

Reproductive efficiency of ewe lambs kept on tropical pastures under different feeding systems

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[Eficiência reprodutiva de borregas mantidas em pastagens tropicais sob diferentes sistemas de alimentação]

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ABSTRACT

The aim of this study was to analyze the productive and reproductive performance of lambs submitted to different forms of feed supplementation in the growth phase and breeding season. Twenty-eight Texel sheep aged between three and 12 months were used. The lambs were distributed in two treatments with protein-energy supplementation at levels 1.6 and 2.4% of body weight and reared on *Brachiaria brizantha* cv. Marandu. The performance was evaluated at the beginning of the experimental period and every 28 days until the end of the breeding season, the following data were observed: final body weight, average daily gain (ADG) and total weight gain (TWG). In the growth period, the lambs supplemented with 2.4% BW presented higher average daily gain, which resulted in higher total weight gain and final weight. Thus, the ewe lambs supplemented with 2.4% BW showed greater subcutaneous fat thickness in the growth phase. However, during growth the lambs supplemented with 1.6% of BW showed better body condition score than those supplemented with 2.4% BW. There was no effect of supplementation on the size of the reproductive organs of the lambs at the end of the growth phase and at the beginning of the reproductive season. The supplementation levels used affected the pregnancy rate of the lambs. The group that received 1.6% BW had a higher pregnancy rate than the group treated with 2.4% BW. Thus, it is concluded that supplementation with 1.6% BW was economically viable to promote weight gain, body condition score, and stimulate fertility rate for primiparous lambs in a 45-day reproductive season.

Keywords: consumption estimate, nulliparous, operating costs, pasture, sheep farming.

RESUMO

O objetivo deste estudo foi analisar o desempenho produtivo e reprodutivo de cordeiras submetidas a diferentes formas de suplementação alimentar na fase de crescimento e na estação de monta. Foram utilizadas 28 cordeiras Texel, com idades entre três e 12 meses. As cordeiras foram distribuídas em dois tratamentos, com suplementação proteico-energética em níveis de 1,6 e 2,4% do peso corporal (PC) e mantidas em pastos de *Brachiaria brizantha* cv. Marandu. O desempenho foi avaliado no início do período experimental e a cada 28 dias até o final da estação de monta, observando-se os seguintes dados: peso corporal final, ganho médio diário (GMD) e ganho de peso total (GPT). No período de crescimento, as cordeiras suplementadas com 2,4% do PC apresentaram maior GMD, o que resultou em maior GPT e peso final. Assim, as cordeiras suplementadas com 2,4% do PC apresentaram maior espessura de gordura subcutânea na fase de crescimento. No entanto, durante o crescimento, as cordeiras suplementadas com 1,6% do PC apresentaram melhor escore de condição corporal do que aquelas suplementadas com 2,4% do PC. Não houve efeito da suplementação no tamanho dos órgãos reprodutivos das cordeiras no final da fase de crescimento e no início da estação reprodutiva. Os níveis

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Submitted: February 26, 2024. Accepted: June 18, 2024.

de suplementação utilizados afetaram a taxa de gestação das cordeiras. O grupo que recebeu 1,6% do PC teve uma taxa de gestação mais alta do que o grupo tratado com 2,4% do PC. Assim, conclui-se que a suplementação com 1,6% do PC foi economicamente viável para promover ganho de peso, escore de condição corporal e estimular a taxa de fertilidade para cordeiras primíparas em uma estação reprodutiva de 45 dias.

Palavras-chave: custos operacionais, estimativa de consumo, nulíparas, ovinocultura, pastagem

INTRODUCTION

The production of sheep meat in Brazil presents great growth potential, however, the biggest obstacle to the growth of this activity refers to the low efficiency of the flocks (Debortoli *et al.*, 2021). For the improvement of productive performance, different pasture feeding systems have been evaluated, especially regarding improving the performance of lambs (Silva *et al.*, 2022), the response to health challenges (Melo *et al.*, 2019) to improve meat and carcass characteristics (Silva *et al.*, 2020) and to evaluate reproductive responses in sheep (Ferelli *et al.*, 2023).

In the case of ewes, which constitute the most numerous categories and stay longer in the flock, nutrition influences the estrous cycle of the sheep, the ovulation rate and the fertility rate, in addition to embryonic survival (Ferelli *et al.*, 2023). Important factors for the profitability of the breeding system, because the greater the number of lambs, the greater the number of twin births and, in the shortest possible time, the greater the amount of meat produced and the gross income (Arco *et al.*, 2021). In this context, it is essential to adopt food and economic management strategies aimed at improving and increasing the productive and reproductive life of lambs, to reduce the interval between births and increase the number of lambs produced per ewe.

