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RESEARCH ARTICLE

Increasing levels of concentrate supplement in the post-weaning period of steers on tropical pasture during the rainy season

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ABSTRACT

The intensification of cattle post-weaning phase in tropical pastures depends on supplementation strategies. The objective of this study was to assess the effect of increasing levels of concentrate supplement on the intake, apparent digestibility of nutrients, feeding behavior, and performance of Girolando steers on tropical pasture during the post-weaning phase in the rainy season. Forty uncastrated male Girolando steers, initially weighing 266.62 ± 32.95 kg and aged 11 mo, were allocated into four concentrate supplement levels: 0.2%, 0.3%, 0.4%, and 0.5% body weight. The steers grazed on *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Marandu' pasture. The intakes of supplement DM, non-fibrous carbohydrates (NFC), and total digestible nutrients increased linearly (P < 0.05) with the level of supplement offered to the steers. In a similar response, the apparent digestibility of DM and NFC from the diet also rose linearly (P < 0.05). Grazing time, total feeding time, and total chewing time decreased (P < 0.05) with the increasing levels of concentrate supplementation. In contrast, the time expended on feeding at the trough, biting rate, and the time taken to ruminate each cud increased (P < 0.05) with the supplementation level. Final body weight and average daily gain increased linearly (P < 0.05) with increasing concentrate supplementation. We recommend supplying concentrate supplement at a level of 0.5% of the body weight of steers on tropical pasture during the post-weaning phase in the rainy season.

Key words: Crude protein level, feeding behavior of cattle, grazing cattle.

INTRODUCTION

The most extensive cattle herds are situated in tropical areas of the American and Asian continents (Greenwood, 2021). In these regions, the seasonal climate poses challenges to grazable biomass production, particularly during the dry season, impacting herd performance at the same stocking rate in the pasture area (Jayasinghe et al., 2022). To address this challenge, new pastures are established, leading to substantial deforestation of tropical biomes (e.g., Amazon forest, cerrado, etc.), compromising biological diversity and contributing to global warming (Dick et al., 2021). Strategies such as pasture management and concentrate supplementation can mitigate seasonality in nutrient supply to cattle herds on pasture during the post-weaning period while contributing to environmental preservation (Costa et al., 2021; Carlson et al., 2023).

Concentrate supplementation in tropical pastures is constantly discussed in the literature (Tambara et al., 2021). However, many gaps persist, particularly concerning the amount of concentrate supplement to be supplied and its relationships with levels and types of crude protein (i.e., non-protein nitrogen – NPN or true protein) (Cox et al., 2022). The level of crude protein in the concentrate supplement is expected to enhance the utilization of neutral detergent fiber from tropical forage, directly influencing the performance of grazing cattle during the post-weaning period (Detmann et al., 2014). Nonetheless, limited information is available regarding crude protein content and the level of concentrate supplement for steers on tropical pastures in the post-weaning phase (Almeida et al., 2022).

Our hypothesis posits that an increase in concentrate supplement supply, coupled with a reduction in its crude protein content, enhances the performance of steers reared on tropical pasture during the rainy season. Thus, our objective was to evaluate the effects of increasing levels of concentrate supplement on the intake, apparent digestibility of nutrients, feeding behavior, and performance of steers on tropical pasture in the post-weaning phase during the rainy season.

MATERIAL AND METHODS

Locations, animals, and treatments

The experimental protocol for this research received approval from the Animal Use Ethics Committee (CEUA) of the State University of Southwest Bahia, in Bahia, Brazil, with approval number 84/2015.

The experiment was conducted at coordinates 15°26′46″ S and 40°44′24″ W, at an altitude of 800 m, in Bahia, Brazil. The region experiences a tropical climate with a type Aw dry season, according to Köppen-Geiger.

