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Effects of different backgrounding supplementation on performance and rumen morphometrics of Nellore bulls finished on tropical pasture

Jéssica Geralda Ferracini[1], Daniel Polli[2], Mariana Bassanezi Gasparim[3], Luanda Torquato Feba[3], Rodrigo José de Oliveira[4], Ariany Faria de Toledo[4], Danilo Domingues Millen[4*]

[1] Universidade Estadual de Maringá, Departamento de Zootecnia, Maringá, PR, Brasil.
[2] Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Tecnológicas, Dracena, SP, Brasil.
[3] Universidade do Oeste Paulista, Departamento de Agronomia, Presidente Prudente, SP, Brasil.
[4] Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias, Departamento de Zootecnia, Jaboticabal, SP, Brasil.

ABSTRACT - This study aimed to evaluate the effects of backgrounding supplementation, by increasing the levels of energy-protein supplements during the growing phase on the performance and rumen morphometrics of Nellore bulls intensively finished on pasture. Ninety-six Nellore bulls were blocked according to initial body weight (BW) of 385.6 ± 7.3 kg and randomly assigned to one of 24 paddocks of *Urochloa brizantha* cv. 'Piata' (four animals/paddock). The animals were supplemented during the growing phase as follows: (1) energy-protein supplementation at 0.05% BW, (2) energy-protein supplement at 0.1% of BW, (3) energy-protein supplement at 0.3% BW, and (4) energy-protein supplement at 0.5% of BW for 112 days. Thereafter, all bulls were fed a concentrate at 1.5% BW for 84 days in the finishing phase on pasture. The supplement intake, BW assessment, and average daily gain (ADG) were recorded every 28 days. At the end of the trial, the hot carcass weight was recorded. Rumen and cecum were scored, and morphometric parameters evaluated. Dry matter intake during both the growing and finishing phases increased with higher levels of supplementation ($P<0.01$). There was a quadratic effect ($P = 0.03$) during the growing phase, with bulls supplemented at 0.3% and 0.5% of BW showing greater ADG; however, during the finishing phase, a linear decrease effect was observed ($P = 0.01$). A linear increase effect was observed for final BW, with bulls consuming 0.05% of BW being lighter. In addition, as the level of supplementation increased, hot carcass weight also increased ($P<0.01$), while no effects were observed on rumen and cecum parameters. Providing an energy-protein supplement during the growing phase is an effective nutritional strategy. Higher levels of supplementation result in greater final body weight at the end of the growing phase and, consequently, improved performance during the finishing phase of Nellore bulls finished on pasture.

Keywords: beef, cattle, finishing, grazing, supplement

***Corresponding author:**
danilo.millen@unesp.br

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1. Introduction

In tropical regions, the growing phase predominantly relies on pastures. However, when these systems are not properly managed, especially during dry periods, poor animal performance and land degradation can occur. These challenges highlight the need for improved pasture and herd management practices (Barbizan et al., 2020).

Although intensive finishing systems are traditionally associated with feedlots, pasture-based finishing systems have gained popularity in Brazil. These systems integrate high levels of concentrate feeds into the diet to enhance growth and finishing performance. Bulls are typically raised to about 450 kg of BW during the growing phase before transitioning to a pasture-based finishing system. In contrast, the higher energy density in feedlot finishing systems allows cattle to start on feed at lighter weights, approximately 380 kg (Silvestre and Millen, 2021).

Since the growing phase typically occurs during Brazil's dry season, it is crucial to adopt suitable nutritional strategies to support the transition to the finishing phase, especially in pasture-based systems where animals begin finishing at heavier weights. In this context, the appropriate level of energy-protein supplementation can improve ruminal fermentation and enhance the efficiency of microbial protein synthesis, particularly when pasture forage availability is limited (Caldas Neto et al., 2007).

