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Effect of nutritional flushing on productive and reproductive efficiency in ewes

Efeito do flushing alimentar sobre a eficiência produtiva e reprodutiva em ovelhas

Gabriela Rodrigues de Paula*[1], Edson Luis de Azambuja Ribeiro[1], Sandra Maria Simonelli[1], Fernando Augusto Grandis[1], Bruna Silva Marestone[1], Fernado Luiz Massaro Junior[1], Thaís Campos de Freitas[1], Valter Harry Bumbieris Junior[1], Maria Teresa Rodrigues de Souza[1]

1 Universidade Estadual de Londrina (UEL), Londrina, Paraná, Brazil

*corresponding author: gabrielarodrigues.p@uel.br

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Abstract: The study evaluated dietary flushing on reproductive efficiency in 60 Santa Ines ewes, divided into three groups: (1) no supplementation, (2) 0.50% and (3) 1.00% supplementation of body weight. The supplement contained corn, soybean meal, oats, lime, bicalcium phosphate, mineral mixture, urea and yeast, administered three weeks before and during mating, which lasted for 46 days. Weight, body condition and weight gain were measured at the beginning and end of the feeding period. Milk production, lamb weight and biometric measurements were recorded until weaning. Supplementation did not significantly affect the ewes' weight, body condition indices or milk production. The percentages of twin births were: 19%, 52.9% and 44.4% (P=0.08), respectively for the ewes in the control group and for those that received supplements (0.50% and 1.00%). Lamb weight and biometric measurements were not significantly affected by maternal treatment or the sex of the lamb. Lambs born from single births were heavier than those from twin births (P<0.05), but the combined weights of twins at weaning were higher. Ewes with twins tended (P<0.09) to be more efficient than those with single birth lambs, weaning 41 kg of lambs per 100 kg of ewe weight, compared to 36 kg for single birth ewes. Flushing did not affect ewe weight or milk production, but it did increase the rate of twin births, improving reproductive efficiency.

Key-words: production; prolificacy; reproduction; santa inês; sheep.

Resumo: Avaliou-se o flushing alimentar sobre a eficiência reprodutiva em 60 ovelhas Santa Inês, distribuídas em três grupos: (1) sem suplementação, (2) 0,50% e (3) 1,00% de suplementação do peso corporal. O suplemento continha milho, farelo de soja, aveia, calcário, fosfato bicálcico, mistura mineral, ureia e levedura, administrado três semanas antes e durante o acasalamento, que perdurou por 46 dias. Peso, condição corporal e ganho de peso foram medidos no início e no fim do período de alimentação. A produção de leite, o peso dos borregos e as medições biométricas foram registados até o desmame. A suplementação não afetou significativamente o peso das ovelhas, os índices de condição corporal ou produção de leite. As percentagens de nascimentos gemelares foram de 19%, 52,9% e 44,4% (P=0,08), respectivamente, para o grupo sem suplementação e para os grupos que receberam suplementos (0,50% e 1,00%). Durante a análise, constatou-se que o peso do cordeiro e as medidas biométricas não foram significativamente afetados pelo tratamento materno ou pelo sexo do cordeiro. Os borregos nascidos de partos simples eram mais pesados que os de partos gemelares (p<0,05), mas os pesos combinados dos gêmeos ao desmame eram mais elevados. As ovelhas com gêmeos tenderam (p<0,09) a ser mais eficientes do que aquelas com partos simples, desmamando 41 kg de cordeiros por 100 kg de peso corporal, em comparação com 36 kg nas ovelhas com nascimento único. Concluiu-se que o flushing não afetou o peso da ovelha nem a produção de leite, mas aumentou a taxa de nascimentos de gêmeos, melhorando a eficiência reprodutiva.

Palavras-chave: produção; prolificidade; reprodução; santa inês; ovinos.

1. Introduction

Nutritional management is the basis of the sector's profitability from a quantitative and economic point of view, as it represents between 60% and 85% of production costs[1]. The livestock sector has been undergoing a complex transformation, as the geographic distribution pattern of its production adapts to the rational use of natural resources and the production of highly nutritious and safe foods[2].

Animal production demands high nutritional and reproductive efficiency to ensure sustainability in production systems. In this sense, nutritional flushing is a technique used to increase[3]. It also aims to increase the reproductive efficiency of females, that is, to increase the supply of nutrients before the reproductive season to allow them to accumulate energy reserves, improving the quality of the embryos[4].

According to Jafari *et al.*[5], feed intake in the period before ewe mating should be increased to improve body condition and increase the ovulation rate. The nutritional flushing practice has been effective in improving reproductive performance in ewes of different breeds and production systems(6). Importantly, the nutritional status of the mother determines the vigor at birth and the development of lambs until weaning. Moreover, the birth weight of the offspring is mainly responsible for its survival capacity under adverse environmental conditions during this period[4].