The study involved 40 male, uncastrated Girolando steers (half-blood) with an average body weight of 266.62 ± 32.95 kg and 11 mo of age. Prior to the experimental period, the cattle underwent treatment against endo- and ectoparasites. The experiment lasted 224 d, including the post-weaning phase, and occurred during the rainy season. The experimental design was completely randomized, comprising four treatments with 10 replicates each. Treatments involved increasing levels (0.2%, 0.3%, 0.4%, and 0.5%) of supplementation based on the percentage body weight (BW) of the animals, and formulated with grain sorghum, soybean meal, urea, and mineral salt (Table 1). The supplement was consistently provided at 10:00 h in uncovered troughs made from reused plastic barrels, accessible from both sides (70 linear cm per animal). Diets were formulated in accordance with NRC (2016) guidelines to meet the nutritional requirements of animals weighing 350 kg and anticipating gains of 0.8 kg d^{-1}.

Table 1. Percentage and chemical composition of concentrate supplements and forage. [1]Provided per kilogram: 175 g Ca; 60 g P; 107 g Na; 12 g S; 5000 mg Mg; 107 mg Co; 1300 mg Cu; 70 mg I; 1000 mg Mn; 18 mg Se; 4000 mg Zn; 1400 mg Fe; 600 mg F (maximum). [2]Simulated grazing. [3]Neutral detergent fiber corrected for ash and protein. [4]Non-fibrous carbohydrates. [5]Indigestible neutral detergent fiber. [6]Estimated total digestible nutrients.

Ingredient (g kg^{-1})		Concentrate supplement level in the diet (% body weight)			
		0.2	0.3	0.4	0.5
Ground sorghum grain		492.2	688.6	800.6	863.3
Soybean meal		313.4	190.8	113.0	67.7
Urea		139.1	83.9	59.1	45.0
Mineral salt[1]		55.3	36.7	27.3	24.0
Component, g kg^{-1} DM	*Brachiaria brizantha* 'Marandú'[2]				
DM, g kg^{-1} as fed	302.2	865.2	880.5	879.0	889.1
Mineral matter	104.6	104.8	73.0	55.5	46.6
Crude protein	103.2	568.5	392.9	293.9	237.4
Ether extract	21.1	23.8	22.2	21.5	24.9
NDFap[3]	624.2	87.3	116.1	148.6	233.0
NFC[4]	143.5	467.6	548.7	588.5	539.1
iNDF[5]	210.0	12.1	13.6	16.9	17.5
TDN[6]	549.5	649.6	713.6	743.9	762.0

The animals were distributed across a 14 ha area, comprising 12 paddocks of approximately 1.17 ha each, planted with *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Marandu'. The area was divided into three modules of four paddocks, equipped with troughs and automatic drinkers. Animals were moved across the module's paddocks every 7 d to minimize the impact of paddocks on steer performance. After a 28 d stay, a new module was occupied, and relocations within the module followed the aforementioned procedure.

Forage evaluation

Forage evaluation took place at 28 d intervals in the four entry and exit paddocks of the utilized module. The comparative visual yield method was employed to assess the total forage DM availability (Table 2).

In the entry paddocks, all collections were combined, and approximately 300 g fresh forage material was collected for manual separation. This separation aimed to identify components such as the leaf blade, stem + sheath, and senescent material, with the goal of determining the availability of each component (green DM) and understanding the leaf:stem ratio.

To calculate the forage supply (kg DM 100 kg^{-1} BW d^{-1}), it was necessary to estimate the residual dry biomass and daily DM accumulation rate. The residual dry biomass was estimated using the double-sampling methodology, while the DM accumulation rate was estimated. The potentially digestible DM in the pasture was estimated according to equation:

Potentially digestible DM = 0.98 (100- neutral detergent fiber, %) + (neutral detergent fiber, %- insoluble neutral detergent fiber, %).

Table 2. Characteristics of the pasture during the steer post-weaning period.