Therefore, supplementation should be adjusted according to seasonal variations and the nutritional requirements for growth (Silva et al., 2017). Depending on pasture conditions, the level of supplementation can significantly influence animal performance by affecting nutrient digestibility and utilization efficiency (Sampaio et al., 2009). Enhancing nutrient intake through supplementation before finishing, primarily using concentrate ingredients, may improve performance, shorten the production cycle, and facilitate the adaptation of bulls to pasture-based finishing (Moraes et al., 2010).

Despite the growing adoption of intensive pasture-based finishing systems, research on backgrounding supplementation strategies during the growing phase remains limited. Further studies are needed to maximize performance and ensure an efficient transition to the finishing stage. According to the requirements for a Nellore bull weighing 350 kg to 450 kg to gain between 600 g and 700 g of weight per day during a typical dry season in Brazil, the supplement should be fed at 0.3% BW (NASEM, 2016). However, for cattle that will be finished on pasture by consuming a significant amount of a concentrate ration, supplementation during the background phase might be 0.1% or even 0.05% BW, aiming to explore the potential for compensatory gain in the finishing phase.

Thus, we hypothesize that cattle do not need supplementation exceeding 0.3% of BW during the growing phase in the dry season when they are later finished on pasture, consuming a concentrate ration at 1.5% of BW to achieve higher final BW and hot carcass weight. This study aims to evaluate the effects of varying levels of energy-protein supplementation (0.05, 0.1, 0.3, and 0.5% of BW) during the growing phase, conducted in the dry season, on the performance, carcass characteristics, and rumen morphometrics of Nellore bulls finished on tropical pasture while consuming a concentrate ration at 1.5% of BW.

2. Material and methods

2.1. Ethical standards

The Institutional Ethics Committee on the Use of Experimental Animals approved all study procedures (Protocol no. 21/2022). This study was conducted between May and December 2022 at the beef cattle facilities of Presidente Bernardes Farm, São Paulo, Brazil. The farm is located at an elevation of 429 meters, within the coordinates 22°00'22" S latitude and 51°33'11" W longitude. During this period, the average temperature was 21 °C, with a maximum of 26 °C and a minimum of 13 °C. The mean relative humidity was 75%, and the average monthly rainfall was 69.42 mm.

2.2. Animals and treatments

Ninety-six Nellore bulls with an initial BW of 385.6 ± 7.3 kg from a commercial farm were enrolled in this study. The bulls were blocked according to the initial BW (six blocks) and randomly assigned to

24 paddocks with 2.0 ha of *Urochloa brizantha* 'Piata' per paddock (four animals/paddock) and six paddocks/treatment.

The bulls received *Urochloa brizantha* cv. Piata pasture and an energy-protein supplement during the growth phase according to the treatments: (1) energy-protein supplementation at 0.05% BW; (2) energy-protein supplementation at the rate of 0.1% BW; (3) energy-protein supplementation at the rate of 0.3% BW; and (4) energy-protein supplementation at the rate of 0.5% body weight, for 112 days, divided into four 28 days periods.

After that, all bulls remained in the pasture for the finishing phase (n = 24) and were fed with the same concentrate ration at 1.5% BW for 84 days. The chemical compositions of the pasture from the whole period are presented in Table 1, and the composition of the four energy-protein supplements used for the growth phase and the concentrate supplement for the finishing phase are presented in Table 2.

Table 1 - Forage mass and chemical composition of Piata grass pastures (*Urochloa brizantha* cv. Piatã), during the growing and finishing phase

	Experimental period			
Months	28	56	84	112
Forage mass (ton/ha)	4.64	3.92	3.83	2.72
Nutritional composition (% of dry matter, DM)				
Dry matter (% of organic matter)	36.7	43.5	84.4	67.8
Crude protein	4.00	4.42	2.64	3.33
Neutral detergent fiber	78.4	82.3	85.1	86.1
Acid detergent fiber	43.2	45.0	51.8	52.0
Ash	6.73	6.72	5.64	6.00
Ether extract	1.20	1.20	0.70	0.90
Total digestible nutrients[1]	52.6	51.7	48.3	48.2

[1] Total digestible nutrients = 40.26 + (0.196 × CP) + (0.482 × NFC) + (1.058 × EE) − (0.469 × ADF), as described by Weiss et al. (1992).

