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Effect of supplementation of ewes in the final third of gestation on the development of their lambs

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ABSTRACT - This study examined the effect of different supplementation strategies for ewes in the last third of gestation, kept on a deferred *Brachiaria brizantha* cv. Marandu pasture, on their performance and the growth curve of their lambs. A total of 54 ewes, of no defined breed, with an average weight of 41.10±3.10 kg, were used in a completely randomized design, divided into three groups (18 ewes per treatment). In total, 61 lambs were born, 28 females and 33 males, with 3.70±0.55 and 3.68±0.69 kg birth weight, respectively. Treatments were as follows: multiple mixture *ad libitum*, concentrate supplement at 0.4% live weight (LW), and concentrate supplement at 0.8% LW. Average daily weight gain (ADG, g/animal/day) and total weight gain (TWG, kg/animal) were evaluated in ewes and lambs. Reproductive efficiency indices were measured in the ewes and biometric variables in the lambs. The ADG and TWG of ewes in the last third of gestation were higher in animals supplemented at 0.8% LW. Reproductive efficiency results were superior in ewes supplemented at 0.4% LW. The effect of ewe supplementation on lamb growth curve as estimated by the Gompertz model did not reveal differences between the curves of lambs born to ewes that received supplementation at 0.4 and 0.8% LW. However, supplementing ewes with a multiple mixture induced a reduction in the growth curve parameters of their lambs. The use of concentrated supplementation, at levels of 0.4 and 0.8% of LW, provides greater productive and reproductive performance for ewes and lambs.

Keywords: body biometrics, *Brachiaria*, reproductive efficiency, weight gain

1. Introduction

Despite the environmental adversities encountered in the Brazilian semiarid, the sheep farming activity in that region is associated with the economy and social development (Araújo et al., 2019; Silva et al., 2021). Thus, it is essential to implement pasture management techniques that are able to minimize the adverse effects of drought on pasture-based animal production.

The control of efficiency in the supply of concentrate supplementation lies in the availability and structure of the pasture and in the type and amount of supplement to be offered to the animal

(Vedovatto et al., 2019; Silva et al., 2022) so that weight gain and productive and reproductive performance can be enhanced.

Inadequate nutrition of the ewe, especially in the last third of gestation, is associated with a reduction in lamb birth weight and development, low vigor, and high neonatal mortality (Fraga et al., 2018; Gurgel et al., 2020; Arco et al., 2021). Moreover, ewes need a greater nutrient supply in a smaller volume of feed due to the reduction in abdominal space while pregnant. Dietary adjustments through the use of concentrate supplementation can mitigate this limitation. In addition, it can allow greater postnatal body weight recovery and a shorter lambing interval, increasing the chances of an earlier breeding season (Araújo et al., 2019; Arco et al., 2021).

Given the above-described facts, understanding the impacts of nutrition on the performance of ewes and lambs can help define more efficient feeding management practices on pasture. Our hypothesis is that concentrate supplementation in the last third of gestation would improve ewe and lamb performance. Therefore, the objective of this study was to examine the effect of different supplementation strategies for ewes in the last third of gestation, kept on deferred *Brachiaria brizantha* cv. Marandu pastures, on the productive and reproductive performance of dams and the vigor of lambs at birth.

2. Material and Methods

2.1. Ethics committee

All procedures were reviewed and approved by the Ethics Committee on the Use of Animals for Research (CEUA) (approval no. 053/2015).

2.2. Experimental site and period

The experiment was conducted in an experimental area of forage in Macaíba, RN, Brazil (5°53'34" S, 35°21'50" W, 11 m asl), from December 2015 to June 2016.

According to the Köppen classification, the climate in the region is a BSh'W type, i.e., dry and hot semiarid. Monthly precipitation was measured daily by a rain gauge that was installed in the experimental area (Figure 1). Temperature data were obtained from the INMET (National Institute of Metereology) platform.