However, there is still controversy regarding the effect of nutritional flushing on the productive and reproductive efficiency of ewes and lambs. Boucinhas, Siqueira & Maestá[7] concluded that the management system in which ewes are supplemented three weeks before and four weeks after the start of management for conception, three weeks before lambing, and during lactation positively influences weight, body condition, fertility, and prolificacy of ewes. In contrast, Cirne *et al.*[8] observed no significant interactions between feed supplementation before and during the breeding season on the variables body weight, average weight gain, and body condition score of Ile de France ewes.

Given the importance of nutrition before and during the breeding season, we hypothesize that the greater the supplementation during this phase, the better the reproductive results of the ewes will be. Therefore, this study aimed to assess the reproductive and productive performance of ewes receiving 0.50% and 1.00% of their body weight just before and during breeding.

2. Material and methods

The experiment was conducted on the school farm of the State University of Londrina, located in the municipality of Londrina, State of Paraná (23°20'10'' south latitude and 51°09'15'' west longitude), Brazil, at 610 meters above sea level. The mean annual ambient temperature is 20.6 °C, and the mean annual precipitation is 1,439.8 mm, with a maximum in January, reaching a mean of 201.4 mm, and a minimum in June, reaching a mean of 56.5 mm[9]. The experiment was approved by the Animal Use Ethics Committee (CEUA) under protocol No. 017.2021.

We used 60 Santa Inês ewes, which were kept on *Coast Cross* (*Cynodon dactylon* (L.) Pers) pasture during the day in an area of 5 hectares in which five paddocks were used with the rotational stocking grazing method. The experimental design was completely randomized with three treatments: treatment 1 (control) without supplementation (21 ewes), treatment 2 with supplementation of 0.50% of body weight at the beginning of supplementation (20 ewes), and treatment 3 with supplementation of 1.00% of body weight (19 ewes). The supplementation was based on a concentrate mix of corn (40%), soybean meal (10%), oat (45.6%), limestone (0.8%), dicalcium phosphate (0.4%), mineral mix (2%), urea (0.6%), and yeast (0.6%) supplied every day in the afternoon. The mineral mix contained both macro- and microminerals. The macrominerals were calcium, sulfur (20 g), phosphorus (65 g), magnesium (20 g), and sodium (170 g). The microminerals included cobalt (85 mg), fluorine (65 mg), iodine (54 mg), manganese (1,700 mg), selenium (25 mg), and zinc (3,400 mg).

The facilities consisted of a management pen, with semi-covered pens with concrete floors, collective feeding and drinking troughs, and paddocks equipped with drinking troughs. Supplementation was implemented three weeks before the breeding season and lasted until the third week after the start of the breeding season. All ewes received feed supplementation in the last month of gestation and throughout 75 days of lactation following the nutritional requirements recommended by NRC[10].

The reproductive period occurred from January 27th to March 13th, 2022, totaling 46 days. Natural mating was used, with rams of the same breed being released together with the ewes at night and mating occurring randomly. The animals were dewormed at the beginning of feed supplementation (BS) and later according to the animal's symptoms, using the Famacha© method. This method recommends deworming from grade 3 and with the egg count per gram of feces (EPG), obtained by examining feces using the technique by Gordon and Whitlock[11]. In this case, animals with moderate and massive infections were treated with an anthelmintic (Cydectin, Fort Dodge).

The ewes began to receive corn silage (250 g/head/day), supplied in feeding troughs in a management pen every day in the morning from April to November. From lambing, the ewes received around 250 g per head per day of the concentrate mix with corn silage. After birth, the lambs were identified and remained in confinement for 48 hours with their respective mothers, who received corn silage served ad libitum. Lambs were weaned at 75 days of age.

Chemical and bromatological analyses of the pasture, corn silage, and feed supplement were performed to measure the composition of dry matter (DM), crude protein (CP), ether extract (EE), and mineral matter (MM)[12]. Analyses of neutral detergent fiber and acid detergent fiber were conducted using the methods by Detmann *et al.*[13]. Total digestible nutrients (TDN) were calculated according to Paterson[14], with TDN = 889 – 0.779 x ADF%. Table 1 shows the results of these analyses.

Table 1. Chemical-bromatological composition of the feed used in this study.

Feed	DM $g.kg^{-1}$ (NM)	CP ($g.kg^{-1}$ DM)	EE ($g.kg^{-1}$ DM)	NDF ($g.kg^{-1}$ DM)	ADF ($g.kg^{-1}$ DM)	MM ($g.kg^{-1}$)	TDN ($g.kg^{-1}$)
Coast Cross	427.30	104.50	14.40	783.50	373.60	78.00	598.00
Corn silage	314.60	64.50	21.70	632.50	315.70	49.00	643.10
Oat (grain)	881.00	159.50	-	293.00	257.00	56.00	688.80
Soybean meal	904.00	454.00	-	134.00	68.70	55.60	835.50
Corn (grain)	879.00	90.10	31.80	122.50	48.50	61.20	851.20
Concentrate feed	-	171.00	42.00	196.00	143.00	88.00	738.10

DM: dry matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; MM: mineral matter; TDN: total digestible nutrients.