Table 2 - Feed ingredients and chemical composition of experimental supplements during the growing and finishing phase

	Growth				Finishing
	0.05%	0.1%	0.3%	0.5%	1.5%
Ingredients (%)					
Finely ground corn	10.0	18.6	59.0	59.0	55.0
Cottonseed meal	-	15.0	1.50	1.50	6.20
Wheat bran	-	9.00	7.00	7.00	12.0
Rice bran	-	11.0	8.00	8.00	10.0
Dry distiller's grains	-	5.00	5.00	5.00	5.00
Urea	7.00	6.50	3.50	3.50	1.00
Mineral supplement	83.0	34.9	16.0	16.0	10.80
Nutritional composition (% of dry matter, DM)					
Dry matter	91.9	90.9	88.9	88.9	88.8
Crude protein	37.1	42.1	22.7	22.7	17.2
Neutral detergent fiber	1.00	13.7	12.4	12.4	15.8
Acid detergent fiber	0.40	7.00	5.21	5.22	6.94
Ash	15.1	9.60	5.30	5.30	5.20
Ether extract	2.00	3.95	4.32	4.32	4.64
Starch	19.5	23.1	47.5	47.5	45.4

The bulls were supplemented every morning (10:00 h), and the supplements were allocated in an uncovered feeder with a linear space of 0.6 m per animal. The amount of supplement was adjusted according to the average BW of each paddock every 28 days. The supplements used during the growing phase and the concentrate provided during the finishing phase were both formulated according to the National Academies of Sciences, Engineering, and Medicine (NASEM, 2016). During the growing phase, all supplements were formulated to meet nutrient requirements. Supplements fed at 0.05% and 0.1% BW were expected to achieve an ADG of 0.57 kg, while those fed at 0.3% and 0.5% BW had an expected ADG of 0.77 kg. The concentrate provided during the finishing phase contained the same ingredients, expecting an ADG of 1.5 kg, and the forage source in the pasture was Piata grass. Considering the estimated pasture intake and supplement consumption, the total amount of protein ingested by the Nellore cattle in this study should be comparable. However, pasture intake was not measured in this study.

2.3. Measurements and sample collection

The supplement and concentrate intake were calculated daily by weighing the amount of feed offered and refused and expressed in kilograms and as a percentage of BW. The bulls were weighed after a 16-h feed and water fasting period at the trial's beginning (day 0), and end of backgrounding (day 112) and finishing phases (day 196). Intermediate weighing, with no fasting, was also conducted at the end of each 28-day experimental period (days 28, 56, 84, 140, and 168); a 4% weight discount was applied to estimate the shrunk BW (NRC, 2016). Individual average daily gain (ADG) was calculated by subtracting each animal's initial body weight from its final body weight recorded during the experimental period and then dividing the result by the total number of days in that period. The mean ADG per paddock was used to calculate feed conversion efficiency, as feed intake was measured at the paddock level.

The supplement intake for each paddock was associated with the average daily gain data to calculate the feed conversion of the supplement. At the end of the trial, the animals were slaughtered at a commercial slaughterhouse (Frigorifico Naturafrig Alimentos S/A, Pirapozinho, SP, Brazil).

The hot carcass weight was obtained at the time of slaughter after evisceration and removal of kidney, pelvic, and heart fat. The dressing percentage was calculated as the ratio of hot carcass weight to final BW (Pereira et al., 2020). After bull evisceration, the rumen was washed and scored for the presence of lesions (rumenitis) and abnormalities (e.g., papillae clumped) using a 10-point scale (0 = no lesions and abnormalities and 10 = severe ulcerative lesions) as described by Bigham and McManus (1975) and Pereira et al. (2016). The epithelium of the cecum was classified based on lesions and abnormalities of the cecal wall, following the method adapted from Pereira et al. (2020).