In this case, supplementation is a tool that allows to increase and improve performance and reproductive parameters, mainly by providing energy and proteins, nutrients related to the development of maintenance, growth and reproduction processes (Thompson *et al.*, 2021). However, supplementation can generate costs and make the feeding system inefficient, thus reducing the profitability of the herd.

In addition, to optimize the production of lambs in a sustainable way, it is necessary to evaluate the appropriate level of supplementation to

increase the fertility rate and shorten the breeding season of the sheep. According to González-García and Hazard (2016) puberty arises only when the lambs reach a weight and a minimum age, in this sense, in sheep, puberty depends on the growth rate, which fundamentally depends on the interaction between nutrition and environmental factors.

Thus, our research group has been developing nutritional strategies using increasing levels of supplementation to evaluate the growth of lambs kept in tropical pastures (Ferelli *et al.*, 2023), found that the level of 2.4% of BW promotes better performance rates. However, the results of supplementation with 1.6% are promising and may be a viable alternative to produce female lambs that reach early age and weight for entry into the first reproductive season. It is worth mentioning that the excess nutrients ingested by the ewes during puberty can impair productivity, since high levels of feeding increase the ovulation rate also increasing embryonic mortality, resulting in lower parity rate (Campos *et al.*, 2022). In addition to increasing costs with nutritional inputs in the most numerous categories of the herd.

Therefore, our studies demonstrate the importance of knowing the interactions between nutritional level, environment and physiological parameters, aiming to improve the productive and reproductive performance of sheep in the tropical region. Thus, our hypothesis was that protein-energy-mineral supplementation based on ground corn grain and soybean meal and mineral mixture provided at 1.6% of body weight would be sufficient to maintain productive and reproductive indexes compatible with a supplementation provided at 2.4% of BW of lambs kept in pastures of *Brachiaria brizantha* cv. Marandu, thus anticipating the first mating. The objective of this study was to analyze the productive and reproductive performance of lambs submitted to different forms of feed

supplementation in the growth phase and breeding season.

MATERIAL AND METHODS

The experiment was conducted at the Farm (20°26'34.31"S, 54°50'27.86"W, 530.7m a.s. l) of the Federal University of Mato Grosso do Sul (UFMS), Brazil. All procedures with animals were approved by Ethical Committee (protocol 654/2015).

Twenty-eight nulliparous Texel ewe lambs (22.9±4.5 kg BW) weaned at 90 days were evaluated up to 12 months of age. The experimental trial was divided into two periods: The period of growth was from March to December, beginning with the weaning of the lambs and ending with the beginning of the reproductive life of the ewe lambs. After weaning, the ewe lambs were divided into two nutritional treatments, both supplements based on corn grain and soybean meal to meet the maintenance requirements according to the NRC (Nutrient..., 2007).

All ewe lambs were divided into two groups of fourteen animals according to the nutritional treatments (1.6 or 2.4% BW of supplement). The breeding season was from December until February, with the beginning of the breeding

season and ending with the diagnosis of pregnancy of the ewe lambs. In December, all ewe lambs were submitted to the first breeding season by 45 days, which were evaluated for reproductive performance. The experimental area corresponded to a total area of 2.6 ha, being 1.3 ha for each nutritional treatment, with three replications (three paddocks of 0.43 ha each) per treatment. The experimental area, for both phases, was formed by grasses *Brachiaria brizantha* cv. Marandu. Continuous grazing was carried out, with a variable stocking rate. To maintain the supply of leaves at 86.95 grams/kg BW, regulator animals were used.

The ewe lambs remained in continuous grazing receiving water and mineral supplementation *ad libitum*. The protein-energetic-mineral supplement was supplied daily at 8:00 am, containing 250 g/kg of crude protein and 3.05 Mcal ME/kg of dry matter, based on ground corn grain, soybean meal, and mineral mix (Table 1). In the rearing phase, the ewes were previously adapted to the respective nutritional treatments, as described by Arco *et al.* (2021). To estimate ME, the following equations were used: $DE \times 0.82 = ME$; and $DE = 4.409 \times TDN$, where: DE = digestible energy; ME = metabolizable energy; TDN = total digestible nutrients (Nutrient..., 2007).

Table 1. Ingredients and chemical composition of the protein energy supplement provided for the ewe lambs

Supplement (g/kg)	
Corn grain milled (g/kg)	517.0
Soybean meal (g/kg)	473.0
Mineral mix	10.0
Chemical composition (g/kg DM)	
Dry matter (g/kg)	830.0
Mineral matter (g/kg)	90.0
Organic matter (g/kg)	910.0
Crude protein (g/kg)	250.8
Ether Extract (g/kg)	15.6
Neutral detergent fiber (g/kg)	10.74
Acid detergent fiber (g/kg)	4.62
Total digestible nutrients (g/kg)	842.7

Note: Mineral mix: Ca 6000mg/kg, Co 0.3mg/kg, Cu 3.75mg/kg, S 750mg/kg, P 4800 mg/kg, I 0.42mg/kg, Mn 9.00mg/kg, Se 0.12mg/kg, Na 1100mg/kg, NNP equiv Protein 14g/kg.

