the case of ewes and suckling lambs. Studies become even rarer when studying animals kept in tropical pastures. In the present study, we evaluated the effects of supplementation offered in creep feeding to lambs on the productive and reproductive performance of ewes, their immune responses to the parasitic challenge, and the effect of protein-energy supplementation on creep-feeding on the chemical and structural characteristics of Brachiaria-grass pasture.

Therefore, our hypothesis is that supplementation in creep-feeding for lambs would indirectly affect the productive and reproductive performance of ewes and offer better conditions of resistance and tolerance to parasitism. Likewise, this nutritional management would change the chemical and physical characteristics of the pastures. The objective of the research was to evaluate the effects of creep-feeding supplementation for suckling lambs on the productive and reproductive performance of ewes and on the chemical and physical characteristics of signal grass pastures.

MATERIALS AND METHODS

Experimental Design

The experiment was carried out in the sheep sector of the School Farm of the Faculty of Veterinary Medicine and Animal Science (FAMEZ) of the Federal University of Mato Grosso do Sul (UFMS), located in the municipality of Terenos-MS, Brazil. This study was approved by the Ethics Committee for the use of Animals in Experiments (protocol no. 481/2012). The trial period lasted 100 days, beginning in March and ending in June. The experimental period started with the first parturition and ended with the weaning of the lambs, including the suckling phase as a trial period.

The ewes and their respective lambs were kept in paddocks of Brachiaria-grass pastures in an area of 4.77 ha, divided into 6 paddocks (3 replicates per treatment). Immediately after births, the ewes and their lambs were identified, weighed, and distributed into groups according to the gender of the lamb (male or female), type of parturition (single or twin), and matrices category (female lambs or ewes), allowing distribution similar between the groups (Table 1). Ewes and lambs were kept in continuous grazing, with variable stocking rates. To adjust the stocking, regulatory animals were used (sheep with BW of approximately 50 kg), depending on the offers of leaf blades, allowing an offer of 10% depending on the average body weight of the herd. All paddocks were provided with drinking fountains with unrestricted access to animals.

Nutritional Management

The lambs were divided into two experimental treatments, with two different nutritional strategies, as described in Silva *et al*. (2022): Treatment (1) suckling lambs kept in Brachiaria-grass pasture, receiving mineral supplementation; and Treatment (2) suckling lambs kept in Brachiaria-grass pasture, receiving mineral supplementation and protein-energy supplementation in creep-feeding. In treatment (2), the lambs received daily, at 8:00 am, protein-energy supplementation *ad libitum* in

Table 1. Distribution of animals in the nutritional treatments of lambs according to the reproductive category of the ewe (multiparous and primiparous), type of delivery (single and twin), and lamb sex (male and female)

Distribution of animals	Control[1]	Creep-feeding[2]
Pluriparous ewes	13.0	13.0
Primiparous ewes	1.0	1.0
Simple birth	10.0	11.0
Twin birth	4.0	3.0
Males	9.0	9.0
Females	9.0	8.0

Note: [1]Control: suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation; and treatment. [2]Creep-feeding: suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation and protein-energy supplementation in creep-feeding.

Table 2. Chemical composition of supplements offered to lambs and ewes during the experimental period

Chemical composition	Lambs[2]	Ewes[3]
Dry matter (g/kg)	897.9	900.1
Organic matter (g/kg DM)	932.0	904.0
Crude protein (g/kg DM)	230.3	163.9
Ether extract (g/kg DM)	26.4	27.7
Neutral detergent fiber (g/kg DM)	143.2	170.5
[1]Total digestible nutrients (g/kg DM)	828.4	812.8

Note: [1]Total digestible nutrients (value estimated by the equation of Capelle *et al*. (2001): TDN= 91.0246-0.571588 (r2= 0.61; p<0.01). [2]Ingredients (g/kg): 517.0 corn, 472.0 soybean meal, 10 mineral premix. [3]Ingredients (g/kg): 761.1 corn, 198.9 soybean meal, 40 mineral premix.

creep-feeding formulated to obtain average gains of 200 grams/day (NRC, 2007). To calculate the average daily consumption of the lambs' group, the supplement offered in creep feeding and the leftovers were quantified daily.

The feeding management of the herd followed the protocol established by the sheep sector of the school farm, according to the nutritional needs of each category and the protocols established by this experiment. The feeding management started at 8:00 am.