A sample of rumen epithelium, measuring 1 cm^2 per animal, was collected from the ventral sac and placed in a PBS solution for subsequent macroscopic morphometric evaluation, as described by Pereira et al. (2016).

2.4. Analytical procedures

Forage mass (ton of DM/ha) was measured every 28 days. Four random points/paddocks of Piata grass were measured using a graduated ruler (Barthram, 1985). Four representative grass samples of average height were collected from each paddock by cutting 2 cm above the soil of all herbage using a 0.25-m^2 metal frame. The four samples were split into two portions to determine the DM content and chemical composition.

The forage, supplements, and concentrate samples were oven-dried at 65 °C for 72 h and ground to pass a 1-mm screen using a Wiley mill according to AOAC International (2002; method 930.15). The DM and ash (2002; method 925.40; 942.05), total nitrogen concentration (2002; method 968.06), CP (2002; method 954.01), and ether extract (EE) (2002; method 920.39) contents were analyzed. Sequential detergent fiber analyses were used to determine the concentration of NDF (Van Soest et al., 1991) and ADF (Goering and Van Soest, 1970). Heat stable α-amylase and sodium sulfite were included in the NDF analysis. The total digestible nutrients (TDN) of the supplements and forage were estimated using the following equation: TDN = 40.26 + (0.196 × CP) + (0.482 × NFC) + (1.058 × EE) − (0.469 × ADF), as described by Weiss et al. (1992).

2.5. Statistical analysis

The experimental design was a randomized complete block, with initial body weight used as the blocking criterion. Data were analyzed using the PROC MIXED procedure of SAS (SAS Institute Inc, Cary, NC, USA, 2003). All response variables were tested for normality using the Shapiro-Wilk and Kolmogorov-Smirnov tests, and no data transformation was necessary as the residuals were normally distributed. Rumen lesion scores met the normality assumptions and were analyzed using parametric methods. The significance level was set at $P<0.05$. The statistical model used was:

$$Yij = \mu + Si + bj + eij,$$

in which μ is the overall mean, Si is the fixed effect of supplement level, bj is the random effect of block, and eij is the residual error. Means were obtained using the LSMEANS statement.

To evaluate the effect of increasing supplement levels during the growing phase (0.05, 0.1, 0.3, and 0.5% of BW), orthogonal polynomial contrasts (linear, quadratic, and cubic) were performed using the CONTRAST statement in PROC MIXED. The ORPOL function in SAS was used to generate the appropriate contrast coefficients, considering the uneven spacing of the supplementation levels. This approach allows for proper regression analysis within the mixed model framework. In the end, cubic responses were not significant and are not included in the results and discussion sections.

3. Results

A quadratic effect on dry matter intake (DM intake; kg and % of body weight) was observed throughout the trial, except during the 112–196 day period. Increasing levels of energy–protein supplementation significantly increased DM intake during the growing and finishing phases, with significant linear and quadratic effects ($P<0.01$; Table 3).

Table 3 - Supplement intake of Nellore cattle finished on pasture and fed at different levels of supplement during the growing phase