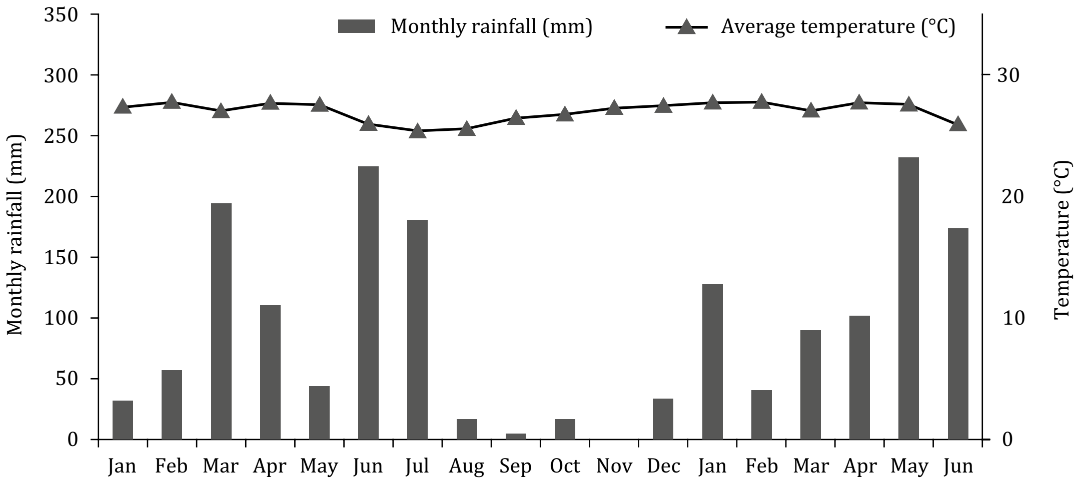

Figure 1 - Average monthly precipitation and average temperature in the period from January 2015 to June 2016.

2.3. Experimental design

The experiment was laid out in a completely randomized design with three treatments and eighteen replicates (animal units). Treatments were as follows: multiple mixture *ad libitum*, concentrate supplement at 0.4% live weight (LW), and concentrate supplement at 0.8% LW.

The experimental area was 5.1 ha (50,103 m^2), which was covered with *Brachiaria brizantha* cv. Marandu. The pasture was closed in July 2015 and used from October of the same year until June 2016. Continuous grazing was performed with a variable stocking rate. Variable stocking was carried out through the use of regulator animals that were kept out of the experiment and used whenever there was a need to adjust the stocking rate to maintain the height goals of the pasture. The pasture was sampled every 28 days to estimate the forage mass and percentages of the morphological constituents (Table 1).

The collections to determine forage mass and morphological components were collected every 28 days. Forage mass was estimated by cutting, at ground level, samples of four squares (1 m × 1 m) per paddock (Davies et al., 1993). Cutting was performed with a manual cutter. Samples were divided into two: one of the subsamples was weighed and dried in an oven at 65 °C until constant weight, and the other separated into leaf (leaf blade), stem (sheath and stem), and dead material. The proportion of each component was expressed as a percentage of total weight (Davies et al., 1993).

Afterwards, the dry samples were ground in 1-mm sieves for further chemical analysis according to the AOAC methodology (AOAC, 1990) for the determination of dry matter (DM), ash (MM), crude protein (CP), and ether extract (EE); neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the procedures described by Mertens (2002). Total digestible nutrients (TDN) were estimated using the equation: TDN g/kg DM = 105.2 − 0.68 × (FDN g/kg DM), proposed by Chandler (1990). For the estimation of non-fibrous carbohydrates (NFC), the following equations proposed by Sniffen et al. (1992): NFC (%) = 100 – (NDF + CP + EE + MM).

The sheep remained on pasture from 07:00 to 16:00 h, where they had free access to water. Supplementation was calculated for category requirement (NRC, 2007) and was provided after 16:00 h. The supplements were administered from the last third of gestation until weaning and adjusted according to the weight of the animals, which was measured every two weeks (Table 2).

2.4. Animals

Fifty-four ewes, with no defined breed pattern, with an average weight of 41.10 kg, at 120 days of gestation, were used in the experiment. The breeding season was 45 days; the herd of breeders was divided into two groups, for a male:female ratio of 1:27. The lambing period was from January 30 to March 20, 2016. A total of 61 lambs were born: 21 (3.41±0.59 kg birth weight) lambs from the multiple mix treatment, 18 (3.99±0.50 kg birth weight) lambs from the 0.4% supplementation treatment, and 22 (3.40±0.65 kg birth weight) lambs from the 0.8% treatment were born of supplementation. In total, 47 (3.06±0.64 kg birth weight) lambs from single births and 14 (3.90±0.48 kg birth weight) from twins. Furthermore, 28 females and 33 males were born, with birth weight of 3.70±0.55 and 3.68±0.69, respectively.