Variable	Value
Total DM availability, kg ha^{-1}	3.426
Digestible DM availability, kg ha^{-1}	2.840
Green DM availability, kg ha^{-1}	2.540
Forage allowance, kg DM 100 kg^{-1} BW d^{-1}	14.12
Leaf:stem ratio	1.55

Collection, processing, and analysis of food samples

Forage samples from simulated grazing were obtained following Johnson (1978). These samples were utilized to estimate nutrient intake and apparent digestibility coefficients. Samples of the concentrate supplement were collected in each period using an aliquot, and, at the conclusion of the experiment, a composite of all the material was made. The supplement and forage samples were dried in a forced-air oven at 55 °C and ground in a Wiley mill to 1 mm for chemical analyses.

The dry matter (DM), ash, crude protein (CP), and ether extract (EE) contents were determined according to the AOAC (1990) methodology. Neutral and acid detergent fibers were determined following the methodology of Van Soest et al. (1991). Ash-and protein-free neutral detergent fiber (NDFap) was measured as described by Mertens (2002). Non-fibrous carbohydrates were determined also free of ash and protein (NFCap), by the following equation: NFCap = 100- ash- CP- EE- NDFap. Because the supplement contained urea, its NFCap content was determined by the following equation: NFCap = 100- ash- EE- NDFap- (CP- CPu + U), where CPu is CP in urea; and U is urea content. Total digestible nutrients (TDN) were calculated using the equation TDN% = DCP + DNDFap + DNFC + 2.25 DEE, where DCP is digestible CP; DNDFap is digestible NDFap; DNFC is digestible NFC; and DEE is digestible EE.

Nutrient intake and apparent digestibility

Between the 134th and 145th experimental days, estimates of fecal output, intake, and digestibility of DM and nutrients were conducted. Fecal DM output was estimated using the external marker chromic oxide (10 g $animal^{-1}$ d^{-1}), administered for 12 d at 07:00 h through forced ingestion of a candy containing the marker. The first 7 d were allocated for adaptation, and the final 5 d included fecal collection at different times: 16:00 (1st day), 14:00 (2nd day), 12:00 (3rd day), 10:00 (4th day), and 08:00 h (5th day). Following collection, fecal samples were stored in the freezer at 10 °C, individually pre-dried, and ground in a Wiley mill (sieve with 1 and 2 mm screens) for chemical composition analyses, as described in the previous topic. Chromic oxide quantification, with readings performed on the atomic absorption spectrophotometer (Avanta Sigma, GBC Scientific Equipment, Perai, Malasia). Fecal output was calculated as the ratio between the amount of marker supplied and its concentration found in the feces, as shown below: FO = AMS $(MCFe)^{-1}$ × 100, where AMS is amount of marker supplied (g); and MCFe is marker concentration in the feces (%).

The estimate of forage DM intake utilized the internal marker indigestible NDF (iNDF), obtained after ruminal incubation for 288 h, from 0.5 g forage samples, supplement, and feces in duplicate. Non-woven fabric (TNT) bags with a grammage of 20 mg cm^{-2} and dimensions of 5 × 5 cm were used for the incubation. The remaining material underwent extraction with neutral detergent to determine iNDF.

Once the values of fecal output and iNDF were known, it was possible to estimate forage DM intake using the equation: Forage DM intake (kg d^{-1}) = {[(Fecal output, kg d^{-1} × Concentration of marker (iNDF) in feces, %) – Quantity of the marker (iNDF) in the concentrate supplement, kg]/Concentration of marker (iNDF) in the forage, kg kg^{-1}}.

The intake of DM from the supplement was estimated using the external marker titanium dioxide (TiO_2) (15 g $animal^{-1}$ d^{-1}), mixed with the concentrate for 11 d. It was supplied directly in the trough. The estimation was achieved through the equation: Supplement DM intake (kg d^{-1}) = [(Fecal output, kg d^{-1} × Concentration of titanium dioxide in feces, %)/Concentration of titanium dioxide in the supplement, %]. Titanium dioxide quantification with readings on the atomic absorption spectrophotometer (Libra S22, Biochrom, Cambridge, UK).