Days	Treatments[1]				SEM	P-value[2]	
	0.05%	0.1%	0.3%	0.5%		L	Q
Dry matter intake (kg)							
0–28	0.19	0.34	1.15	1.89	0.029	<0.01	<0.01
0–56	0.19	0.36	1.20	1.99	0.027	<0.01	<0.01
0–84	0.19	0.38	1.24	2.05	0.027	<0.01	<0.01
0–112	0.19	0.39	1.27	2.11	0.027	<0.01	<0.01
0–140	0.69	0.89	1.69	2.44	0.032	<0.01	<0.01
0–168	1.36	1.57	2.31	2.98	0.042	<0.01	<0.01
0–196	2.37	2.59	3.18	3.78	0.058	<0.01	<0.01
112–196	6.72	6.98	7.01	7.12	0.133	<0.01	0.21
Dry matter intake (% of body weight)							
0–28	0.05	0.08	0.29	0.47	0.004	<0.01	<0.01
0–56	0.05	0.09	0.29	0.48	0.003	<0.01	<0.01
0–84	0.05	0.09	0.30	0.49	0.002	<0.01	<0.01
0–122	0.05	0.09	0.30	0.50	0.002	<0.01	<0.01
0–140	0.17	0.21	0.39	0.56	0.002	<0.01	<0.01
0–168	0.32	0.36	0.51	0.66	0.002	<0.01	<0.01
0–196	0.53	0.57	0.69	0.81	0.003	<0.01	<0.01
112–196	1.39	1.40	1.37	1.39	0.008	<0.01	<0.01

SEM - standard error of the mean.
[1] Supplements during the growing phase: energy-protein supplement at 0.05, 0.1, 0.3, and 0.5% of body weight.
[2] L - linear; Q - quadratic.

A significant linear and quadratic increase in body weight (BW; kg) was observed at the end of the growing and finishing phases (112 and 196 days; P = 0.03 and 0.01, respectively; Table 4). Moreover, a quadratic effect was found for ADG during the growing phase (0–112 days; P<0.01), with bulls fed 0.3% and 0.5% BW showing greater ADG values. Conversely, a linear decrease in ADG was observed with increasing supplementation levels during the finishing phase (112–196 days; P = 0.01).

A quadratic effect on supplement feed conversion was also observed during the growing phase (0–112 days; P<0.01), while a linear increase was found in the finishing phase (112–196 days; P<0.01), with greater values for 0.3% and 0.5% supplementation. Hot carcass weight increased linearly with supplementation level (P<0.01; Table 4). Additionally, no effect was observed on dressing percentage (P>0.05).

Supplementation had no effect on lesion scores for rumenitis and cecum. Additionally, supplementation did not affect macroscopic measurements of the rumen, except for the papillae area, expressed as % of ASA. Bulls supplemented at 0.3% BW showed increased papillae area (P = 0.05; Table 5).

Table 4 - Performance and carcass traits of Nellore cattle finished on pasture fed at different supplement levels during the growing phase

Days	Treatments[1]				SEM	P-value[2]	
	0.05%	0.1%	0.3%	0.5%		L	Q
Body weight (kg)							
0	385.3	385.8	385.8	385.5	7.308	0.86	0.61
28	406.1	414.5	412.7	414.5	6.995	<0.01	0.03
56	420.9	428.5	433.6	431.3	8.123	<0.01	0.05
84	420.9	433.1	442.3	440.8	8.359	<0.01	0.03
112	420.0	437.8	454.2	457.4	8.292	<0.01	0.03
140	457.2	469.5	487.1	485.4	9.547	<0.01	0.09
168	503.4	516.4	524.4	527.5	9.013	<0.01	0.33
196	554.0	573.3	575.3	576.5	9.085	0.01	0.11
Average daily gain (kg)							
0–28	0.74	1.03	0.96	1.04	0.064	<0.01	0.06
0–56	0.64	0.76	0.85	0.82	0.044	<0.01	0.08
0–84	0.42	0.56	0.67	0.66	0.038	<0.01	0.05
0–112	0.31	0.46	0.61	0.64	0.028	<0.01	0.03
0–140	0.51	0.60	0.72	0.71	0.030	<0.01	0.12
0–168	0.70	0.78	0.82	0.85	0.029	<0.01	0.37
0–196	0.86	0.96	0.97	0.97	0.027	0.01	0.12
112–196	1.51	1.52	1.36	1.34	0.052	0.01	0.72
Feed conversion[3] (kg/kg)							
0–28	0.27	0.33	1.24	1.85	0.080	<0.01	<0.01
0–56	0.31	0.48	1.44	2.57	0.082	<0.01	<0.01
0–84	0.48	0.68	1.89	3.15	0.095	<0.01	<0.01
0–112	0.63	0.87	2.13	3.30	0.088	<0.01	<0.01
0–140	1.37	1.51	2.37	3.45	0.099	<0.01	<0.01
0–168	1.95	2.03	2.84	3.53	0.102	<0.01	0.01
0–196	2.77	2.71	3.32	3.89	0.096	<0.01	<0.01
112–196	4.48	4.61	5.26	5.34	0.214	<0.01	0.93
Hot carcass weight (kg)	315.6	319.9	327.5	328.4	5.394	<0.01	0.56
Dressing (%)	57.0	55.8	56.9	57.0	0.004	0.48	0.10