Regardless of the nutritional treatment offered to the lambs, all matrices (female lambs and ewes) received 350 grams of energy supplementation daily to meet 30% of the total requirement (maintenance + lactation) for ewes with 50 kg of body weight (BW), with a milk yield production of 380 to 750 grams/day and a dry matter intake (DMI) of 1.26 kg (NRC, 2007; Buonaiuto *et al*., 2021). Data on the chemical composition and ingredients of lamb supplements (only treatment-2) and of ewes are available in Table 2.

In the control treatment, the lambs were separated at the time of ewe supplementation (8:00 am). Immediately after the ewes finished taking the supplement, the lambs were placed together with the ewes in their respective paddocks and nutritional treatments.

In the creep-feeding treatment, the lambs received food supplementation at 8:00 am and had free access for 24 hours. The internal area of creep feeding corresponded to 2.6 m^2 (2.00 m x 1.30). The troughs remained inside wooden fences, provided with opening systems measuring 30 cm high and 20 cm wide, and were located close to the sheep resting area (Melo *et al*., 2019). In this treatment, there was no need to separate the lambs and ewes because the lambs entered the creep-feeding to perform the supplement ingestion in the private troughs.

The ruffians received protein-energy supplementation to meet moderate gain requirements, as recommended by the NRC (2007), with a consumption of 1.5% of BW. All animals, regardless of the nutritional treatments of the lambs, received mineral supplementation *ad libitum*, and in all the paddocks, there were drinking fountains with clean and fully available water.

Pasture Management

To evaluate the forage mass on a dry matter basis (kg/ha/DM), pasture was collected every 28 days. Six samples were collected per paddock using a metallic square of 0.5 m^2 of area (1.0 m x 0.5 m) at random and representative points of each paddock. Subsequently, the samples were weighed and separated into leaf blades, stem (stem + sheath), and senescent material. The leaf blade samples collected from the experimental paddocks were also used to maintain a similar supply of leaf blades between the evaluated groups.

After morphological separation, the samples were submitted to pre-drying in a forced ventilation oven at 55 °C for 72 hours and crushed in a knife mill equipped with a sieve with a 1 mm sieve for determination of dry matter (DM), crude protein (CP), and ethereal extract (EE) by methodology AOAC (2000), through the procedures 930.15, 976.05, and 920.39. For determination of neutral detergent fiber (NDF) and acid detergent fiber (ADF) used the methodology described in Goering and Van Soest (1970), through the procedures INCT – CA-F-002/1, INC – CA F-004/1 (Table 3).

Criteria for Weaning, Determination of Performance of Lambs and Ewes

The weight determined for weaning the lambs was 18 kg, as recommended by Silva *et al*. (2022) for suckling lambs kept on Brachiaria-grass pasture. To determine the performance of lambs and ewes, the average daily gain in grams was calculated through the difference between weaning weight and birth weight, divided by the age of the lambs (days) at weaning. Additionally, matrices were weighed every 28 days to assess the body condition score (BCS) through palpation and evaluation of the amount of muscle and fat of the transverse and dorsal processes of the lumbar vertebrae, giving scores from 1 to 5 (Kenyon *et al*., 2014).

Measuring Milk Production and Composition

From the second week of lactation, the milk production of the ewes was evaluated every seven days using the indirect method of double weighing or weigh-suckle-weigh (Mohapatra *et al*., 2020). In the morning,

Table 3. Chemical composition of Brachiaria grass leaves as a function of nutritional treatments and experimental period (months)

Chemical composition	Control[1]			Creep-feeding[2]			Average	SEM[3]	p-Value		
	April	May	June	April	May	June			P_1	P_2	P_3
DM (g/kg)	310.09	319.51	316.25	277.85	324.72	348.2	316.94	107.089	0.889	0.151	0.263
CP (g/kg DM)	133.66	138.77	142.25	132.78	120.91	109.95	129.89	79.212	0.161	0.894	0.547
EE (g/kg DM)	28.95	19.84	23.45	30.49	17.64	22.9	23.18	41.984	0.901	0.034	0.299
NDF (g/kg DM)	690.41	742.29	668.25	674.91	731.93	668.25	444.41	379.249	0.853	0.134	0.946
ADF (g/kg DM)	348.94	395.15	330.65	352.96	394.61	344.73	374.92	327.234	0.827	0.160	0.939
TDN[4] (g/kg DM)	668.25	532.3	562.78	560.04	536.56	563.61	652.54	158.189	0.853	0.134	0.946