Table 1 - Mean values of forage mass and percentage of structural components of *Brachiaria brizantha* cv. Marandu during the experimental period

Variable	Oct	Nov	Dec	Jan	Feb	Apr
Forage mass (kg ha^{-1})	8382.9	6466.2	4925.7	5724.8	5425.2	8448.6
Leaf blade (%)	17.7	6.3	10.7	0.0	7.6	24.6
Stem (%)	40.6	43.0	22.3	5.3	9.4	36.1
Dead material (%)	41.7	50.7	69.0	94.7	83.0	39.3

Table 2 - Centesimal and chemical composition of deferred marandu grass pasture and supplements for ewes in the last third of gestation

	Ingredient (% of the mixture on a dry-matter basis)				
	Ground maize	Soybean meal	NaCl	Urea	Soybean oil
Ewe concentrate	80.5	14.6	1.2	3.7	-
Lamb concentrate	66.0	29.5	3.0	-	1.5
Multiple mixture	40.0	30.0	20.0	10.0	-
Variable	Chemical composition				
	Marandu grass	Massai grass	Ewe concentrate	Lamb concentrate	Multiple mixture
Dry matter[1]	50.05	-	88.51	88.61	91.32
Mineral matter[2]	4.89	7.20	3.38	5.8	2.15
Ether extract[2]	3.04	-	3.50	4.68	2.16
Crude protein[2]	2.41	6.40	24.84	20.35	46.46
Lignin[2]	6.07	58.60	1.18	1.25	0.95
Neutral detergent fiber[2]	76.31	27.80	13.15	13.45	10.01
Acid detergent fiber[2]	43.64	4.30	4.33	5.08	4.14
Non-fibrous carbohydrates[2]	14.64	26.05	61.84	55.59	37.07
Total digestible nutrients[2]	54.31	58.83	80.76	83.39	58.44

[1] g/100 g fresh matter.
[2] g/100 g dry matter.

For seven days after lambing, ewes and lambs were kept in a nursery paddock of *Panicum maximum* cv. Massai. After these seven days, the lambs had contact with their mothers from 17:00 to 07:00 h. The ewes were then returned to the deferred *Brachiaria brizantha* cv. Marandu pastures, whereas the lambs remained on the *Panicum maximum* cv. Massai pasture. Both received concentrate supplementation calculated to meet the requirements for the different phases, following the recommendations of the NRC (2007). Weaning took place at 90 days of age.

2.5. Evaluation of ewes

For the performance evaluations, ewes were weighed every two weeks. Before all weighing, the animals were subjected to solid fasting for 16 h. Average daily weight gain (ADG, g/animal/day) was calculated as the difference in animal weight between the weighing sessions divided by the number of days between each session. Total weight gain (TWG, kg/animal) was determined by adding all the weight gains until the weaning day.

The total number of lambs born, including simple and twin births, was recorded. Reproductive efficiency indices were measured from the following variables: reproduction rate, fertility rate at lambing, prolificacy, lamb mortality rate, and weaning rate. These were calculated as follows: reproduction rate = number of lambs weaned/number of ewes exposed to the sire × 100; fertility rate at lambing = number of lambed ewes/number of ewes exposed to the sire × 100; prolificacy = total number of lambs born/total number of lambed ewes in each group; lamb mortality rate = number of dead lambs/number of lambs born × 100; weaning rate = number of lambs weaned/number of ewes serviced × 100 (Simplício, 2006).

2.6. Evaluation of lambs

Lamb weight was monitored throughout the pre-weaning phase (from 7 to 91 days of age) by weighing the animals weekly on a sheep scale (BL300pro LABOREMUS©) with a capacity of 300 kg. In addition, biometric measurements were performed using an adapted ruler and a flexible measuring tape, following the methodology described by Cezar and Souza (2007). The evaluated measurements were body length (distance between the cervical-thoracic joint and the base of the tail at the first intercoccygeal joint) and withers height (distance between the withers and the distal end of the forelimb).

Lamb weight and biometric measurement data were adjusted using the Gompertz nonlinear model $P(t) = A\exp(-B\exp(-kt))$, to draw the lamb growth curve. The parameters of the Gompertz model can be interpreted biologically as follows: P(t) is weight at age t; parameter A is the asymptotic weight when it tends to infinity; the B value is established by the initial values of P and t; and K represents the change in body weight relative to body weight at maturity, an indicator of the rate at which the animal approaches its adult body weight.