SEM - standard error of the mean.
[1] Supplements during the growing phase: energy-protein supplement at 0.05, 0.1, 0.3, and 0.5% of body weight.
[2] L - linear; Q - quadratic.
[3] Average supplement intake expressed in kg by average daily gain expressed in kg.

Table 5 - Evaluation of epithelial lesions and rumen morphometrics of Nellore cattle finished on pasture fed at different supplement levels during the growing phase

Item	Treatments[1]				SEM	P-value[2]	
	0.05%	0.1%	0.3%	0.5%		L	Q
Lesion scores							
Rumenitis	1.63	1.67	1.83	1.38	0.214	0.55	0.25
Cecum	1.51	1.24	1.50	1.26	0.330	0.74	0.95
Rumen morfometrics							
Papillae area (cm^2)	0.46	0.42	0.46	0.40	0.030	0.36	0.45
Number of papillae (n)	60.0	54.8	61.7	59.6	2.890	0.50	0.70
Absorptive surface area (ASA, cm^2)	27.4	23.5	28.6	24.4	2.240	0.82	0.37
Papillae area (% of ASA)	96.4	95.8	96.5	96.0	0.260	0.81	0.39

SEM - standard error of the mean.
[1] Supplements during the growing phase: energy-protein supplement at 0.05, 0.1, 0.3, and 0.5% of body weight.
[2] L - linear; Q - quadratic.

4. Discussion

Cattle in tropical and subtropical regions are expected to be more productive during the wet than dry season (Tambara et al., 2021). The wet season provides favorable weather conditions for plant growth and improved nutritive value of forage grazed (Boval et al., 2015). On the other hand, we observed a decline in forage mass (t/ha) and quality parameters, such as CP and TDN content, along with increased NDF and ADF levels during the dry season, corroborating with previous studies that highlight the negative impact of climatic seasonality on pasture growth (Barbero et al., 2020).

These findings are consistent with the expected decrease in forage nutritive value due to plant maturity, lignification, and reductions in cellular content, particularly from May to December, a typical period of low precipitation, reduced photoperiod, and lower temperatures in Brazil (Gomes et al., 2015). Therefore, the results of this study reinforce the importance of well-managed, pasture-based systems in tropical regions, where seasonal variations significantly influence forage availability and quality (Torrecilhas et al., 2021).

Strategies for pasture management, including supplementation, are crucial for addressing seasonal forage availability and quality deficiencies. It is important to note that pasture intake was not directly measured in this study, which limits the precision of total nutrient intake estimation. However, due to the inherent challenges of accurately quantifying intake under grazing conditions, cattle performance was used as an indirect indicator of the adequacy of nutrient supply.

Our study demonstrated that supplementation at 0.05% of BW led to lower weight gain (0–112 days) than bulls receiving greater supplementation levels. In tropical grazing systems during the dry season, protein is often the most limiting nutrient for cattle production (Reis et al., 2009). When forage protein content is low (≤ 7% CP in DM), nitrogen availability for microbial metabolism in the rumen is restricted, reducing nutrient intake and fiber digestibility (Detmann et al., 2014), consequently impacting weight gain. This effect may have occurred in our study, as forage quality declined throughout the trial, although pasture intake was not measured.