Note: [1]Control: Suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation; and treatment. [2]Creep-feeding: Suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation and protein-energy supplementation in creep-feeding. [3]SEM: Standard Error of Mean. DM: Dry matter, CP: Crude protein; EE: Ethereal extract; NDF: Neutral detergent fiber; ADF: Acid detergent fiber. [4]TDN: Total digestible nutrients (value estimated by the equation of Capelle et al. (2001): TDN= 83.79-0.4171*NDF (r2 = 0.82; p<0.01). P1: Lamb nutritional treatment (Control x Creep-feeding). P2: Experimental period (April, May, June). P3: Effect of the interaction between nutritional treatment and the experimental period.

the lambs were separated from the ewes, which only allowed visual contact between lambs and ewes. The separation period corresponded to three hours. After this period, the lambs returned to the ewes to empty the udder. The weight difference between suckling was measured to determine milk consumption. Indirectly, milk production was measured in a three-hour period, which was extrapolated to a 24 hour production (daily production).

Milk samples were collected every seven days to evaluate their chemical composition, with manual milking, followed by pre-dipping and post-dipping, without oxytocin. For that, 150 mL of milk was collected, stored in sterile flasks, cooled, frozen, and later taken for laboratory analysis. To determine the contents of fat, defatted dry extract, density, protein and lactose, the equipment Ekomilk total - Ultrasonic Milk Analyzer from the Mesoregional Milk Center Laboratory, from the State University of Maringá, Maringá-Paraná was used.

Determination of Reproductive Efficiency

To evaluate the reproductive performance of ewes, monitoring of the return to estrus was carried out through the presence of vasectomized ruffians. The ruffians were allocated to each paddock 15 days after calving and remained with the ewes for 24 hours until weaning. The ruffians had the sternal region painted with a mixture of powder paint and grease, in the proportion of 1:4, to mark the lumbar region of the females that showed estrus. Observations and notes were taken daily.

Evaluation of Parasitic Load

Fecal samples were collected directly from the rectum of each lamb and ewe every 15 days to quantify the number of eggs per gram of feces (fecal egg count, FECs). The animals (lambs and ewes) were dewormed with monepantel or nitroxinil when FECs were ≥1000.

Statistics

The study comprised the suckling period (from birth to weaning). The experimental design in the suckling period was in randomized blocks according to the sex of the lambs, party type, and part order in the treatment (control and creep feeding), and analyzed according to the statistical model: $Yijk= \mu + Ti + Sj + TSij + Bk + eijk$, where Yijk is the value of animal k, referring to the treatment, sex j, within block k, μ is the general constant, Ti is the treatment effect (i= 1, 2), Sj is the effect of sex (j= 1, 2); TSij is the effect of the treatment × sex interaction, B is the effect of the block k, eijk is the random error associated with each observation. The data were evaluated using analysis of variance (ANOVA) and considered different by the Tukey test at the 0.05 level of significance.

RESULTS

There was no interaction between the nutritional treatments and the experimental period for the variables of the chemical composition of the Brachiaria-grass pasture. The variables of DM (316.94 g/kg), CP (129.89 g/kg DM), EE (23.18 g/kg DM), NDF (444.41 g/kg DM), ADF (374.92 g/kg DM), and TDN (652.54 g/kg DM) showed no significant difference as a function of the nutritional treatments and the months of evaluation (Table 3).

There was no interaction between the nutritional treatment offered to the lambs and the gender of the lambs (Table 4). There was no significant effect of lambs' gender on the calving weight (average ± SD: 50.74±1.61), weaning weight average ± SD: 46.41±1.42), milk production (average ± SD: 1.47±0.10), days to estrus return (average ± SD: 42.42±7.19), body condition score at calving (average ± SD: 2.22±0.22), and body condition score at weaning of ewes (average ± SD: 2.07±0.37). Ewe performance variables (calving weight, weaning weight, and milk production) did not differ significantly as a function of the nutritional treatments of the lambs. Likewise, variables such as milk production corrected for fat and milk production corrected for fat and protein also did not differ significantly (Table 4).