The estimate of leaf blade consumption based on DM (g/day) was performed using internal markers: indigestible dry matter – MSi; non-digestible neutral detergent fiber – NDF; non-

digestible acid detergent fiber – ADFi; indigestible lignin in acid detergent – iADL according to methodology described by Costa *et al.*, 2023. To pasture consumption estimate, 12

testers lambs were used, with an average body weight of 17.52 kg, adapted to the consumption of the grass *Brachiaria* and adapted to molecular markers. Evaluations to estimate pasture consumption were carried out simultaneously with the development of this study, in paddocks formed by *Brachiaria brizantha*, adjacent to the lamb performance assessment area. The pasture had chemical and structural characteristics similar to the pastures described in this study, as described in Costa *et al.*, 2023.

Chemical analysis of the supplement offered to the ewe lambs were carried out (Table 1). The analyses were performed using the methods described by AOAC (Official..., 2016) to determine the contents of dry matter (DM; method no. 930.15), crude protein (CP; method no. 976.05), ether extract (EE; method no. 920.39), and ash (method no. 942.05). Organic matter (OM) content was calculated as the

difference between 100 and the percentage of ash (100—% ash). To determine neutral detergent fiber (NDF) and acid detergent fiber (ADF), the Van Soest (1991) test methodology was used with procedures INCT – CA F-002/1 and INCT – CA F-004/1.

Every 28 days pasture was collected to determine the forage mass. A metal square measuring 0.5 m² in area (1.0 m x 0.5 m) was used, with four samples being collected per paddock, forming samples composed of nutritional treatment (Table 2). Subsequently, the samples were separated into their morphological components (leaf blades, stem and senescent material) (Table 2). Samples of the pasture were pre-dried in a forced-air oven at 55° C for 72 h and ground on 1 mm particles, for subsequent chemical analysis of the main morphological component (leaf blades) selected by the sheep (Costa *et al.*, 2023) (Table 2).

Table 2. Morphological characteristics and chemical composition of *Brachiaria* -grass pasture offered during the productive and reproductive period of the lambs

	Growing season							Breeding season					Mean	CV (%)
	March	April	May	June	July	August	September	October	November	December	January	February		
Forage mass (kg DM/ha ¹)	5281.5	4758.5	4751.8	6594.2	5512.7	3526.1	4055.2	5858.7	7448.7	5031.1	5982.8	5368.2	5347.5	19.05
Leaves (%)	27.2	29.5	20.3	18.2	21.1	23.0	21.3	15.6	16.7	19.9	20.9	22.7	21.3	17.92
Stem (%)	40.6	30.8	34.2	30.8	29.5	38.5	39.0	31.3	18.8	23.0	18.1	31.9	30.6	23.20
Senescent material (%)	32.2	39.7	46.2	52.7	50.4	38.6	41.1	53.3	64.6	57.5	61.5	45.8	48.6	19.33
DM (g/kg)	439.3	504.0	607.8	574.2	240.1	202.5	214.3	216.8	419.7	417.5	418.1	417.8	389.3	34.66
CP (g/kg DM)	530.0	561.0	503.2	568.3	582.2	550.0	677.7	646.2	737.3	650.0	336.0	493.0	569.6	17.50
NDF (g/kg DM)	759.0	748.1	414.6	601.6	749.0	753.0	679.1	870.0	660.7	593.8	700.0	649.9	681.6	16.00
ADF (g/kg DM)	460.6	488.6	447.1	340.2	490.8	394.7	393.9	346.3	346.7	219.2	364.1	291.7	382.0	20.44
TDN (g/kg DM)	525.4	529.9	667.2	508.5	431.5	527.9	535.9	479.7	565.9	593.4	418.1	505.8	524.1	12.26

Note: CV = coefficient of variation

The ewe lambs were weighed at the beginning of the experimental period and every 28 days until the end of the breeding season. To determine the productive performance, the total weight gain (TWG) in kilograms was calculated through the difference between the final live weight and initial live weight, the average daily gain (ADG) in grams through the difference between the final live weight and initial live weight, divided by the number of days of the experimental period.

The determination of the body condition score (BCS) was carried out every 28 days, through palpation and evaluation of the amount of muscle and fat in the transverse and dorsal processes of the lumbar vertebrae, obtaining scores from one (thin) to five (fat), according to the methodology described by Russel *et al.* (1969).