Apparent nutrient digestibility was determined using the formula: D = [(kg nutrient intake – kg nutrient output)/kg nutrient intake] × 100. Following the intake and digestibility trials, as well as chemical analyses in the laboratory, the chemical composition of the total diet was calculated.

Feeding behavior and performance

Between experimental days 168 and 172, a 96 h assessment of feeding behavior was conducted. The animals in each treatment group underwent visual evaluation by an assigned observer, utilizing clipboards and pens for comprehensive observation recording. Digital clocks were employed to precisely document the time allocated to each activity, supplemented by artificial lighting, including flashlights, during nocturnal observations.

In the development of the ethological study, the animals' activities were recorded in a field spreadsheet at 5 min intervals. The behavioral variables observed and recorded included grazing time, rumination time, feeding time at the trough, and idle time. Total feeding time was derived by summing grazing time with the time expended on feeding at the trough, while total chewing time represented the cumulative duration of grazing, rumination, and feeding at the trough.

Bite-related aspects were documented during two distinct periods of the day (09:00 to 12:00 h and 16:00 to 19:00 h). The number of bites during grazing activity was recorded, along with the time allocated to this activity in seconds. Upon commencement of the grazing activity (prehension of forage), the number of bites and time were recorded until the moment the animal swallowed the prehended forage. This approach facilitated the calculation of the average number of bites per swallow and the average time, in seconds, devoted to this activity. These variables were then used to calculate biting rate.

Rumination aspects were evaluated by an observer specifically trained to record the number of chews and the time spent ruminating each rumen cud for each animal. During the same aforementioned periods (09:00 to 12:00 h and 16:00 to 19:00 h), observations were made on three rumen cuds per animal. This approach enabled the derivation of an average number of chews per cud dedicated to the rumination process for each animal, along with the average time allocated to this activity per ruminated cud. With these two variables, the number of cuds chewed per day could be calculated.

Feeding and rumination efficiencies, measured in kg h^{-1}, for DM and NDF, were calculated by dividing their intake by the total feeding time (feeding efficiency) or by the rumination time (rumination efficiency).

Average daily gain (ADG) was determined as the difference between final body weight (FWW) and initial body weight. To adjust the supplement supply, the steers were weighed after 12 h fasting every 28 d. Feed conversion was calculated as the ratio between intake (kg d^{-1}) and ADG (kg d^{-1}).

Statistical analysis

The data underwent ANOVA utilizing orthogonal polynomial contrasts for linear and quadratic fits of the concentrate supplementation level (0.2%, 0.3%, 0.4%, and 0.5% BW) regarding the studied variables. The mathematical model used was $Y_{ij} = \mu + H_j + e_{ij}$, where Y_{ij} is value referring to the observation of the repetition i of the treatment j; μ is overall average; H_j is effect of treatment j (0.3%, 0.4%, and 0.5% BW) and e_{ij} is random error associated with observation. A significance level of 5% ($P < 0.05$) was considered, and the statistical package employed was SAEG – Statistical and Genetic Analysis System (SAEG, 2007).

RESULTS

The increasing levels of concentrate supplement in the steers' diet increased (P = 0.001) their intake of supplement DM. However, it did not influence (P > 0.05) the intakes of forage DM or total DM by the animals. Similarly, the intakes of CP and NDFap were not influenced (P > 0.05) by the increased supply of concentrate supplement. On the other hand, the intakes of NFC and TDN exhibited a linear increase (P < 0.05) with the rise in the level of concentrate supplement in the diet (Table 3).

Increasing concentrate supplement levels led to an increase (P < 0.05) in the apparent digestibility coefficients of DM and NFC from the steers' diet.