The increased DMI from the supplement likely improved the supply of fermentable nutrients and rumen-degradable protein, thereby enhancing microbial activity and nutrient utilization. Additionally, the inclusion of concentrate ingredients such as corn and soybean meal may have promoted greater ruminal fermentation efficiency, contributing to improved average daily gain in bulls receiving higher supplementation levels (Nagaraja and Titgemeyer, 2007).

The greater amount of supplement intake may have enhanced ruminal ammonia utilization from true protein and cellulolytic bacterial activity, as supported by Stahlhöfer et al. (2021) and Silva-Marques et al.

(2019). Nonetheless, the greater ADG obtained by cattle fed 0.3% and 0.5% of BW during the growing phase (0–112 days) may also have resulted from the increased availability of branched-chain volatile fatty acids in the rumen. These metabolites, derived from the degradation of amino acids present in protein supplements, stimulate the growth of fiber-degrading bacteria and improve fermentation efficiency (Russell, 2002).

When defining supplementation strategies, it is essential to consider the changing nutritional requirements throughout the growth period. On day 112, at the end of the growing phase, the bulls showed a lower ADG (0.51 kg from 0–112 days) compared to the initial period (0.94 kg from 0 to 28 days on feed), regardless of supplementation level. This reduction in ADG may be related to changes in body composition and a decline in nutrient utilization efficiency as the animals mature (McLennan et al., 2017) rather than a decrease in maintenance or growth requirements.

Furthermore, the efficiency of nutrient utilization tends to decrease as bulls approach maturity, and lower levels of protein supplementation can be economically beneficial (Agastin et al., 2013). In this study, the bulls were in the late growing to early finishing phase, during which growth rate naturally declines, indicating they were approaching physiological maturity.

In this context, the observed reduction in ADG over the growing period highlights the importance of providing an efficient level of supplementation. The 0.1% BW supplementation appears to be a viable alternative, as it supplies sufficient nutrients to maintain acceptable weight gains without excessive feed costs. This strategy becomes even more relevant considering that, in the next phase, the bulls will be finished under intensive pasture-based conditions, where energy supplementation is adjusted to supply glucogenic precursors that support fat synthesis (MacRae and Lobley, 1982).

The level of supplementation also influenced finishing growth performance. While increasing supplement levels from 0.05% to 0.5% of BW resulted in greater ADG during the growing phase, a decreasing linear effect was observed on the ADG in the finishing phase (112–196 days) as supplementation increased. These findings indicate that a high level of energy-protein supplementation may lead to earlier fat deposition and promote a higher carcass yield at the end of the finishing phase (Silva et al., 2021). However, fat and muscle deposition were not measured in this study, which limits further interpretations of body composition changes.

Moreover, bulls with 0.3% BW showed similar feed conversion and hot carcass weight to those receiving 0.5% BW, indicating a potential cost-benefit advantage at the lower supplementation level. These results are consistent with the findings of Valadares Filho et al. (2016), who recommended balancing supplement composition to optimize animal performance while considering economic efficiency.

During the finishing phase, bulls that had previously received only mineral additives and low levels of energy-protein supplementation, 0.05% and 0.1% of BW, exhibited higher ADG, likely due to a compensatory growth effect. These animals entered the finishing phase at a lower body weight and physiological maturity, which may have favored a greater proportion of lean tissue deposition compared with bulls that received higher supplementation levels during the growing phase (Atkinson et al., 2007). Nonetheless, the consistent provision of 1.5% of BW as a concentrate ration during the finishing phase may have enhanced energy and protein retention, offsetting the initial lighter body weight of cattle supplemented at 0.05% and 0.1% of BW.

In addition, even though intake was abruptly increased from the growing to the finishing phase, no negative impacts on rumen or cecum health were observed at slaughter. Specifically, no significant differences were found in rumen morphometric parameters, including papillae height, width, or density, among treatments. These results suggest that the rumen epithelium was able to adapt to dietary changes without showing signs of hyperplasia, or inflammation at the end of the experimental period.