Absolute growth rate (AGR) was estimated based on the model fitted as a function of time ($\partial P/\partial t$) to describe the growth rate of the animals. This variable corresponds to the average daily body weight gain estimated along the growth curve (Sousa et al., 2021).

2.7. Statistical analysis

The variables reproduction rate, fertility rate at calving, prolificacy, lamb mortality rate, and weaning rate were subjected to the chi-square test at 5% significance. The other data were subjected to analysis of variance, and given the physiological impossibility of controlling the type of birth and sex of the lambs, it was not possible to decompose the sources of variation due to the absence of repetition in all combinations of interactions. The means referring to the isolated effect of sex were compared by Fisher's test, whereas the effects of supplements were compared by Tukey's test. Statistical procedures were performed using the MIXED procedure of SAS (Statistical Analysis System, version 9.4).

The following model was used for the ewe-related variables:

$$Y_{ijk} = \mu + S_i + \alpha_{ij} + T_k + TS_{ik} + \beta_{ijk},$$

in which Y_{ij} = value observed with supplement i in replicate j, μ = overall constant (population mean), S_i = effect of supplement i (i = 1, 2, 3), α_{ij} = random error associated with each observation Y_{ij}, T_k = effect of lambing type k (k = 1, 2), TS_{ik} = interaction effect between supplement i and sex k, and β_{ijk} = random error associated with each observation Y_{ijk}.

The Gompertz model parameters were estimated using the modified Gauss Newton method by the NLIN procedure of SAS. The maximum number of iterations used was 100. Then, the effect of ewe diet and lamb sex on the lamb growth curve was evaluated using a dummy variable (Regazzi, 2003). The significance level of 5% was adopted for all statistical analyses.

3. Results

3.1. Ewe performance

The highest ADG of the ewes was observed in the last third of gestation ($P<0.05$), and those supplemented at 0.8% LW had the lowest weight loss (Table 3).

Reproduction rate was higher in the ewes supplemented with concentrate at the levels of 0.4 and 0.8% LW than those supplemented with multiple mixture ($P<0.05$). Ewes supplemented at 0.4% LW showed a higher fertility rate at lambing ($P<0.05$). Regardless of the type and amount of supplement provided, fertility rates were above 85% (Table 4).

There was no effect ($P>0.05$) of type of supplementation on prolificacy rate. There was no mortality among lambs born from ewes supplemented with 0.4% of LW, and the highest mortality rate was found in lambs from ewes supplemented with multiple mixture and 0.8% of LW ($P<0.05$). Females supplemented with 0.4% LW concentrate that conceived were able to wean all their lambs. Ewes supplemented with multiple mixture had the lowest number ($P<0.05$) of lambs weaned compared to those supplemented with concentrate at 0.4 and 0.8% BW (Table 4).

Table 3 - Average daily weight gain (ADG) and total weight gain (TWG) of ewes from the last third of gestation until weaning

	ADG (kg/animal/day)			TWG (kg/animal)
	Pregnancy	Lambing	Weaning	
Multiple mixture	0.026b	−0.134a	−0.008a	−4.775b
0.4%	0.045b	−0.176a	0.006a	−4.517b
0.8%	0.079a	−0.174a	−0.009a	−1.188a
P-value	0.0021	0.2370	0.0043	0.0061

Values followed by different letters in the column differ from each other (P<0.05) by Tukey's test.

Table 4 - Reproductive efficiency indices of ewes supplemented on deferred marandu grass pasture

Variable (%)	Supplementation			P-value
	Multiple mixture	0.4%	0.8%	
Reproduction rate	76.2b	90.0a	90.5a	0.0011
Fertility rate at lambing	85.7b	90.0a	85.7b	0.0042
Prolificacy	1.2a	1.0a	1.2a	0.7813
Lamb mortality rate	23.8a	0.0b	13.6a	0.6314
Weaning rate	88.9b	100.0a	105.6a	0.0016

Values followed by different letters in the row differ from each other (P<0.05) by Chi-Square test.