Table 3. Nutrient intake and apparent digestibility of steers supplemented with increasing levels of concentrate while grazing on tropical pasture during the post-weaning phase. [1]Standard deviation of the mean. [2]Probability of linear and quadratic order effects, significant at the 0.05 probability level. [3]Neutral detergent fiber corrected for ash and protein. [4]Non-fibrous carbohydrates. [5]Total digestible nutrients.

	Concentrate supplement level in the diet (% body weight)				SEM[1]	P-value[2]	
	0.2	0.3	0.4	0.5		L	Q
Intake, kg d^{-1}							
Total DM	9.05	9.73	9.62	10.50	1.792	0.104	0.992
Forage DM	8.17	8.41	7.82	8.33	1.515	0.999	0.971
Supplement DM	0.88	1.32	1.80	2.37	0.641	0.001	0.989
Crude protein	1.35	1.39	1.34	1.43	0.280	0.884	0.980
Ether extract	0.19	0.20	0.20	0.23	0.038	0.032	0.670
NDFap[3]	5.18	5.40	5.15	5.75	0.978	0.295	0.775
NFC[4]	1.58	1.93	2.18	2.47	0.450	0.005	0.989
TDN[5]	5.31	6.05	6.35	7.39	1.494	0.003	0.952
Apparent digestibility, %							
DM	54.05	56.31	57.95	59.44	4.6119	0.009	0.975
Crude protein	63.52	62.00	60.38	58.54	6.3432	0.073	0.999
Ether extract	72.66	74.15	75.36	80.79	12.4592	0.154	0.860
NDFap[3]	54.18	55.46	57.72	57.52	5.7907	0.142	0.919
NFC[4]	61.26	68.80	69.49	75.11	8.7548	0.001	0.947
TDN[5]	59.96	59.03	58.75	59.05	2.8770	0.658	0.716

Grazing time, total feeding time, and total chewing time decreased linearly (P < 0.05) with the increasing level of concentrate supplement offered to the animals. Conversely, the times spent idle and feeding at the trough of the steers increased (P < 0.05) with the levels of concentrate supplement in the diet (Table 4).

During grazing, the steers showed a decrease (P < 0.05) in the time taken to swallow each bite and an increase in biting rate as the level of concentrate supplement was raised. Additionally, the time expended on the rumination of each cud rose (P < 0.05) with the level of concentrate supplement provided.

The final body weight and average daily gain of the steers increased (P < 0.05) with the level of concentrate supplement provided to them. However, feed conversion was not influenced (Table 5).

Table 4. Feeding behavior of steers supplemented with increasing levels of concentrate while grazing on tropical pasture during the post-weaning phase. [1]Standard deviation of the mean. [2]Probability of linear and quadratic order effects, significant at the 0.05 probability level.

	Concentrate supplement level in the diet (% body weight)				SDM[1]	P[2]	
	0.2	0.3	0.4	0.5		L	Q
Grazing time, min	600.38	565.38	552.13	501.63	57.985	0.002	0.544
Rumination time, min	460.00	452.38	462.88	461.00	73.772	0.977	0.980
Idle time, min	361.38	401.63	394.88	448.25	79.464	0.003	0.844
Time at trough, min	18.25	20.63	30.13	29.13	12.692	0.002	0.549
Total feeding time, min	618.63	586.00	582.25	530.75	61.070	0.003	0.416
Total chewing time, min	1078.63	1038.38	1045.25	991.75	79.445	0.003	0.884
Number of bites per swallow, nr	19.18	17.79	18.69	18.45	2.422	0.631	0.135
Time per swallowed bite, s	24.52	23.30	22.10	22.05	4.010	0.002	0.467
Biting rate, nr s^{-1}	47.71	46.39	51.94	50.67	6.762	0.003	0.999
Rumination chews, n cud^{-1}	52.44	54.25	56.82	53.10	7.836	0.094	0.027
Time per ruminated cud, s	51.86	51.45	52.87	53.30	6.641	0.002	0.222
Feeding efficiency, kg DM h^{-1}	0.88	1.01	1.00	1.20	0.224	0.670	0.003
Feeding efficiency, kg NDFap h^{-1}	0.51	0.56	0.54	0.66	0.122	0.134	0.003
Rumination efficiency, kg DM h^{-1}	1.21	1.33	1.27	1.39	0.327	0.919	0.856
Rumination efficiency, kg NDFap h^{-1}	0.70	0.74	0.68	0.70	0.179	0.073	0.986