Ewe performance was measured through weight, weight gain, body condition score, and body condition score gain at the beginning of feed supplementation (WI, ADGI, BCSI, and BCSGI) and at the end of the breeding season (WF, ADGF, BCSF, BCSGF) in a model that includes the fixed treatment effect. Birth weight (BW), weaning weight (WW), and weight gain between birth and weaning (ADGLACT) were also analyzed by a model that included the effects of treatment, type of birth (single and twin), and sex of the lamb (male and female). BCS was assessed through the sensitivity of palpation to fat deposition and the musculature of the vertebrae in the lumbar region, assigning scores from 1 to 5, where 1 corresponds to lean females and 5 corresponds to excessive fat deposition.

Milk production (MP) of females was assessed following Podleskis *et al.*[15] at 19, 33, 47, and 51 days of lactation, in which the statistical model included the effects of treatment, type of lambing, and sex of the lamb. The lambs were separated from their mothers for one hour and reunited again with them for 30 minutes, thus allowing the complete udder emptying. After this period, they were separated from their lambs for ±4 hours and milked. Milkings were performed manually on the right half of the udder with administration of 3 IU of oxytocin intramuscularly. The amount collected was multiplied by two to adjust the production per animal and multiplied by six to adjust the production in 24 hours[16]. The teats were previously sanitized for milk collections. The first jets were discarded, and then antisepsis was performed with a pre-dipping solution.

The zootechnical performance of lambs was assessed by determining the lamb birth weight (LBW), lamb weaning weight (LWW), lamb weight gain (LWG), biometric measurements of length (LE), height (HE), and chest circumference (CC) from birth to weaning. The statistical model included the fixed effects of treatment, type of lambing, and sex of the lamb:

$$Y_{ijkl} = \mu + T_i + L_j + S_k + (T \times L)_{ij} + (T \times S)_{ik} + (L \times S)_{jk} + \varepsilon_{ijkl}$$

Where Y_{ijkl} = the observed value from the l^{-th} observation of the i-th treatment, j^{-th} lambing type and k^{-th} lamb sex; μ = the overall mean; T_i = the fixed effect due to the i-th treatment; L_j = the fixed effect due to the j^{-th} lambing type; S_k = the fixed effect due to the k-th lamb sex; $(T \times L)_{ij}$ = the effect of the interaction of the i^{-th} level of T and the j^{-th} level of L; $(T \times S)_{ik}$ = the effect of the interaction of the i-th level of T and the k^{-th} level of S; $(L \times S)_{jk}$ = the effect of the interaction of the j^{-th} level of L and the k-th level of S; ε_{ijkl} = the random error of the l^{-th} observation.

The data were subjected to analysis of variance at the 5% significance level in the SAS statistical program[17]. The chi-square test was used to compare the percentages of single and twin births between treatments.

3. Results and discussion

No effect (P>0.05) of treatments was observed on the weights of ewes (Table 2). Even ewes that were not supplemented gained weight during the period, demonstrating that the Coast Cross pasture met their nutritional requirements. The similarity between the two treatments of supplemented ewes and animals in the control group was probably due to the substitutive effect of ingesting pasture with supplementary feed.

Table 2. Means (± standard errors) for the weight (kg) and body condition score of ewes according to the treatments.

Variable	Treatment			P-value
	0.0%	0.5%	1.0%	
Weight				
Beginning of supplementation	47.68 ± 1.91	49.88 ± 2.12	49.82 ± 2.06	0.6706
The beginning of mating	49.88 ± 1.77	53.65 ± 1.97	52.71 ± 1.91	0.3290
End of supplementation	50.93 ± 2.15	55.46 ± 2.39	55.74 ± 2.32	0.2374
End of mating	52.61 ± 1.95	55.55 ± 2.10	54.22 ± 2.10	0.6014
ADG supplementation	0.076 ± 0.038	0.130 ± 0.043	0.138 ± 0.041	0.4872
ADG mating	0.059 ± 0.016	0.041 ± 0.017	0.033 ± 0.017	0.5196
ADGI – ADGF	0.073 ± 0.010	0.084 ± 0.011	0.066 ± 0.011	0.4783
Body condition score (BCS)				
Beginning of supplementation	2.86 ± 0.07	2.79 ± 0.07	2.89 ± 0.07	0.6457
The beginning of mating	2.83 ± 0.05	2.91 ± 0.05	2.92 ± 0.05	0.3939
End of supplementation	2.98 ± 0.03	3.00 ± 0.04	2.94 ± 0.04	0.5464
End of mating	2.98 ± 0.03	3.00 ± 0.04	2.94 ± 0.04	0.5464
BCSG at supplementation	0.12 ± 0.07	0.21 ± 0.08	0.06 ± 0.08	0.4461
BCSG at mating	0.14 ± 0.05	0.09 ± 0.06	0.03 ± 0.06	0.3771
BCSGI – BCSGF	0.11 ± 0.07	0.21 ± 0.08	0.06 ± 0.08	0.4461