3.2. Lamb performance

The effect of ewe supplementation on lamb growth curve, as estimated by the Gompertz model, did not reveal differences (P>0.05) between the curves of lambs born to ewes that received supplementation at 0.4 or 0.8% LW (Table 5 and Figure 2). However, supplementing ewes with multiple mixtures generated a different (P<0.05) growth curve for lambs (Table 5 and Figure 2).

Table 5 - Mean estimates of the growth curve parameters of lambs from ewes supplemented on deferred marandu grass pasture

	A±SE	B±SE	K±SE	P-value	R^2
Weight					
Multiple mixture[1]	20.37±3.25	1.76±0.12	0.02±0.00		0.95
0.4%	26.33±3.02	1.79±0.09	0.02±0.00	<0.0001	0.97
0.8%	30.84±5.52	2.09±0.13	0.02±0.00		0.95
Absolute growth rate					
Multiple mixture[1]	0.10±0.02	−0.71±0.37	0.05±0.03		0.45
0.4%	0.15±0.01	−0.49±0.37	0.06±0.04	0.0023	0.62
0.8%	0.16±0.00	−0.46±0.46	0.14±0.02		0.76
Body length					
Multiple mixture[1]	48.12±4.24	0.51±0.10	0.023±0.01		0.99
0.4%	61.69±24.04	0.61±0.30	0.010±0.00	<0.0001	0.99
0.8%	56.80±11.87	0.58±0.09	0.016±0.00		0.99
Withers height					
Multiple mixture[1]	49.64±3.95	0.44±0.09	0.02±0.01		0.99
0.4%	55.81±6.66	0.47±0.05	0.02±0.01	<0.0001	0.99
0.8%	53.04±3.62	0.51±0.09	0.03±0.01		0.99

A is the asymptotic weight when it tends to infinity; the B value is established by the initial values for weight and age; K represents the change in body weight in relation to body weight at maturity; SE - standard error; R^2 - coefficient of determination.
[1] Growth curve of lambs from ewes supplemented with multiple mixture differed significantly (P<0.05).