To measure LEA and SFT *in vivo*, ultrasound equipment (brand Aloka SSD-500) was used, with a linear transducer of 12cm and a frequency of 3.5 MHz. The transducer was placed

perpendicularly to the length of the *longissimus dorsi* muscle, between the twelfth and thirteenth ribs, to take the image, whose reading was the measurement of the maximum length and depth of the muscle, in centimeters (cm), in addition to the thickness of the subcutaneous fat, in millimeters (mm), interpreted using the Lince® Software. The assessments were conducted during two periods, in the final of the growing season and the final of the breeding season.

Transrectal ultrasound of the ewe lambs was performed at final of the growing season to evaluate the size and length of the ovaries and uterus; after evaluation, they were introduced into a natural breeding season lasting 45 days, starting in December, with a male to female ratio of 1:14; Texel breeder was used for each experimental group (Arco *et al.*, 2021). Two vasectomized ruffians per treatment were used, which remained with the females during the day to identify the return to heat. They were marked with specific paint on the pectoral region, with a different color from that used by the breeder. The ewe lambs that were painted by the ruffians were later allocated to the breeder, in the late afternoon, and the control of the mount occurred through individual marking, provided by the painting on the pectoral region by the breeder, with a color that stood out from that used on the ruffians. Every 15 days, the breeder's paint was changed, offering three coverage opportunities for each ewe lamb. After the breeding season, pregnancy diagnosis was conducted to assess the reproductive performance of the ewe lambs by means of ultrasonography (Ferelli *et al.*, 2023).

The data were submitted to variance analysis using the SAS statistical program (2002). The statistical model was used: $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} = observed value for treatment i in repetition j ; μ = general mean effect; T_i = effect of supplementation level, and e_{ij} = random error associated with each observation. The performance data, loin eye area, and subcutaneous fat thickness were analyzed using

the Tukey test, at a 0.05 level of significance. The non-parametric data (initial BCS, during the breeding season, at end of the breeding season, and fertility) were analyzed using the chi-square test, at a 0.05 level of significance.

RESULTS

During the growth and reproduction period, lambs supplemented with 2.4% BW presented higher average daily gain, which resulted in higher total weight gain and final weight (Table 3). However, negative ADG and total weight gain were observed for the lambs that were supplemented with 1.6% BW (Table 3).

The best body score condition in the growth period was found in lambs that were supplemented with 1.6% BW. On average, 53.8% of the lambs that received 1.6% of supplementation had BCS of 2 and 30.8% of the lambs of this treatment had BCS of 3, while 33.3% of the lambs that received 2.4% of supplementation had BCS of 2, and 20% of the lambs of this treatment had BCS of 3. In the breeding season, the behavior of BCS was similar to the behavior of weight (Table 3), with higher mean BCS in the lambs that received 2.4% supplementation (on average, 70% of the ewes had BCS equal to 3), 53.8% of the ewes that received 1.6% of supplementation presented BCS equal to 3. However, no significant differences were observed in the frequency of BCS when we analyzed the breeding period (Table 4).

The highest SFT found was for lambs supplemented with 2.4% BW at the end of the growing season. On the other hand, in this same period there was no effect of the level of supplementation for LEA. Similarly, there was no significant effect for LEA and SFT at the end of the reproductive season (Table 5). It was also observed that there was no effect of supplementation on the measures of the reproductive organs of the ewe lambs (Table 6).

Table 3. Productive performance of lambs submitted to different levels of supplementation maintained in brachiaria grass during the productive and reproductive period

Variables	Treatments		SEM	p-value
	1.6%	2.4%		
Growing season				
Final body weight (kg)	52.4 ^b	57.0 ^a	2.16	0.0027
Average daily gain (g/day)	105.5 ^b	124.5 ^a	15.09	0.0027
Total weight gain (kg)	29.1 ^b	34.4 ^a	4.17	0.0027
Breeding season				
Final body weight (kg)	52.0 ^b	57.51 ^a	6.57	0.0362
Average daily gain (g/day)	-8.6 ^b	11.8 ^a	4.86	0.0362
Total weight gain (kg)	-0.4 ^b	0.5 ^a	1.84	0.0362

Note: a-b Means followed by different lowercase letters in the same line differ from each other by Tukey's test ($p < 0.05$). ADG=Average Daily Gain; TWG=Total Weight Gain.