Similarly, no macroscopic or histological alterations were detected in the cecum, indicating that hindgut fermentation was not adversely affected by the increased intake of non-fibrous carbohydrates. However, it is essential to acknowledge that these measurements were taken only at the end of the finishing phase. By this time, any transient digestive disturbances may have already been resolved. Therefore, the results should be interpreted with caution (Costa et al., 2008).

Increasing energy levels and providing concentrate feed before the finishing phase may help adapt the ruminal bacterial community to ferment non-fibrous carbohydrates, producing short-chain fatty acids and lactic acid. This microbial shift can stimulate epithelial development and mitigate the risk of ruminal or hindgut lesions (Nagaraja and Titgemeyer, 2007). However, despite this theoretical background, no measurable impact on rumen morphometrics or cecal health was detected in this study, possibly due to the duration of the adaptation period or the moderate level of challenge imposed by the dietary transition. Further studies are needed to determine how prior supplementation affects the dynamics of epithelial adaptation and whether changes in gastrointestinal morphology occur earlier in the feeding period but are no longer evident at slaughter.

The economic implications of supplementation strategies should be carefully considered. Although higher supplementation levels increased carcass weight, the 0.3% BW supplementation appears favorable. These results corroborate previous studies indicating that targeted supplementation can improve animal performance, optimize pasture use, and enhance farm profitability (Romanzini et al., 2020; Cardoso et al., 2020). Furthermore, using concentrate feeds in grazing systems can shorten the production cycle and increase economic returns.

The finishing system must also be considered when determining backgrounding supplementation for the growth phase. Based on the results of this study, a supplementation level of 0.5% BW during the dry season improved ADG and initial body weight for finishing compared to lower supplementation levels. However, bulls supplemented at 0.3% BW showed similar overall ADG to those receiving 0.5% BW, suggesting that lower supplementation rates may be sufficient when animals are finished under more intensive systems with higher concentrate intake. Further research is needed to validate these strategies under different finishing conditions.

Therefore, defining the finishing system is crucial for establishing backgrounding supplementation for the growing phase and maximizing production efficiency throughout the cycle. Proper supplementation planning ensures nutrient availability throughout different seasons and promotes satisfactory weight gain in pasture systems. Moderate energy-protein supplementation at 0.3% of BW enhanced performance during the growing phase without compromising results during the finishing phase in the dry season. Moreover, bulls supplemented at 0.3% of BW showed similar performance at the end of the pasture-based finishing phase compared to those receiving 0.5% of BW. Depending on pasture conditions and production goals, 0.3% may be a viable intermediate strategy. In contrast, 0.5% may be more suitable in situations with limited forage availability, aiming for higher individual animal performance.

5. Conclusions

Manipulating backgrounding supplementation by increasing supplement levels can enhance the performance of Nellore bulls fed at 1.5% of body weight during the finishing phase. In the context of this study, the optimal supplementation level for cattle sold based on live body weight is 0.1% of body weight; however, a supplementation level of 0.3% of body weight is strongly recommended for cattle sold on a carcass basis.

Data availability

Data will become available upon request to the corresponding author.

Author contributions

Data curation: Ferracini, J. G. and Millen, D. D. **Formal analysis:** Ferracini, J. G. and Millen, D. D. **Investigation:** Ferracini, J. G. and Oliveira, R. J. **Methodology:** Millen, D. D. **Project administration:**

Polli, D.; Gasparim, M. B. and Millen, D. D. **Supervision:** Feba, L. T. **Writing – original draft:** Toledo, A. F. **Writing– review & editing:** Millen, D. D.

Conflict of interest

The authors declare no conflict of interest.

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Declaration of generative AI in scientific writing

The authors declare that no generative artificial intelligence (AI) tools were used in the writing and editing of this manuscript except for grammar correction, which was conducted under the authors' supervision. The author is responsible for all intellectual contributions, data analysis, and interpretations this manuscript presents.

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