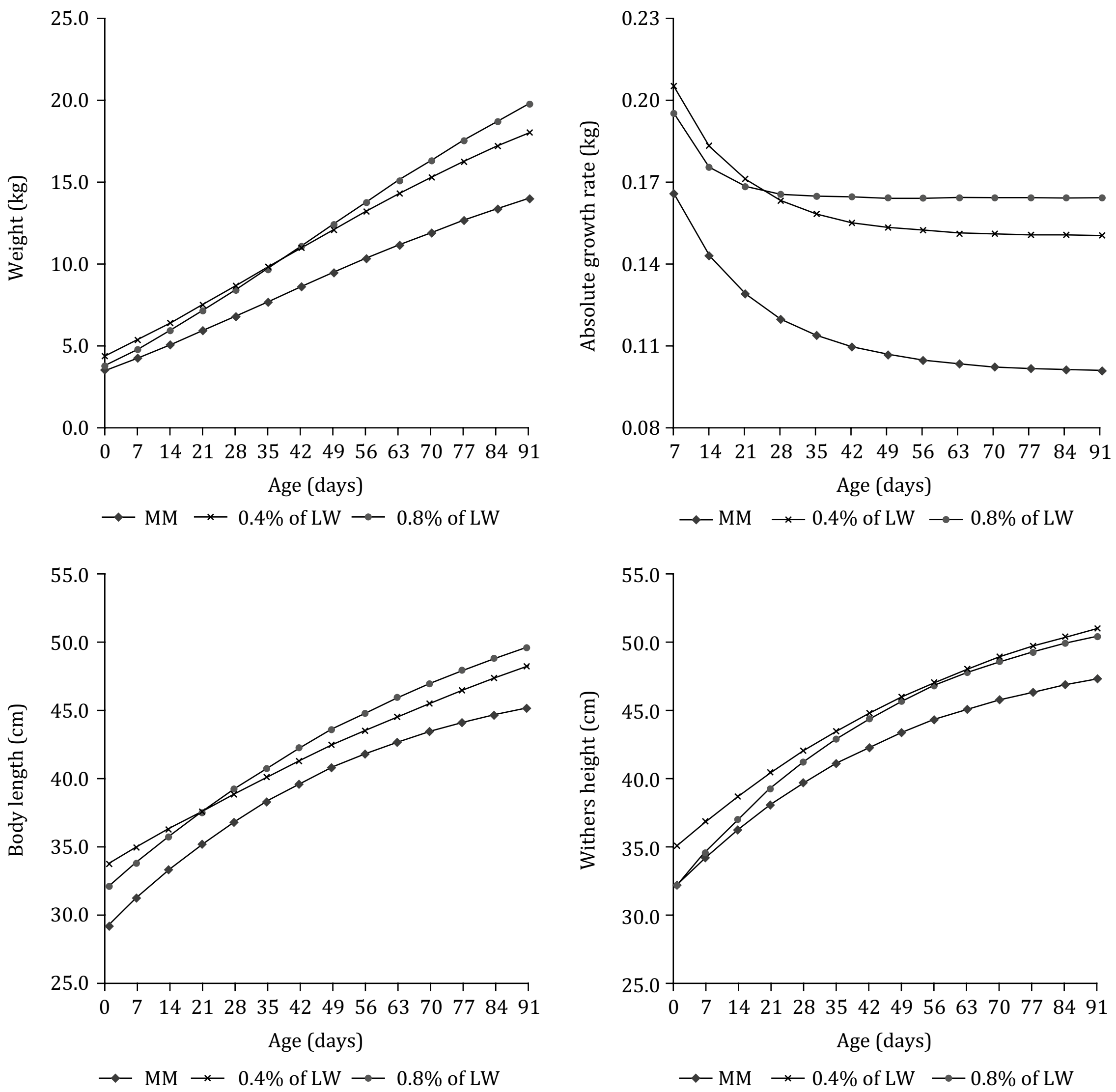

Figure 2 - Growth curves, estimated by the Gompertz model, of lambs born to ewes supplemented on deferred marandu grass pasture.

Weight, absolute growth rate, body length, and withers height at maturity (parameter A) of lambs born to ewes supplemented at 0.4 and 0.8% LW, as estimated by the Gompertz model, were higher than those estimated for lambs born to ewes that received multiple mixture ($P<0.05$). Likewise, the speed with which the animals approach their maturity weight (parameter B) revealed that these lambs showed higher AGR.

Male and female lambs had similar weights up to 50 days (Table 6). From that age, the males became slightly heavier. Thus, the estimated weight at maturity was higher in the males (Table 6). The Gompertz model showed that there was no inflection point for AGR, and this variable decreased for both males and females (Figure 3).

4. Discussion

4.1. Ewe performance

During pregnancy, the ewes that exhibited the highest ADG and TWG were those that received supplementation at 0.8% LW. Weight gain is affected by the energy requirement for maintenance, feed intake, energy and protein utilization efficiency, and physiological status (González-García et al., 2014).

Table 6 - Mean estimates of the growth curve parameters of lambs from ewes supplemented on deferred marandu grass pasture according to sex[1]

	A±SE	B±SE	K±SE	P-value	R^2
Weight					
Males	29.43±5.08	2.02±0.13	0.015±0.003	0.0004	0.94
Females	23.63±2.78	1.81±0.09	0.017±0.003		0.96
Absolute growth rate					
Males	0.15±0.009	−0.63±0.50	0.10±0.09	0.2559	0.99
Females	0.13±0.01	−0.42±0.25	0.05±0.03		0.99
Body length					
Males	62.87±29.87	0.61±0.39	0.009±0.001	0.1366	0.99
Females	51.98±5.12	0.58±0.06	0.02±0.01		0.99
Withers height					
Males	55.46±7.09	0.45±0.05	0.017±0.012	0.0125	0.99
Females	51.56±2.98	0.51±0.08	0.024±0.011		0.99

A is the asymptotic weight when it tends to infinity; the B value is established by the initial values for weight and age; K represents the change in body weight in relation to body weight at maturity; SE - standard error; R^2 - coefficient of determination.
[1] Values followed by different letters in the row differ from each other (P<0.05) regarding the effect of birth types and sex by Fisher's test.