Reproductive variables differ significantly in the function of nutritional treatments of lambs. Ewes, from treatment-1 presented, on average, 49 days to return to estrus. Ewes from treatment-2 presented 36 days to return to estrus. There was a difference of 13-day in return to estrus between treatments (p= 0.0040). The

Table 4. Productive and reproductive performance of ewes as a function of nutritional treatment (control and creep-feeding) and sex of lambs (females and males)

Variables	Treatments				SEM[1]	p-Value		
	Control		Creep-feeding			P_1	P_2	P_3
	Females	Males	Females	Males				
Weight at parturition (kg)	53.33	49.4	50.82	49.39	0.221	0.577	0.278	0.599
Weaning weight (kg)	48.56	44.64	45.89	46.54	0.199	0.885	0.441	0.282
Ewe weight variation (kg)	-4.77	-4.79	-4.94	-2.84	0.131	0.522	0.454	0.448
MP (kg/day)[2]	1.38	1.36	1.54	1.61	0.151	0.187	0.863	0.176
FCMP (kg/day)[3]	1.11	1.12	1.15	1.17	0.108	0.68	0.866	0.951
PFCMP (kg/day)[4]	1.05	1.07	1.1	1.12	0.104	0.620	0.850	0.983
Return to estrus (days)	51.14[a]	47.60[a]	37.33[b]	33.60[b]	10.807	0.004	0.413	0.983
BCS at birth	2.37	1.83	2.33	2.33	0.567	0.375	0.228	0.217
BCS at weaning	2.00[a]	1.50[a]	2.44[b]	2.33[b]	0.602	0.011	0.197	0.400

Note: *Means in the same row with different superscripts differ significantly by Tukey test (p<0.05). [1]SEM: Standard Error of Mean. FCMP: Fat-corrected milk production, PFCMP= Corrected milk production for fat and protein, BCS= Body condition score, [2]MP: Milk production. [3]Value estimated by the equation of Pulina *et al*. (1989): FCMP= (MP. (0.37+0.097. Fat)). [4]Value estimated by the equation of Pulina *et al.* (1989): PFCMP= (MP. (0.25+0.085. Fat+0.035. Protein)). P1: Lamb nutritional treatment (Control x Creep-feeding). P2: Lamb gender Effect (Female x Males). P3: Effect of the interaction between nutritional treatment and gender of lambs.

ewes' body condition score (BCS) at weaning showed a significant difference between treatments (p= 0.0110). Ewes from treatment-1 presented a mean BCS of 1.75, and the ewes from treatment-2 presented a mean BCS of 2.39 (Table 4).

There was no effect of nutritional treatments of the lambs on milk production (average ± SD: 1303.4±421.13), fat content (average ± SD: 5.06.4±1.89), defatted dry extract (average ± SD: 9.33±0.39), protein content (average ± SD: 3.85±0.18), lactose content (average ± SD: 4.74±0.21), and density content (average ± SD: 10.32±0.03) (Table 5). There was an effect of the lactation week on milk production (p= 0.001) and the physico-chemical properties (p<0.05). The ewes presented higher milk production from the 3rd week of lactation (average ± SD: 1510.62±174.82), while the defatted dry extract (p= 0.003) and density content (p= 0.001) showed high variation during the lactation period. The fat content (p= 0.001), protein content (p= 0.001), and lactose content (p= 0.010) showed significantly higher values from the 8th week of lactation (Table 5).

The average values of forage masses (5392 kg of DM/ha) and leaf blades (1582 g of DM/ha) showed no significant interaction. The average values of forage mass and leaf blades were similar between treatments and evaluation months (Table 6).

The proportion of leaf blades (28.90%) showed no significant interaction and was similar between treatments and evaluation months. The proportion (stem + sheath) showed interaction (p= 0.0217) between nutritional treatments and evaluation months. The mean proportion of leaf blades in treatment 1 was 40.14% and the mean proportion in treatment 2 was 43.72%. The proportion of senescent material showed no significant interaction. The evaluation months significantly influenced the proportion of senescent material (p= 0.0389), in which greater proportions of this component are observed in the last months of evaluation (Table 6).

The offer of leaf blades (g/kg of LW) showed the interaction between nutritional treatments and evaluation months (p= 0.0061). The evaluation period influenced the supply of leaf blades (p= 0.0001) since the offer was higher at the beginning of the trial period compared to the end of the experimental period (Table 6).

There was no significant difference between the birth weights of lambs as a function of nutritional treatments. There was a treatment effect on the weaning weight, age at weaning, total weight gain, and average daily gain (ADG) of lambs (Table 7). No significant differences were observed for the productive parameters as a function of the gender of lambs, and there was no significant effect of the interaction between the nutritional treatments and the gender of lambs (Table 7).