Table 4. Frequency of body condition score (BCS) of ewe lambs subjected to different levels of supplementation kept in Brachiaria-grass

	Treatments		p-value
	1.6%	2.4%	
BCS	Growing season (March – December)		0.0377
1	7.7	46.7	
2	53.8	33.3	
3	30.8	20.0	
4	7.7	0.0	
BCS	Breeding season (December – January)		0.3707
1	0.0	0.0	
2	15.4	0.0	
3	61.5	73.3	
4	23.1	26.7	
BCS	End of breeding season (February)		0.8882
1	0.0	0.0	
2	38.5	6.7	
3	46.1	66.7	
4	15.4	26.7	

Note: (p-value) = by Tukey's test ($p > 0.05$).

Table 5. Measurements of loin eye area (LEA) and subcutaneous fat thickness (SFT) by ultrasonography of ewe lambs submitted to different levels of supplementation kept in Brachiaria-grass

of ewe lambs submitted to different levels of supplementation kept in Brachiaria grass				
	Treatments (% BW)		SEM	p-value
	1.6	2.4		
	Final of growing season (November)			
Loin eye area (cm)	15.3	15.7	2.77	0.7323
Subcutaneous fat thickness (mm)	0.3 ^b	1.3 ^a	1.03	0.0203
	Final of breeding season (February)			
Loin eye area (cm)	16.2	16.6	4.68	0.3639
Subcutaneous fat thickness (mm)	5.7	7.3	2.32	0.0827

Note: LEA=loin eye area; SFT= subcutaneous fat thickness; SEM=standard error of the mean

Table 6. Measurements of reproductive organs of female lambs at the end of growing phase submitted to different levels of supplementation kept in *Brachiaria*-grass

	Treatments (% BW)		SEM	p -value
	1.6	2.4		
Left ovary length (mm)	22.9	22.2	1.05	0.8397
Left ovary width (mm)	11.9	12.7	0.45	0.4812
Right ovary length (mm)	21.9	23.6	0.96	0.5981
Right ovary width (mm)	13.0	12.9	0.40	0.9167
Length of Uterus (mm)	43.1	43.2	1.76	0.5449
Width of Uterus (mm)	12.0	12.1	0.36	0.8305

Note: SEM=standard error of the mean

The consumption of pasture (leaf blades) was similar between nutritional treatments in the periods of weaning, rearing and mating. The estimated pasture intake varied according to sheep growth: At weaning, the average intake was 1938.19 grams/day; during growth, the average intake was 4756.34 grams/day; and at mating time was 4761.15 grams/day (Figure 1).

The supplementation levels used affected the pregnancy rate (pregnant ewes in reproduction/pregnant ewes*100) of the ewes. A higher pregnancy rate was observed in the group of ewes that received 1.6% BW, where these lambs had pregnancy rates of 84.6%, while the group of ewes treated with 2.4% BW had a pregnancy rate of 73.33% (Figure 2).

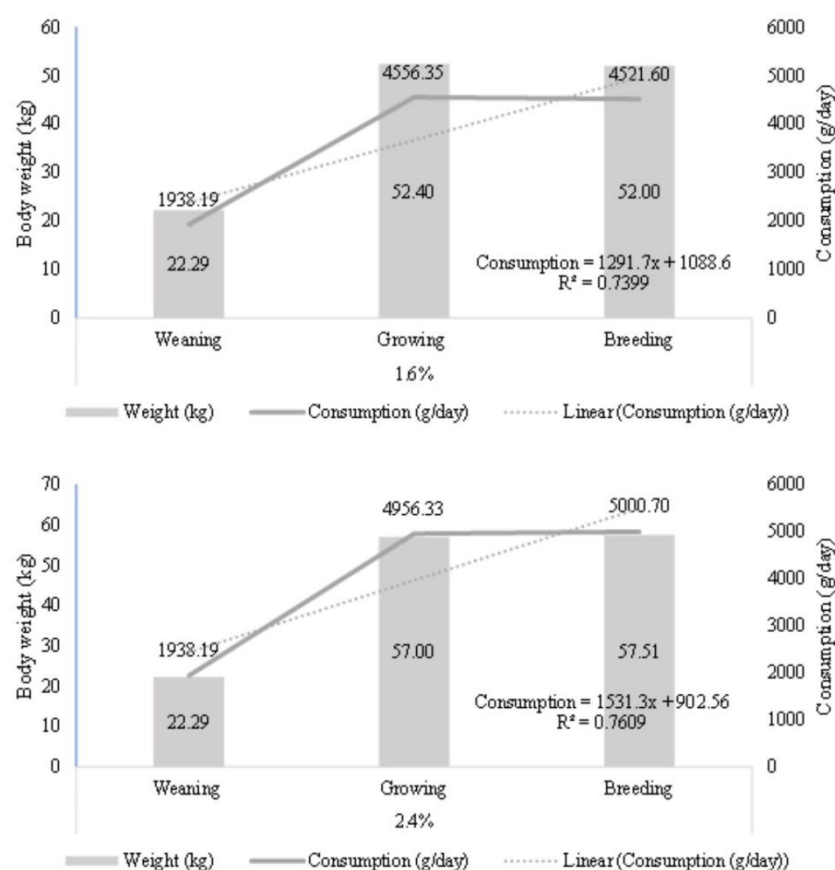


Figure 1. Estimation of pasture (leaf) intake by lambs as a function of weaning, growing and breeding at different levels of supplementation (1.6% BW and 2.4% BW). Data estimated according to Costa *et al.* (2023).