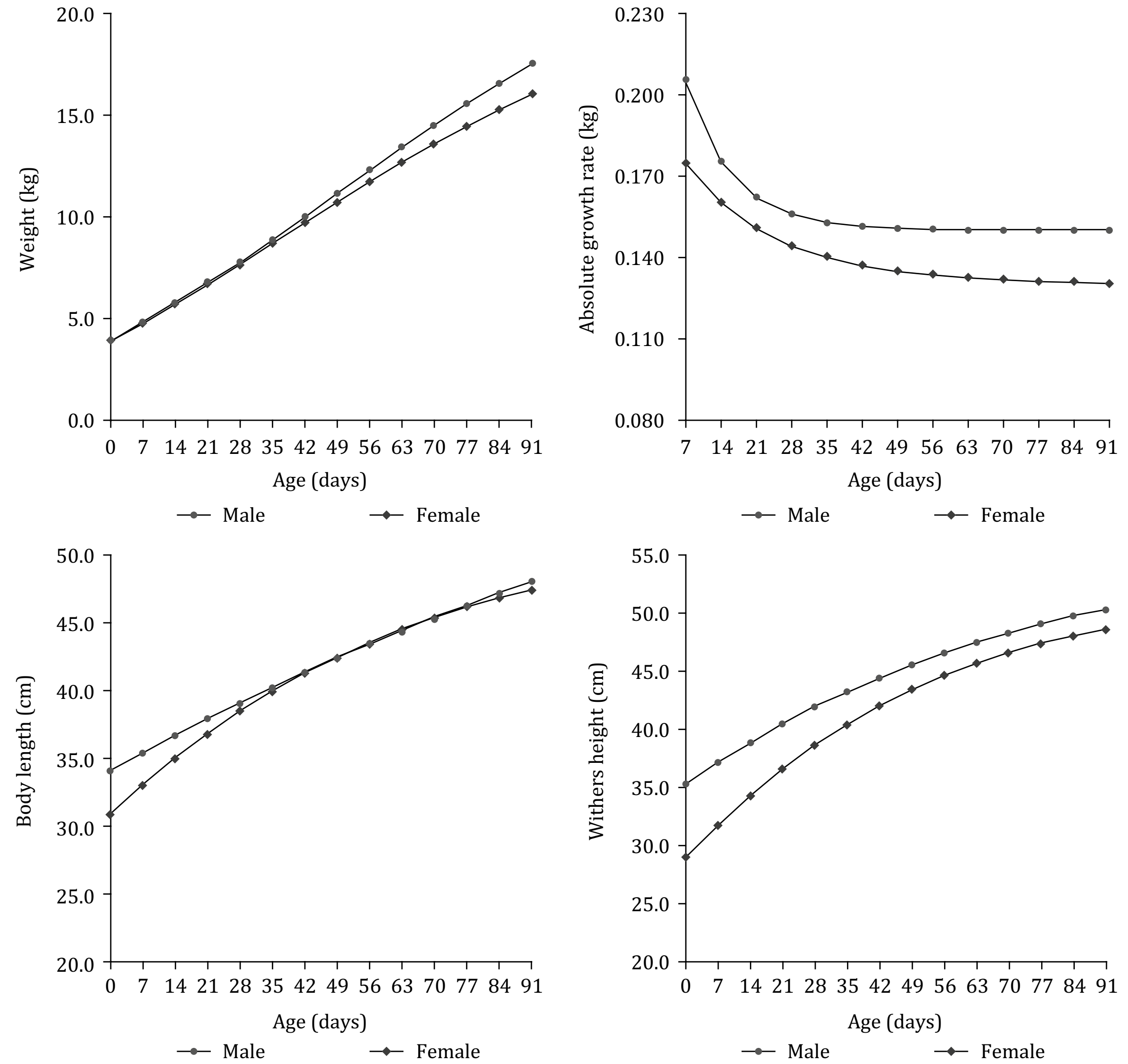

Figure 3 - Growth curves, as estimated by the Gompertz model, of lambs born to ewes supplemented on deferred marandu grass pasture according to sex.

Ewes that received a larger amount of supplement during pregnancy gained more weight, which was likely due to a higher nutrient intake (Pedernera et al., 2018). In addition, the increase in LW that occurs during the last third of gestation is generally related to the increase in weight of the fetus, while there is an accelerated breakdown of previously accumulated fat deposits to support adequate fetal development (Sales et al., 2018).

In the lambing and weaning phases, there were no significant differences in body weight between the ewes. Body weight losses in these cases result from a negative energy balance, that is, the energy requirement increases faster than the intake of DM, and the animals use their body reserves for milk production, mobilizing the adipose and muscle tissues. This is a critical phase, as it can negatively affect milk production, lamb growth, and the subsequent reproductive performance (Torreão et al., 2014).