Table 5. Performance of steers supplemented with increasing levels of concentrate while grazing on tropical pasture during the post-weaning phase. [1]Standard deviation of the mean. [2]Probability of linear and quadratic order effects, significant at the 0.05 probability level.

	Concentrate supplement level in the diet (% body weight)				SDM[1]	P-value[2]	
	0.2	0.3	0.4	0.5		L	Q
Initial body weight, kg	264.00	265.10	263.30	274.10	32.955	0.773	0.884
Final body weight, kg	424.20	436.70	435.60	460.50	36.677	0.045	0.835
Average daily gain, kg d^{-1}	0.71	0.77	0.77	0.83	0.089	0.007	0.986
Feed conversion	12.86	12.75	12.66	12.72	2.667	0.996	0.998

DISCUSSION

The intake of DM from the supplement increased with the increasing quantity of concentrate supplement available in the trough (Lins et al., 2022). However, no decrease in forage DM intake was observed, possibly attributed to the heightened availability of green DM and forage allowance in the pasture during the rainy season (Jayasinghe et al., 2022). This circumstance allowed steers to selectively consume forage mass with higher nutritional density (Chirat et al., 2014), without adversely affecting forage DM intake (see biting rate) (Charmley et al., 2023). The consumption of the more digestible portion of the forage, coupled with increased intake of DM from the supplement, resulted in an enhancement of the apparent digestibility of DM from the steers' diet. Canozzi et al. (2023) similarly reported that moderate levels of corn grain (0.1% and 0.4% BW) elevate the apparent digestibility of DM in the diet of steers.

Crude protein intake remained consistent across supplementation levels in the present experiment, as the reduction in the CP content of the supplement was compensated by the increased level of concentrate supplementation, resulting in a similar amount of CP (g d^{-1}) offered to the animals via the supplement. In contrast, Santos et al. (2019) reported an increase in CP intake by heifers with the rise in the energy content of the supplement. In our study, the alteration of the origin of the supplement's CP, shifting from a greater share of non-protein N (NPN) from urea and true protein from soybean meal to CP primarily derived from sorghum grain, may explain the similarity in CP intake between the steers

(Manoukian et al., 2022). Nonetheless, differences in rumen solubility of CP sources (NPN or true protein) did not appear to influence protein digestibility in the total tract of steers, possibly due to the substantial contribution of CP (103.2 g kg^{-1}) from pasture (Batista et al., 2017) and N recycling (Silva et al., 2019). Although there was no difference in apparent protein digestibility, Silva-Marques et al. (2017) suggest that supplements richer in protein improve the N balance of beef cattle during the rainy season.

Increasing concentrate supplement levels did not affect NDFap intake, potentially due to the elevated NDFap content within the concentrate supplement itself. Additionally, the consistent NDFap intake, even with higher concentrations of concentrate supplementation, can be attributed to the quality and accessibility of the pasture offered to the animals (Barbero et al., 2020). The augmentation in supplement supply, marked by an increase in starch, did not impact the apparent digestibility of NDFap in the steers' diet, possibly because the CP level in the pasture is already sufficient to facilitate ruminal fermentation of the potentially fermentable NDFap from the pasture (Sousa et al., 2022). Lazzarini et al. (2016) similarly observed no effect on the digestibility of NDFap when adding starch or associating starch with protein in steer supplementation on pasture.