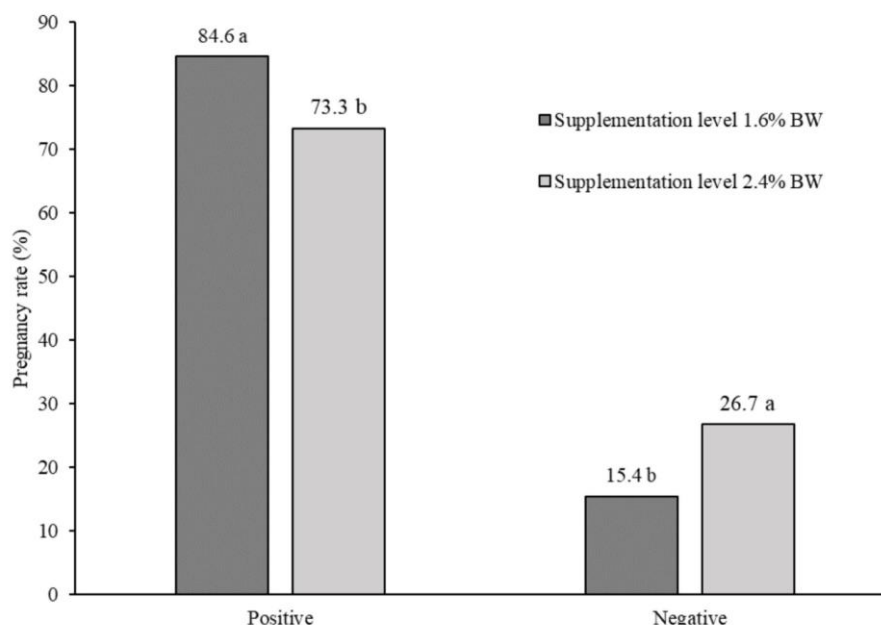


Figure 2. Ewes pregnant (positive) and ewes non-pregnant (negative) submitted and different levels of supplementation maintained in *Brachiaria* grass. Pregnancy rate (pregnant ewes in breeding/pregnant ewes*100).

DISCUSSION

The level of protein-energy-mineral supplementation influenced the ADG and TWG of the lambs. The lambs supplemented with 2.4% BW were significantly heavier at the end of the breeding season (5.5kg) than those treated with 1.6% BW, this fact is related to the difference observed in TWG and ADG during the growing period. The best performance of the animals supplemented with 2.4% BW at the end of the breeding season provides positive ADG and TWG, while lambs that received 1.6% BW showed negative ADG and TWG. The results found in this study are similar to those reported by Heimbach *et al.*, 2020, which verified variations in birth weight at weaning of 6.37kg in multiparous ewes that received protein supplementation energy of 0.8% of BW in pastures of *Brachiaria brizantha* cv. Marandu.

Supplementation with 2.4% BW resulted in greater weight gain throughout the experimental period. According to Souza *et al.* (2014), the objective of analyzing weight gain is to test whether different nutritional treatments provided different since the main cause of reproductive

differences due to nutrition is related to weight loss or gain.

In this case, it is possible to affirm that the supplementation of 2.4% of BW is efficient from the productive point of view, in comparison with lower levels of supplementation, especially because lambs are in the category of best feed conversion and can express all their genetic capacity and reproductive potential, provided their nutritional needs are met (Kenyon *et al.*, 2014). The nutritional level of sheep should be efficient for body development and for them to be introduced in the reproductive season still at puberty (Arco *et al.*, 2021).

However, the heaviest animals are necessarily those in better nutritional condition (D'Occhio *et al.*, 2019), which can be verified in this study, since most of the lambs supplemented with 1.6% BW had BCS between 2 and 3, while most of the lambs supplemented with 2.4% PV showed BCS between 1 and 2 in the growing season. Thus, the BCS evaluation is more adequate to estimate the fluctuations of body reserves, since it is a technique that uses a subjective measure of the amount of muscle and adipose tissue stored by

the body of the animal at a given time of the reproductive period - productive (Russel *et al.*, 1969). Considering that the variation of body weight is due to water and food intake in the gastrointestinal tract and mainly due to the growth of females in the development phase before reaching sexual maturity (D'Occhio *et al.*, 2019).