The supplement consumption by the lambs in the creep-feeding treatment averaged 245 grams/head/day during the trial period, ensuring a weight gain of 200 grams, as recommended by the NRC (2007) for this category.

There was no significant difference in the fecal egg count, FECs of the ewes as a function of the different nutritional treatments of the lambs throughout the experimental period, demonstrating parasitic challenge between treatments. Ewes in treatment-1 presented FEC ranging from 925 to 992 (average ± SD: 965.3±35.5). Ewes in treatment-2 presented FEC that varied from 917 to 950 (average ± SD: 935.0±16.7).

DISCUSSION

In this research, our objective was to evaluate the effects of creep-feeding supplementation for suckling lambs on the productive, reproductive, and health performance of ewes and on the chemical and physical characteristics of signal grass pasture. The reproductive parameters of ewes showed positive and indirect responses to protein-energy supplementation offered to lambs. The return to estrus showed a significant difference as a function of the nutritional treatment of the lambs. The ewes of treatment-1 returned to estrus 49 days postpartum, while the ewes in treatment-2 returned to estrus 36 days postpartum. Heimbach *et al*. (2020) observed a return to estrus with an average of

Table 5. Composition of ewes' milk from the 2nd to the 10th postpartum week, as a function of the nutritional treatments of the lambs (control and creep feeding)

System	Lactation week									SEM[1]	p-Value
	2nd	3rd	4th	5th	6th	7th	8th	9 th	10th		
					Milk production (g/day)						
Control	337.7	1549.5	1577.2	1477.5	1397.1	1242.1	1139.0	969.1	1128.5		
Creep feeding	306.	1989.9	1516.7	1860.3	1553.7	1406.6	1417.1	1340.7	1252.5		
Average	321.8^{b}	1769.7^{a}	1546.9^{a}	1668.9^{a}	1475.4^{a}	1324.8^{a}	1278.0^{a}	1154.9^{ab}	1190.5^{ab}	4.80	0.001
SEM	1.32	14.93	13.18	13.99	12.33	10.47	10.91	9.04	7.57		
P	0.949	0.061	0.796	0.11	0.512	0.513	0.234	0.138	0.699		
					Fat (%)						
Control	2.8	2.8	3.7	5.0	5.2	6.2	6.1	6.9	7.1		
Creep feeding	2.9	2.8	3.0	3.2	4.3	5.7	8.0	6.9	8.5		
Average	2.9^{d}	2.8^{d}	3.3^{d}	4.0^{cd}	4.7^{bc}	5.9^{ab}	6.9^{a}	6.9^{a}	7.4^{a}	0.39	0.001
SEM	0.38	0.351	0.32	0.36	0.43	0.57	0.44	0.46	0.73		
P	0.787	0.886	0.123	0.002	0.154	0.522	0.003	0.942	0.118		
					Defatted dry extract (%)						
Control	9.3	8.4	9.2	9.4	9.3	8.7	9.5	10.0	9.3		
Creep feeding	9.6	9.0	9.6	8.9	9.2	9.6	9.5	9.7	9.8		
Average	9.4^{ab}	8.7^{ab}	9.4^{ab}	9.2^{ab}	9.2^{ab}	8.9^{b}	9.5^{ab}	9.9^{a}	9.4^{ab}	0.25	0.003
SEM	0.25	0.34	0.26	0.3	0.13	0.36	0.28	0.27	0.29		
P	0.373	0.177	0.347	0.232	0.52	0.303	0.96	0.395	0.212		
					Protein (%)						
Control	3.8	3.4	3.8	3.9	3.9	3.6	4.0	4.1	3.9		
Creep feeding	3.9	3.7	3.9	3.7	3.8	3.8	4.0	4.0	4.1		
Average	3.8^{ab}	3.7^{c}	3.9^{abc}	3.8^{abc}	3.8^{abc}	3.7^{bc}	4.0^{ab}	4.1^{a}	3.9^{abc}	0.09	0.001
SEM	0.09	0.12	0.09	0.11	0.05	0.13	0.1	0.1	0.11		
P	0.406	0.105	0.365	0.202	0.419	0.332	0.899	0.375	0.208		
					Lactose (%)						
Control	4.7	4.2	4.7	4.8	4.8	4.4	4.8	5.1	4.7		
Creep feeding	4.9	4.6	4.9	4.6	4.7	4.7	4.8	5.0	5.0		
Average	4.8^{ab}	4.4^{b}	4.8^{ab}	4.7^{ab}	4.7^{ab}	4.5^{ab}	4.8^{ab}	5.1^{a}	4.8^{ab}	0.14	0.01
SEM	0.13	0.18	0.14	0.17	0.07	0.19	0.15	0.15	0.15		
P	0.375	0.186	0.315	0.257	0.379	0.285	0.823	0.396	0.224		
					Density (%)						
Control	10.37	10.29	10.32	10.32	10.32	10.28	10.32	10.33	10.3		
Creep feeding	10.35	10.33	10.34	10.32	10.31	10.31	10.30	10.32	10.31		
Average	10.36^{a}	10.31^{ab}	10.33^{a}	10.32^{ab}	10.32^{ab}	10.30^{b}	10.31^{ab}	10.33^{ab}	10.31^{ab}	1.07	0.001
SEM	1.00	1.05	1.01	1.21	1.04	1.29	1.06	1.18	0.91		
P	0.345	0.091	0.145	0.76	0.474	0.161	0.313	0.401	0.567		