ADG = average daily gain; ADGI = average daily gain at the beginning of supplementation; ADGF = average daily gain at the end of the breeding season; BCS = from 1 (extremely thin) to 5 (extremely fat); BCSC = body condition score gain; BCSI = body condition score gains at the beginning of feed supplementation; BCSF = body condition score gain at the end of the breeding season.

The ADG of supplemented ewes showed values slightly higher (0.130 and 0.138 kg) than those of 0.104 kg found by Gottardi *et al.*[18], who assessed the effect of flushing and the hormonal protocol on the reproductive performance of Morada Nova and Santa Inês ewes in the fifth and sixth week of supplementation.

Mori *et al.*[19] found that ewes subjected to nutritional flushing for 60 days using crushed corn had 5.77 kg more live weight at the end of the reproductive season than females that did not receive supplementation. Furthermore, BCS and BCSG did not change significantly (P>0.05) in the period between the beginning of feed supplementation and the end of the breeding season (Table 2).

On the other hand, Gottardi *et al.*[18] demonstrated that nutritional flushing based on corn bran and soybean meal during the breeding season resulted in a higher gain in BCS of Santa Inês females compared to Morada Nova females. Robertson *et al.*[20] found that soybean meal supplementation during late gestation and lactation did not significantly affect ewe body condition. However, ewes fed a corn- and soybean-based diet had higher body condition scores at weaning, indicating a beneficial effect of this formulation in maintaining maternal nutritional status through the end of lactation.

The body condition of ewes before, during, and after mating presents a significant impact on the gestation rate and the number of born lambs[21]. A very low or very high BCS at the beginning of the mating season is not desirable, but fluctuations in BCS resulting from an adequate energy supply, with an increase during the breeding season, may have a dynamic effect on reproduction(22). The beginning of feed supplementation is recommended in females with a BCS up to 3.0 so that they can reach a BCS between 3.0 and 3.5 when starting the breeding season after being subjected to nutritional flushing[23].

Mori *et al.* [19] described the relationship between body weight and BCS for nutritional assessment, and a higher weight determined a higher BCS in ewes submitted to different feed supplementation before and during the breeding season. LW and WW of ewes did not differ (P>0.05) between treatments (Table 3). It probably occurred because all ewes received the same dietary treatment after the breeding season and had similar weights at the end of the breeding season.

In a study on soybean meal supplementation during the final third of gestation and the lactation period in Barbados Blackbelly and St. Croix ewes, Wildeus *et al.* [24] reported no significant effects on dam body weight or reproductive performance. The lack of statistical differences between ewes supplemented with soybean meal and those receiving a corn–soybean mixture suggests that both diets were equally effective in maintaining maternal nutritional status during these critical periods. Although lambs from ewes fed the corn–soybean diet showed a trend toward higher average daily gain, this did not result in a significant difference in the number of lambs weaned per ewe.

Table 3. Means (± standard errors) for birth and weaning weights (kg) of ewes according to the treatments.

Variable	Treatment			P-value
	0.0%	0.5%	1.0%	
LW	54.63 ± 2.43	57.71 ± 2.60	53.05 ± 2.44	0.4063
WW	50.39 ± 2.62	51.13 ± 2.76	46.73 ± 2.60	0.4405
ADGLACT	-0.056±0.014	-0.087±0.014	-0.083±0.013	0.2127

LW = lambing weight; WW = weaning weight; ADGLACT = average daily gain during lactation.

According to Scaramuzzi *et al.*[25], nutrition can influence the ovulation rate in ewes through two events: the static effect and the dynamic effect. The static effect refers to the observation of a higher ovulation rate in females with an adequate body condition score compared to ewes with a low body condition score[26]. On the other hand, the dynamic effect is characterized by an increase in ovulation rate in response to increased weight and body condition score during a period of supplementation that occurs 3 to 4 weeks before mating[21].

The static effect is associated with the body condition of ewes, or the live weight achieved by the female at the time of mating, because of energy consumption during the production cycle, in which body reserves are reestablished, and the dynamic effect is associated with the actual energy consumption levels. For this reason, with changes in live weight in the immediate period before and during the reproductive season (45-day period), females were influenced by the dynamic effect relative to the static effect, as all females gained weight throughout the supply of supplementation (Table 2).