The intake and apparent digestibility of NFC were enhanced with the increased supply of concentrate supplement for the steers, likely due to the greater availability of NFC, primarily starch, present in the sorghum grain of the concentrate supplement. It can be inferred that the increased availability of energy from the elevated intake of digestible NFC resulted in heightened serum insulin (Almeida et al., 2018) and stimulated anabolism in the steers, as evidenced by the increase in ADG. This rise in NFC intake and digestibility may have contributed to the observed increase in TDN intake by the steers with an elevated supply of concentrate supplement.

The approximately 100 min d^{-1} reduction in the steers' grazing time, even without a decrease in forage DM intake, can be ascribed to alterations in their grazing behavior resulting from the increased supply of concentrate supplement. The cattle likely adjusted the depth, rate, and number of bites to the forage mass with the augmented supply of concentrate supplement (Lins et al., 2022) to meet their energy requirements through both forage and concentrate supplement. Furthermore, the greater availability of concentrate supplement also accounts for the extended time expended by animals at the trough (Mendes et al., 2014).

Supplement DM intake rose with the increase in concentrate levels, which likely elevated the proportion of DM in the steers' rumen content (Goulart et al., 2020). This occurrence may be linked to the observed increase in the number of chews per cud and the time per cud chewed by the steers. In other words, cattle supplemented with higher concentrations of concentrate performed more chews on ruminated cuds with higher DM content (Sugg et al., 2021). This may also elucidate the greater number of chews per cud and time per cud chewed by the steers.

The increased TDN intake resulted in a rise in the ADG and final body weight of steers receiving an increased supply of concentrate supplement in the trough during the post-weaning phase. The modest increase (approximately 100 g d^{-1}) in performance with the rise in concentrate supplement from 0.2% to 0.5% BW may be attributed to the availability of green DM from the pasture and the high protein content of the forage (103.2 g kg^{-1} DM). Sousa et al. (2022) reported that even during the rainy season, there is a response to supplementation as long as the CP content of the pasture is below 150 g kg^{-1} DM. Additionally, Fernandes et al. (2015) indicated that the improvement in the performance of steers supplemented with different protein levels and profiles only occurs with the provision of proteins with lower degradation rates. These findings support our results, as sorghum grain protein (predominant at higher levels of supplementation) is a prolamin with low rumen solubility (Liu et al., 2019).

During the rainy season with ample forage availability (14.12 kg DM 100 kg^{-1} BW d^{-1}), increasing the energy density of the supplement while maintaining a constant supply of CP (g d^{-1}) improves the performance of steers in the post-weaning phase and can be a strategic approach in the production of lean cattle for sale.

CONCLUSIONS

Increasing the supply of concentrate supplement while maintaining the amount of crude protein per day for steers in the post-weaning phase increases nutrient intake from the supplement, improves DM digestibility, reduces grazing time, and enhances animal performance. Therefore, it is advisable to provide concentrate supplement at a level equivalent to 0.5% of body weight for steers on tropical pasture during the post-weaning phase in the rainy season.

Author contribution

Conceptualization: D.S.B., F.F.S., L.V.S., G.T-J., J.W.D.S., T.R.P. Methodology: D.S.B., F.F.S., L.V.S., G.T-J., J.W.D.S., T.R.P. Software: F.B.L.M., G.G.P.C. Validation: F.B.L.M., G.G.P.C. Formal analysis: L.V.S., R.R.S. Investigation: D.S.B., F.F.S., L.V.S., G.T-J., J.W.D.S., T.R.P., F.B.L.M. Resources: R.R.S. Data curation: G.G.P.C., D.M.L-J., R.R.S. Writing-original draft: D.M.L-J. Writing-review & editing: D.M.L-J. Visualization: D.M.L-J. Supervision: R.R.S. Project administration: F.F.S., R.R.S. Funding acquisition: G.G.P.C., F.F.S., R.R.S. All co-authors reviewed the final version and approved the manuscript before submission.

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