Concentrated supplementation, due to higher energy levels in the diet, has been shown to have positive effects on reproductive performance, especially on fertility, ovarian development, and pregnancy-related hormone production (Habibizad et al., 2015; Khlil et al., 2017). In the present study, supplementation at 0.4% LW provided the highest ewe fertility rate at lambing, likely due to the improvement in embryo-fetal survival (Chávez et al., 2015), which is confirmed by the zero mortality of lambs from ewes that received supplementation at this level.

In addition, all lambs born to ewes supplemented at 0.4% LW were born from single births and were consequently heavier, which provided a greater prospect of life in comparison with the lambs from twin births. Ewes supplemented at 0.8% LW and with multiple mixture showed higher prolificacy values, because these ewes had twin births and, thus, stood out numerically in number of lambs.

Ewes supplemented at 0.8% LW had more twin births than the group supplemented at 0.4% LW and, therefore, showed a higher lamb weaning rate. The lower weaning rate described in ewes supplemented with multiple mixtures may be related to a limited nutritional supply due to the lactation phase, and, consequently, a lower number of lambs weaned and higher lamb mortality.

4.2. Lamb performance

The lamb growth curve was adjusted using the Gompertz model. This model is part of a group of non-linear models that have long been employed to describe the growth of living beings (Fernandes et al., 2012) and is one of the most used to describe the growth curve of small ruminants (Sarmento et al., 2006; Sousa et al., 2021). Lewis et al. (2002) chose the Gompertz model to adjust the growth curve of Suffolk sheep, because, according to the authors, this model has desirable properties of a growth function. Sarmento et al. (2006) selected the Gompertz model due to its better goodness of fit among the different non-linear models studied by the authors.

Lambs born to ewes supplemented at 0.4 or 0.8% LW showed superiority in growth curve parameters. The weight and body condition of ewes are crucial to the development of the fetal skeletal muscle, since the number of muscle fibers does not increase after birth, and prenatal growth requires high availability of maternal nutrients (Zhu et al., 2006). Therefore, proper use of supplementation during the gestation period increases the weight of neonates and, consequently, the morphological structure of the muscle fibers, modulating the body development of lambs (Wang et al., 2019).

The superior biometric measurements in the lambs from ewes supplemented with concentrate highlight the importance of nutrition for fetal growth (Sales et al., 2018). Ewes supplemented at 0.4% LW gave birth to a single lamb, which consequently had greater fetal growth as compared with the twins. Factors involved in fetal nutrition, especially in ewes with twin births, are potential targets for intervention strategies to improve the productive and reproductive potential of the animal, mainly in challenging environments.

Absolute growth rate did not show an inflection point, regardless of ewe supplementation or lamb sex, suggesting that the maximum growth rate was reached very early. In studies in which LW is monitored to adulthood, AGR decreases until the values approach zero, when asymptotic weight is reached (Silva et al., 2011; Sousa et al., 2021). Therefore, AGR allows identifying the ideal age for slaughter, since, after asymptomatic weight is reached, there is a reduction in feed conversion (Silva et al., 2011). Studies have shown that AGR increases from birth to maximum growth, declining thereafter (Sarmento et al., 2006; Sousa 2021).

Lambs of both sexes followed a similar growth pattern until 50 days of age, which diverged around 90 days. This indicates sexual dimorphism, in which faster growth is inversely related to sexual maturity, since late-puberty animals—such as the mixed-breed ewes used in this experiment—maintain longer periods of growth and weight gain (López et al., 2018; Pinheiro et al., 2020). Similar results (differences between the growth curves of different sexes) were also observed by Gurgel et al. (2021), who adjusted growth curves for Santa Inês sheep in the pre-weaning phase using a first-degree linear equation, and by Kopuzlu et al. (2014), who used a Brody model to adjust the growth curves of male and female sheep of wooled breeds.

Therefore, the results presented here confirm the hypothesis that concentrate supplementation in the last third of gestation improves ewe performance, changing the growth curve of their lambs.

5. Conclusions

The use of concentrated supplementation, at the levels of 0.4 and 0.8% of body weight, provides greater productive and reproductive performance for ewes and lambs. Ewes that receive supplementation levels of 0.4% LW have the highest fertility and embryo-fetal survival rates, managing to wean all lambs. Ewes that receive 0.8% LW show greater productive performance and birth of twin lambs.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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