Although greater weight loss during lactation (ADGLACT, Table 3) might be expected in supplemented ewes (0.50% and 1.00%) due to higher twinning rates (Table 9) compared to control ewes, no significant differences were observed (P > 0.05). Ewes with twin lambs typically produce 20% to 40% more milk than those with single lambs[10], indicating higher lactational demands and nutritional requirements. Despite this, no significant differences (P > 0.05) were found in weight or average daily gain (ADG) between ewes with single and twin births (Table 4), nor between ewes that gave birth to male or female lambs.

In a study on supplementation of lactating Pampinta ewes, animals were fed either soybean hull- or corn grain-based supplements for five weeks. Milk samples were analyzed for composition and fatty acid profile. Although dry matter and forage intake were significantly higher in ewes receiving soybean hulls (P < 0.05), no differences were observed in milk yield, protein, or fat content between treatments[27].

Ribeiro *et al.*[28] concluded that ewes supplemented with 0.5 kg of crushed corn grain per animal/day two weeks before and two weeks after the beginning of the reproductive season did not present higher rates of twin births than those not supplemented. However, Roda & Otto[29] obtained higher percentages of twin births from ewes receiving 1 kg/day of concentrate feed with mineral composed of iodized salt and dicalcium orthophosphate before the breeding season compared to ewes that did not receive supplementation.

Tabela 4. Means (± standard errors) for lambing and weaning weights (kg) of ewes according to the type of birth and sex of the lamb.

Variable	Type of birth (TB)		Lamb sex (LS)		P-value	
	Single	Twin	Female	Male	TB	LS
Lambing weight	52.77 ± 1.59	57.48 ± 2.79	54.65 ± 2.11	55.60 ± 2.06	0.1597	0.7316
Weaning weight	47.36 ± 1.69	51.47 ± 2.96	48.54 ± 2.24	50.29 ± 2.19	0.2460	0.5505
ADG lactation	-0.071±0.009	-0.080±0.015	-0.081±0.012	-0.071±0.011		0.5128

ADG = average daily gain.

Females should be supplemented during the lactation period, especially before fetal and mammary gland development, to meet the energy demands of both periods and not be affected by the negative energy balance at the beginning of lactation[30].

No differences (P>0.05) were found for the milk production volume of ewes between treatments (Table 5), for the type of birth and sex of the lamb (Table 6). This result may be a consequence of the same dietary conditions that females received during lactation, which resulted in similar productions between all treatments. In contrast, Vasconcelos *et al.*[31] observed that milk production was influenced by the type of birth in ewes supplemented with 1.00% crushed corn relative to the average live weight. Moreover, Podleskis *et al.*[15] found that milk production was 26.6% higher in ewes with lamb males.

Table 5. Means (± standard errors) for milk production (mL) in 24 hours according to the treatments provided to ewes.

Variable	Treatment			Overall mean	P-value
	0.0%	0.5%	1.0%		
MP at 19 days of lactation	1,938 ± 258	2,448 ± 272	2,250 ± 246	2,208 ± 954	0.3476
MP at 33 days of lactation	1,740 ± 204	2,316 ± 218	2,034 ± 192	2,034 ± 762	0.1371
MP at 47 days of lactation	1,710 ± 228	2,178 ± 242	1,956 ± 216	1,938 ± 852	0.3390
MP at 61 days of lactation	1,842 ± 240	2,292 ± 256	2,076 ± 228	2,124 ± 900	0.4165
Mean MP	1,806 ± 210	2,292 ± 219	2,070 ± 198	2,076 ± 768	0.2386

MP = milk production.

Rosa *et al.*[32] evaluated the performance of ewes from different genetic groups that received supplementation and concluded that non-supplemented ewes had a decrease in weight in the final third of gestation, which may be related to energy mobilization for milk production. According to Sasa *et al.*[33], ewes that have higher genetic potential for milk production tend to lose more weight during lactation, as more nutrients are allocated to milk production, resulting in the mobilization of body reserves for milk production.

Daily milk production averages remained relatively stable across the four observation points (19, 33, 47, and 61 days of lactation), with an overall mean of 2,076 mL. According to Ferreira *et al.*[34], a decline in milk production is typical in meat-purpose breeds from the third week of lactation onward. However, Santa Inês ewes exhibit good milk yield despite being primarily selected for meat production. Similarly, Vasconcelos *et al.*[31] reported that Rabo Largo ewes, whether supplemented or not, reached peak milk production in the second week of lactation, followed by a consistent decline in both groups.

Ribeiro *et al.*[35] obtained a mean milk production of 2.25 L/ewe/day in Santa Inês ewes receiving oxytocin, with a peak milk production starting in the fifth week of lactation. On the other hand, Ferreira *et al.*[34] obtained a lower milk production, with values reaching 1.00 L/ewe/day in Santa Inês ewes, whereas Vasconcelos *et al.* [31] observed a milk production of 1.13 L/ewe/day in supplemented Rabo Largo ewes.