Note: Means in the same row with different superscripts differ significantly by Tukey test ($p<0.05$). [1]SEM: Standard Error of Mean.

50 days in ewes kept in tropical pastures, coming from single and twin births. The difference in the 13-day estrus return observed corresponds to the difference in age at the weaning of the lambs. The mean age at weaning lambs from treatment-1 and treatment-2 was 85 and 72 days, respectively.

We suggest that this difference in the return to estrus is related to the mechanisms of action of the anterior pituitary protein hormones. Specifically, three hormones are important for promoting these reproductive events. The main function of FSH is to promote follicle growth; LH is important for the granulosa luteinization process, which results in the formation of the corpus luteum, the action of both being synergistic. The third corresponding hormone is prolactin, which has as its main functions the development of the secretory tissue of the mammary gland and the maintenance of lactation (Lopes *et al.*, 2019).

We hypothesized that lambs in treatment-1 had a longer suckling period; thus, ewes had a longer postpartum anestrus. The presence of lambs associated with a longer period of sucking generated neural, sensory, and olfactory metabolic responses that may have inhibited LH synthesis and, consequently, decreased oocyte maturation (Risques *et al.,* 2020). In treatment-2, the shorter sucking time may promote greater prolactin control through hypothalamic factors. Consequently, increased LH surges may have occurred, and increased concentrations of LH and FSH receptors in follicles, generating oocyte maturation and ovulation, 13 days postpartum (Buso *et al.*, 2018).

Considering that ewes are in estrus at regular intervals and that the duration of the estrous cycle is, on average, from 16 to 19 days, and that in the case of young females, this interval can be up to two days shorter (Ferreira *et al.,* 2020; Lozano *et al.,* 2020), we recommend

Table 6. Means of forage mass (kg of DM/ha), leaf blades (kg of DM/ha), proportion of leaf blades (%), proportion of stem + sheath (%), proportion of senescent material (%) and offer of leaf blades (g/kg of LW) according to nutritional treatments (1 or 2)[1] and months of use

Variables	Treatment[1]	Month			Average	SEM[2]	p-Value		
		April	May	June			P_1	P_2	P_3
Forage mass	1	4480	5103	5430	5004				
	2	5006	4377	7953	5779	0.959	0.342	0.104	0.271
	Average	4743	4740	6692	5392				
Leaf blades	1	1590	1967	1017	1524				
	2	1870	1517	1533	1640	0.300	0.646	0.248	0.282
	Average	1730	1742	1275	1582				
Proportion of leaf blades	1	37.60	25.49	22.07	28.39				
	2	40.43	25.63	20.65	28.90	73.419	0.9327	0.079	0.958
	Average	39.01	25.56	21.36	28.65				
Proportion of stem + sheath	1	44.58^{ab}	47.45^{a}	28.39^{b}	40.14				
	2	45.17^{ab}	39.77^{b}	46.22^{ab}	43.72	39.724	0.292	0.1672	0.022
	Average	44.88	43.60	37.31	41.93				
Proportion of senescent material	1	17.82	27.05	46.97	30.62				
	2	14.05	34.59	31.65	26.77	80.626	0.570	0.039	0.395
	Average	15.94^{b}	30.82^{ab}	39.31^{a}	28.69				
Offer of leaf blades	1	98.93^{a}	91.57^{ab}	71.03^{c}	87.18				
	2	99.07^{a}	84.23^{b}	84.70^{ab}	89.33	0.265	0.340	<0.0001	0.006
	Average	99.00^{a}	87.90^{b}	77.87^{c}	88.26				