Arco *et al.* (2021), evaluating Texel lambs, with a mean age of 5 months, which were distributed in two nutritional treatments (energy protein supplementation at the levels of 1.6 and 2.4% BW) verified the same results for total weight gain (TWG) and average daily gain (ADG). However, unlike the results obtained in the present study, the mean body condition scores were similar among the animals during the experiment.

Probably this difference was due to the process of allometric growth of animals, which is due to changes in the functional capacity of various organs and the tissue of the animal, which occur from conception to maturity (Pena-Bermudez *et al.*, 2020). The speed and intensity of these changes depend on nutrition, body weight, race and their interactions. Similarly, the values related to the proportion of fat and protein per unit of gain in the body may vary depending on breed, sex, age of the animal and rate of gain or weight loss (Souza *et al.*, 2020). Thus, when performing BCS in young animals should consider changes in the energy cost of fat and protein deposition, and in the deposition rates of these tissues (Resende *et al.*, 2008).

In general, there was no difference between the treatments studied for BCS of the lambs during the reproductive season. Since, in both treatments, the ewes presented BCS 3. In this period of body development, the BCS values show a relationship between the average weights of the animals. At this stage, the skeleton is fully developed and with BCS of 2.8 to 3.0 for sheep, estimated on a scale of 1 to 5. It should be considered that at this stage of development sheep should have 25% body fat (Nutrient..., 2007; Resende *et al.*, 2008).

The evaluation of the loin eye area represents the amount and distribution of muscle mass in the carcass. Late maturity muscles reliably represent muscle tissue development and size (Pena-

Bermudez *et al.*, 2022). In this study the LEA was not influenced by nutritional treatments, with an average of 15.5 mm in the growing season and 16.4 mm in the breeding season. The values found for the present study are within the values considered ideal by the literature, ranging from 14.7 cm to 19.25 cm for lambs up to 12 months kept in feedlot (Rezende *et al.*, 2017; Itavo *et al.*, 2019; Silva *et al.*, 2020; Rodrigues *et al.*, 2022). However, these values are higher than those found by Silva *et al.* (2020), who observed mean values of 11.73 cm of LEA for lambs up to 6 months of age, kept in *Brachiaria* pastures brizantha, in conditions similar to those of the present study.

As the protein-energy supplementation reflected on body weight, the same was verified for the measurements of the SFT, a greater nutritional contribution had as consequence a greater deposition of muscles in the carcass of the lambs, i.e., lambs supplemented with 2.4% BW at the end of the growing season showed higher SGE values than ewes supplemented with 1.6% BW. According to Fernandes Junior *et al.*, (2021) the SFT values are higher as the live weight of the animals increases. These same authors concluded that the desired fat thickness in sheep during the growth phase varies from 0.3 to 6 mm, values close to those found in this study.

Thus, the monitoring of in vivo characteristics, such as LEA and SFT performed in the longissimus dorsi muscle between the 12th and 13th rib, assists in the choice of animals for slaughter and provides useful information for incorporation in growth models, since these measures make it possible to monitor changes in the tissues of the animal carcass (Pinheiro *et al.*, 2014). The deposition and mobilization observed in the body tissues (fat and muscle) in the periods of growth and reproductive are known and followed the variations of weight of the animals and demonstrated that the sheep were in good feeding conditions and did not present health complications during the experimental period.

It is known that increased nutrition and live weight gain during the mating period increases the ovulation rate of adult sheep and fertility and reproductive rate of lambs (Thompson *et al.*, 2021). However, it is accepted that the reproductive performance of lambs is

consistently lower than that of 2-year-old and mature sheep, since in lambs that had their first mating at 7-9 months of age, the percentage of births can vary between 47% and 82% compared to 85%-97% in mature multiparous ewes (Corner-Thomas *et al.*, 2015). In our study the pregnancy rate was higher in lambs that were supplemented with 1.6% of BW (about 84.6%) compared to those that were supplemented with 2.4% of BW (73.3%).

In this sense, the reserve of muscle and adipose tissue at a certain point in the reproductive-productive cycle was significantly related to zootechnical indicators, such as fertility (Carvalho *et al.*, 2016). And the increase in the level of protein-energy supplementation did not increase the fertility rate of sheep. Corroborating the findings of this study, Campos *et al.* (2022) observed that ewes supplemented with 0.4% of BW had a higher fertility rate at birth when compared to the higher supplementation level of 0.8% of BW. These authors justified this response by higher embryofetal survival, which was confirmed by zero mortality of lambs from sheep that received supplementation with 0.4% of BW.