Table 6. Means (± standard errors) for milk production (mL) according to the type of birth and sex of the lamb.

Variable	Type of birth (TB)		Lamb sex (LS)		P-value	
	Single	Twin	Female	Male	TB	LS
MP at 19 days of lactation	2,220 ± 168	2,202 ± 282	2,082 ± 222	2,340 ± 204	0.9676	0.3814
MP at 33 days of lactation	2,070 ± 132	1,992 ± 222	1,944 ± 174	2,118 ± 162	0.7799	0.4563
MP at 47 days of lactation	1,968 ± 150	1,932 ± 246	1,902 ± 198	1,992 ± 180	0.9075	0.7321
MP at 61 days of lactation	2,178 ± 156	1,962 ± 264	1,944 ± 210	2,196 ± 192	0.4861	0.3564
Mean MP	2,112 ± 132	2,004 ± 148	1,962 ± 180	2,154 ± 168	0.7011	0.4068

MP = milk production.

Lambs showed no significant differences in weight or biometric measurements based on the treatments received by the ewes (Table 7). These findings align with those of Olivera-Muzante *et al.*[36], who supplemented Corriedale ewes with an energy-protein block—containing soybean meal, corn, molasses, and urea (24% crude protein and 14.6 MJ/kg metabolizable energy)—administered collectively between 10 and 6 days before lambing. Although supplementation did not affect lamb growth parameters, it increased colostrum volume (312 mL) and weight (324 g), and reduced viscosity (5.0), compared to non-supplemented ewes (158 mL, 156 g, and viscosity of 3.9).

In contrast, Makela *et al.*[37] found that low nutritional levels during lactation significantly reduced birth weight (P < 0.001). Fetal growth was faster during the suboptimal season, but lambs were heavier at birth during the optimal season (P < 0.001), indicating that both maternal nutrition and season of conception influence fetal development and birth weight in Dorset × Polypay and Dorset ewes.

Lamb performance is directly related to MP, which also did not differ between treatments. Thus, the similarity in the performance of ewes allows explaining the performance of lambs. Ribeiro *et al.*[28] evaluated the effect of feed supplementation for 14 days before and during the mating period in ewes from different genetic groups, with no difference in average daily gain between ewes supplemented or not.

The lambs had a mean birth weight of 4.4 kg and a mean weaning weight of 15.36 kg. These weaning results are considered satisfactory and similar to those found by Koritiaki *et al.*[38], who evaluated Santa Inês lambs at 70 days of age and had a mean weaning weight of 13.55 kg.

The characteristics of milk composition and production are closely related to the nutritional status of the female. Therefore, the suckling phase directly reflects on the body development of the offspring, that is, the quality and quantity of the milk offered to the offspring will result in better development and weaning of heavier animals.

Geeraseev *et al.*[39] concluded that restriction during the final third of gestation directly affects animal development and performance during and after weaning, providing lower weight gain and higher slaughter age, indicating that it is not possible to compensate for restrictions imposed during the prenatal period at a later stage.

Table 7. Means (± standard errors) for weights (kg) and body measurements (cm) of lambs according to the treatments provided to the ewes.

Variable	Treatment			Overall mean	P-value
	0.0%	0.5%	1.0%		
LBW	3.99 ± 0.16	4.31 ± 0.15	4.11 ± 0.15	4.14 ± 0.70	0.3179
LWW	15.35 ± 0.75	15.80 ± 0.70	15.48 ± 0.70	15.36 ± 3.34	0.8988
ADG until weaning	0.150±0.008	0.153±0.008	0.150±0.008	0.150±0.038	0.9539
LE at birth	27.51 ± 0.66	27.06 ± 0.61	27.18 ± 0.61	27.09 ± 2.93	0.8744
LE at weaning	44.62 ± 0.81	45.05 ± 0.75	45.36 ± 0.75	44.77 ± 3.61	0.7961
LE gain	17.11 ± 0.95	17.99 ± 0.88	18.17 ± 0.88	17.67 ± 4.22	0.6800
HE at birth	37.73 ± 0.67	38.48 ± 0.63	37.77 ± 0.63	37.96 ± 3.00	0.6492
HE at weaning	56.08 ± 0.89	56.75 ± 0.82	56.06 ± 0.82	56.16 ± 3.95	0.7989
HE gains	18.34 ± 0.87	18.28 ± 0.82	18.29 ± 0.82	18.19 ± 3.92	0.9983
CC at birth	36.50 ± 0.69	37.83 ± 0.64	36.66 ± 0.64	36.88 ± 3.08	0.2952
CC at weaning	58.90 ± 1.06	58.15 ± 0.99	58.98 ± 0.99	58.52 ± 4.74	0.8127
CC gain	22.40 ± 0.97	20.32 ± 0.90	22.33 ± 0.90	21.64 ± 4.32	0.1963

a, b = Means for the effect of type of birth, followed by different letters, differ statistically from each other. LBW = lamb birth weight; LWW = lamb weaning weight; ADG = average daily weight gain; LE = length; HE = height; CC = chest circumference.