Note: Means in the same row with different superscripts differ significantly by Tukey test (p<0.05).
[1]Treatment 1: Suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation; and treatment; Treatment 2: Suckling lambs kept in mixed pastures of *Brachiaria* spp. receiving mineral supplementation and protein-energy supplementation in creep-feeding; [2]SEM: Standard error of mean; P1= Lamb nutritional treatment (Control x Creep-feeding); P2= Lamb gender Effect (Female x Males); P3= Effect of the interaction between nutritional treatment and the experimental period.

Table 7. Mean and standard deviation of birth weight, weaning weight, age at weaning, total weight gain, and average daily gain, as a function of the nutritional treatments of the lambs and the gender of the lambs (females and males)

Variables	Treatments				SEM[1]	p-Value		
	Control		Creep-feeding			P_1	P_2	P_3
	Females	Males	Females	Males				
Weight at birth (kg)	3.83 ± 1.09	3.85 ± 0.88	3.33 ± 1.01	3.66 ± 0.95	0.033	0.358	0.598	0.673
Weaning weight(kg)	15.97 ± 2.83^{a}	15.86 ± 3.07^{a}	17.87 ± 4.23^{b}	17.74 ± 3.70^{b}	0.117	0.052	0.928	0.991
Age at weaning (days)	87.29 ± 7.61^{a}	82.14 ± 10.06^{a}	71.75 ± 10.55^{b}	71.78 ± 12.47^{b}	0.358	0.002	0.546	0.501
Total weight gain (kg)	12.14 ± 2.63^{b}	12.02 ± 2.38^{b}	14.54 ± 3.47^{a}	14.08 ± 3.12^{a}	0.098	0.004	0.985	0.710
Average daily gain (g/day)	141.91 ± 41.61^{b}	150.07 ± 41.30^{b}	208.65 ± 63.47^{a}	202.54 ± 57.09^{a}	1.729	0.048	0.776	0.878

Note: Means in the same row with different superscripts differ significantly by Tukey test (p<0.05). [1]SEM: standard error of mean. P1: Production System effect (control x creep feeding). P2: Lambs Gender effect (Female x Males). P3: Effect of Interaction between Lamb's Production System and Gender.

indirect nutritional support via supplementation of lambs as a way to improve reproductive efficiency.

The body condition score (BCS) of the ewes at weaning showed a statistical difference as a function of the supplementation of lambs. The average BCS of treatment-1 was 1.75, which is below recommended (BCS= 2.0) for ewes at weaning (Kenyon *et al.,* 2014). The BCS 2.39 observed in treatment-2 is within the recommended range for ewes at weaning (Melo *et al.,* 2019; Heimbach *et al.,* 2020; Arco *et al.,* 2021). The BCS 2.0 would be the minimum value to avoid negative impacts on herd productivity in future mating (Kenyon *et al.,* 2014).

The increment in protein and energy to the lambs improved the body conditions of the ewes. This bettering is ideal to considerably increase the reproductive parameters by activating ovarian follicular reserves, increasing the growth rate and size of ovulatory follicles, increasing the ovulation rate, and increasing the number of fertilized eggs (Lozano *et al.,* 2020), and, probably, the incidence of twin births associated with lower embryonic mortality.

Milk production showed no significant difference as a function of the nutritional treatments of the lambs. However, there was an effect of the week of lactation on milk production. In the 2nd week of lactation, the average milk production was 328 g/d. The average milk production was 1517.66 g/d between the 3rd and 8th week (peak lactation). The average milk production was 1216.45 g/d in the 9th and 10th weeks. The ewe produces 80% of the milk in the first eight weeks, and under normal conditions, after the 12th week, milk production is minimal, and ewes' milk supplies less than 10% of the nutritional requirements of lambs (NRC, 2007).