The increase in the level of supplementation of the lambs did not affect the measures of the reproductive organs. Similarly, in the research conducted Arco *et al.* (2021), which did not observe changes in the development of reproductive organs when there was a greater nutritional contribution to the supplementation of lambs. Our mean values of measurements of ovary and uterus are similar to those observed by Arco *et al.* (2021) using primiparous lambs at 8 months of age. Decisions on the age of the first mating in lambs are based on the growth rate of the first year (González-García and Hazard, 2016). The variation in the size of the ovary and uterus, weight of the lambs during the breeding season can be influenced mainly by the age and number of births of females (Kenyon *et al.*, 2014).

The estimated intake of pasture (leaves) was similar between treatments and correlated with the increase in sheep weight, demonstrating that the variations observed in this study are related to the protein-energy increase (250.8g/kg CP and 842.7g/kg/kg). kg TDN per DM) offered to sheep via supplementation. The Braquiaria

brizantha cv. Marandu is a grass adapted to the adversities of the tropical climate and low fertility soils of the Brazilian Cerrado region (Antunes *et al.*, 2021). However, these forage adaptations affect their morphology and nutritional composition, to the detriment of the nutritional requirements of the animals. In the case of lambs, the nutrients ingested and absorbed are directed to the maintenance of body protein, growth and reproduction (Sphor *et al.*, 2021), but the consumption of pasture alone does not meet the nutritional requirements of this category.

In our study, the pasture presented morphological characteristics considered critical, such as the percentage of leaves, with an average of 21.28% in the periods of growth and reproduction. According to Fontes *et al.* (2014), these values characterize a low-quality forage, especially for sheep, which are selective animals when compared to cattle. Therefore, this low percentage of leaves in the forage canopy contributed to the selection of components of lower nutritional value.

In addition to morphological characteristics, another aggravating factor is related to the nutritional value of the leaves. At the times of growth and reproduction, the means of CP and TDN were 569.59g/kg DM and 524.11 g/kg DM, values that justify the protein supplementation nutritional requirements of lambs that are in the growth and development phase of the reproductive cycle (Arco *et al.*, 2021; Silva *et al.*, 2022; Ferelli *et al.*, 2023). In addition, the grasses of the present study presented a mean of NDF of 681.58 g/kg DM, a characteristic strictly linked to voluntary intake, since high concentrations of NDF lead to a slow rate of passage in the gastrointestinal tract and low fiber degradation, filling and consequently lower nutrient intake (Euclides *et al.*, 2018). In this case, protein-energy supplementation is an alternative to meet the nutritional requirements of lambs and to enhance the available forage resources (Melo *et al.*, 2019).

In contrast, the increased supply of protein-energy supplementation did not increase the fertility rate of sheep. In addition, the productive cost of treatment with 2.4% BW was higher than the treatment 1.6% BW, generating a difference with nutritional inputs in the margin of US\$

1,265.37, which comparatively impacted negatively on the economic-financial indexes, with this. Despite the higher weight gain of the lambs in the treatment of 2.4% BW, the cost of treatment supplementation was not exceeded. In this case, in addition to observing increased spending on supplementation in treatment 2.4% BW, we can say that the deposition of muscle and adipose tissue associated with weight gain of these sheep increased energy expenditure. With the increase in protein-energy food intake, there is an increase in metabolic rate and consequent increase in maintenance needs (Nutrient..., 2007). Morais *et al.* (2016) observed that there was an increase in the efficiency of energy use for gain with increased levels of supplementation in the diet of lambs kept in feedlot but observed lower efficiency of energy use for maintenance with higher levels of supplementation.

The effects observed in this study were determined by the nutritional requirements of the animals and the quality of the pasture. It was expected that the inclusion of the supplement in the diet could reduce the consumption of pasture, characterizing a substitutive effect by increasing the level of supplementation. But it was observed that the consumption of pasture was not altered by the level of supplementation, but by the live weight of the sheep. It was found that the additive effect occurred, with total consumption (pasture + supplement) at different levels of supplementation. In this case, pasture consumption was not significantly reduced between treatments, since voluntary consumption is already low under these conditions (Melo *et al.*, 2019). Silva *et al.* (2022) observed through ingestive behavior that lambs in growth phase and kept in pastures of *Brachiaria* spp. showed no difference in grazing time (hours), with different levels of protein-energy supplementation.

CONCLUSION

Under grazing conditions on grasses formed by Marandu grass, protein-energy supplementation proved to be efficient for lambs in the growing and reproductive seasons. We recommend supplementing 1.6% BW for ewes to achieve optimal gains, body scores, and fertility rate for the first mating in a 45-day breeding season.

ACKNOWLEDGMENTS

The authors are grateful to the Universidade Federal de Mato Grosso do Sul, the Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia de Mato Grosso do Sul (FUNDECT), the Coordenação de aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES), Financial Code 001 and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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