The isolated evaluation of the effect of TB showed that lambs from single births were heavier than lambs from twin births from birth to weaning, in addition to having a higher ADG weight from birth to weaning (Table 8). Ribeiro *et al.*[40] found similar results when evaluating the performance of lambs from ewes of different genetic groups subjected to nutritional flushing. According to Siqueira, Simões & Fernandes[41], lambs from twin births tend to show less growth than single offspring due to the lower milk availability.

The mean LWG was reflected in the final weaning weight, in which lambs from single births presented a difference of 4.94 kg relative to lambs from twin births (Table 8). The increase in the number of offspring born per birth leads to a decrease in birth weight due to competition in the uterine environment, with a limitation of resources such as the nutrients and space shared between developing fetuses [42]. However, lambs from single births have a higher pre- and post-weaning growth rate compared to those from twin births[43].

Table 8. Means (± standard errors) for weights (kg) and body measurements (cm) of lambs according to the type of birth and sex of the lamb.

Variable	Type of birth (TB)		Lamb sex (LS)		P-value	
	Single	Twin	Female	Male	TB	LS
LBW	4.59 ± 0.12 a	3.68 ± 0.12 b	3.98 ± 0.12	4.30 ± 0.12	0.0001	0.0576
LWW	18.01 ± 0.59 a	13.07 ± 0.57 b	15.31 ± 0.59	15.77 ± 0.56	0.0001	0.5569
ADG until weaning	0.177±0.006 a	0.124±0.006 b	0.150±0.007	0.152±0.006	0.0001	0.8806
LE at birth	28.11 ± 0.52 a	26.38 ± 0.50 b	26.93 ± 0.51	27.57 ± 0.49	0.0180	0.3537
LE at weaning	47.73 ± 0.64 a	42.28 ± 0.62 b	44.83 ± 0.63	45.18 ± 0.60	0.0001	0.6815
LE gain	19.62 ± 0.75 a	15.90 ± 0.72 b	17.90 ± 0.74	17.61 ± 0.71	0.0006	0.7675
HE at birth	38.95 ± 0.53 a	37.04 ± 0.51 b	37.33 ± 0.52	38.66 ± 0.50	0.0113	0.0652
HE at weaning	58.65 ± 0.70 a	53.95 ± 0.67 b	56.03 ± 0.69	56.56 ± 0.66	0.0001	0.5666
HE gains	19.70 ± 0.70 a	16.90 ± 0.67 b	18.70 ± 0.68	17.91 ± 0.65	0.0046	0.3948
CC at birth	38.35 ± 0.55 a	35.63 ± 0.53 b	36.85 ± 0.54	37.14 ± 0.52	0.0006	0.6930
CC at weaning	61.63 ± 0.84 a	55.72 ± 0.81 b	58.57 ± 0.83	58.79 ± 0.80	0.0001	0.8442
CC gain	23.28 ± 0.77 a	20.09 ± 0.74 b	21.71 ± 0.75	21.65 ± 0.72	0.0034	0.9471

a, b = Means for the effect of type of birth, followed by different letters, differ statistically from each other. LBW = lamb birth weight; LWW = lamb weaning weight; ADG = average daily weight gain; LE = length; HE = height; CC = chest circumference.

Similarly to weights, body measurements of lambs showed a significant difference depending on TB for the characteristics LE, HE, and CC (Table 8). Lambs from single births were around 3.7 cm larger in LE, around 2.8 cm taller, and 3.19 cm larger in CC compared to lambs from twin births. Koritiaki *et al.*[38] found values for chest circumference of 60.70 cm in lambs from single births and 53.75 cm in lambs from twin births.

Grandis *et al.*[44] worked with Texel animals and reported that CC measurements can reliably predict body weight, regardless of their sex and age. Therefore, the assessments enable improvements in zootechnical control for producers who do not have access to a scale. In this study, lambs that had a larger chest circumference at weaning came from single births, associated with higher weaning weight at 75 days of age and, consequently, higher daily weight gain than lambs from twin births.

When twin weights were combined rather than analyzed individually, no significant differences were observed among feeding treatments for lamb weaning weight (LWW) or efficiency, measured as LWW per 100 kg of ewe body weight (Table 9). Similarly, no differences were found in birth type percentages among treatments. However, ewes receiving nutritional flushing tended to show a higher percentage of twin births (P = 0.076). The rate of twin births was higher in ewes supplemented at 0.5% of body weight than in the control treatment, without supplementation. Ewes supplemented with 1% of body weight showed intermediate results.