Data on milk production in ewes kept on Brachiaria-grass pastures are scarce in the literature. In our study, the average milk production at peak lactation corresponds to the values found in previous studies. The estimated milk production in Hampshire Dawn, Ile de France, and Santa Cruz ewes on varied pastures was 1045.97 g/d, 962.29 g/d, and 1950.0 g/d, respectively (Podleskis *et al.,* 2005; Merchant *et al.,* 2021). The fat, protein, and lactose contents were significantly higher values from the 8th week of lactation. The lactation phase can influence the milk's physicochemical properties. Walter *et al*. (2022) observed that fat, protein, and lactose were proportionally lower in early lactation than in the middle and late lactation periods. In other words, the greater the production, the lower the concentration of proteins, fats, and lactose in milk (Freitas-de-Melo *et al.,* 2017).

The chemical composition of the leaf blades of *Brachiaria* spp., of the experimental paddocks forage, as the concentrations of CP (129.89 g/kg of DM), NDF (441.41 g/kg of DM), ADF (374.92), and TDN (652.54) indicated that there was a need to include protein and energy to complete the nutritional requirements of the categories of ewes and lambs in the lactation period. High fiber (NDF) concentrations associated with low concentrations of CP are related to low voluntary consumption of forage due to slow pass rate and low fiber degradation (Melo *et al*., 2019).

The average forage mass production (kg of DM/ha) and the average production of leaf blades (kg of DM/ha) remained constant between treatments and during the evaluation period, demonstrating that the growth characteristics of the pasture were related to the intrinsic factors of the plant and showed the low influence of nutritional management of lambs. Silva *et al*. (2022) observed average values for forage mass and the production of leaf blades of 5016.83 (kg of DM/ha) and 1190.0 (kg of DM/ha), respectively, between July and September. The authors observed that different levels of protein-energy supplementation offered to lambs in the finishing phase did not influence the forage mass and leaf production variables, as seen in the present study.

The proportion of leaf blades remained similar throughout the experimental period and between nutritional treatments. However, the proportion of stem showed an interaction between the nutritional treatments and the months of evaluation. In treatment-1, there was a lower proportion of stem (28.39%) in the last month of evaluation (June), while in treatment-2, the lowest proportion of stem (39.77%) was observed in May. We suggest that the supplementation offered to the lambs reduced the grazing time of the lambs since the lowest proportion of stem was observed in treatment-1, in which the lambs received only mineral supplementation. Lambs kept on *Brachiaria* spp. receiving mineral supplementation grazed an average of 4.75 hours (considering a period of 12 hours), while lambs that received protein-energy supplementation in creep-feeding grazed an average of 4.0 hours (considering a period of 12 hours) (Melo *et al.,* 2022).

The proportion of senescent material significantly differentiated the function of time. For both treatments, we observed a higher proportion of senescent material in the last month of evaluation. We can say that the pasture was in a seasonal production cycle characteristic for the season (autumn and winter) since the production and nutritional value of forage were in decline during the experimental period (Barbero *et al.,* 2021). This fact justifies the adoption of nutritional strategies for categories of high nutritional demand, such as lactating ewes and growing lambs.

The offer of leaf blades (g/kg of LW) showed the interaction between nutritional treatments and evaluation months. In treatment-1, we can observe that the supply of leaf blades (71.03 g/kg of LW) was significantly lower in the last month of the trial period (June), while in treatment-2, we observed that the offer of leaf blades (87.90 g/kg of LW) was significantly lower in May.

The offer of leaf blades is an important parameter for animal production since it is known that the leaf is the main component (with greater nutritional value) to be consumed by the animal (Barbero *et al.,* 2021). One of the main objectives of a pasture production system is to increase the supply of leaves in the ruminant diet. We suggest that protein-energy supplementation can be used as a useful nutritional tool to increase the productive efficiency of pastures and improve sheep conditions to better select and utilize the nutrients that are available in these pastures, especially in periods of low production and low nutritional value as observed in the present study.

The performance of lambs in the creep-feeding treatment was significantly higher when compared to lambs in the control treatment. These benefits of protein-energy supplementation on the development of suckling lambs also have been highlighted by Melo *et al*. (2019) and Silva *et al*. (2022).

CONCLUSION

Protein-energy supplementation in creep feeding is a nutritional tool that benefits lambs kept on Brachiaria-grass pastures. The supplementation of lambs efficiently improved the reproductive indices of ewes, such as the return to estrus and body condition score, without affecting the immune response of ewes to gastrointestinal parasitism. This nutritional tool can improve the supply of leaves and provide the best conditions for the selection and use of nutrients present in the leaves.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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