Nutritional flushing allows an increase in the incidence of twin births[45], as it stimulates the maturation and release of additional eggs. However, it does not turn an infertile ewe into a fertile female, as observed in the results, in which none of the ewes in the control treatment failed (100% lambing), while three in the 0.5% treatment and one in the 1.0% treatment failed. The results of using food flushing may vary due to other factors, often unobservable. For example, Mori *et al.*[19] observed that flushing in ewes did not determine a higher number of twin births.

Table 9. Means (± standard errors) for lamb weaning weight (twin lambs combined), ewe efficiency (kg), and percentages of births and twin births, according to the treatments.

Variable	Treatment			Overall mean	P-value
	0.0%	0.5%	1.0%		
LWW	21.44 ± 1.21	20.81 ± 1.25	21.11 ± 1.19	19.77 ± 4.46	0.9326
Efficiency	38.33 ± 2.27	37.35 ± 2.36	40.51 ± 2.24	37.31 ± 8.38	0.5930
Birth, %	100.00	85.00	94.74	93.33	0.1501
Twin births, %	19.05 b	52.94 a	44.44 ab	37.5	0.0761

[a] Efficiency = (lamb weaning weight/ewe weight at the end of mating) * 100. a, b = Means for the same effect, followed by different letters, differ from each other. LWW = Lamb weaning weight.

The analysis of LWW relative to TB (Tables 8 and 10) showed that lambs from single births were heavier when compared individually to lambs from twin births. However, the sum of the weaning weights of twin births was higher than single births. Thus, it shows the trend (P=0.086) for twin births to be more efficient (Table 10), demonstrating a satisfactory result from the implementation of nutritional flushing.

Table 10. Means (± standard errors) for LWW (sum of twin lambs) and ewe efficiencya (kg) according to the type of birth and sex of the lamb.

Variable	Type of birth (TB)		Lamb sex (LS)		P-value	
	Single	Twin	Female	Male	TB	LS
LWW	18.06 ± 0.81 b	24.17 ± 1.31 a	20.38 ± 1.03	21.85 ± 0.99	0.0005	0.2942
Efficiency	36.07 ± 1.53	41.39 ± 2.48	39.68 ± 1.94	37.78 ± 1.87	0.0858	0.4690

[a] Efficiency = (lamb weaning weight/ewe weight at the end of mating) * 100. a, b = Means for the same effect, followed by different letters, differ from each other. LWW = Lamb weaning weight.

In this study, LS did not influence LWW or efficiency (Table 10). The animals were weaned with relatively low weight, with no differences that are more visible at puberty, influenced by hormonal factors, in which nutrition can delay the beginning of the reproductive period. According to Gois *et al.*[46], sexual condition is an important factor, as it is related to satisfactory weight gain, affecting the growth rate and deposition of different body tissues, with non-castrated males showing higher growth rates than castrated and females.

In a study conducted by Ehrhardt *et al.*[47], the impact of pre-conception nutrition on sheep reproduction across different reproductive seasonality patterns was investigated. In the first experiment, different levels of energy intake were tested for 21 days before breeding, influencing reproductive response after the introduction of fertile rams. The second experiment evaluated the effect of energy status during lactation and flushing, revealing that higher energy intake significantly increased lamb size. Additionally, lactation nutrition influenced the return to estrus, highlighting the importance of nutritional management in optimizing conception rates and reproductive efficiency without the need for exogenous hormones. These findings reinforce the role of nutrition in maximizing reproductive productivity in accelerated management systems.

4. Conclusion

Nutritional flushing for six weeks—starting three weeks before and continuing three weeks after the beginning of the breeding season—using a daily supplement equivalent to 0.5% of body weight increased the incidence of twin gestations. Ewes with twins showed greater efficiency by weaning more total kilograms of lambs. Male and female lambs performed similarly until weaning. Nutritional flushing with corn, soybean meal, and oats is recommended when used at appropriate levels and aligned with production cost considerations.

Conflict of interest statement

The authors declare no conflict of interest.

Data availability statement

Data will be made available on request.

Author contributions

Conceptualization: G. R. de Paula and E. L. A. Ribeiro. Data curation: G. R. de Paula. Formal analysis: E. L. A. Ribeiro and B. S. Marestone. Funding acquisition: E. L. A. Ribeiro. Project administration: G. R. de Paula. Methodology: G. R. de Paula, B. S. Marestone and E. L. A. Ribeiro. Resources: F. L. M. Junior and V. H. B. Junior. Supervision: E. L. A. Ribeiro. Investigation: B. S. Marestone, T. C. de Freitas and M. T. R. de Souza. Visualization: G. R. de Paula. Original Draft: G. R. de Paula. Review and Editing: E. L. A. Ribeiro, F. A. Grandis and S. M. Simonelli.

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