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Effects of supplement type during the pre-finishing growth phase on subsequent performance of Nellore bulls finished in confinement or on tropical pasture

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ABSTRACT

Objective: Our objective was to evaluate the effect of supplement type fed during the pre-finishing growth phase of grazing Nellore bulls on gain performance during the subsequent finishing phase, either in confinement or on pasture. During the pre-finishing growth phase, bulls were grazed on pastures of *Urochloa brizantha* cv. Marandu. Bulls were supplemented with 1 of 4 supplements: (1) ad libitum mineral mixture (MM), (2) ground corn (GC), (3) GC with soybean meal (SBM), or (4) GC with dried distillers grain (DDGM). All supplements were administered at 3 g/kg of body weight (BW) on a dry matter (DM) basis.

Materials and Methods: Eighty bulls were distributed in a completely randomized, 4 × 2 factorial arrangement, with 4 pre-finishing supplementation treatments (MM, GC, SBM, or DDGM) and 2 finishing systems (pasture or confinement). Ten cattle from each postweaning treatment were kept on pasture (n = 3 paddocks/treatment), and 10 bulls were housed in confinement pens (n = 3 pens/treatment). Bulls finished on pasture were offered a concentrate supplement consisting of 337.6 g/kg dried distillers grain (DDG), 611.2 g/kg GC, and 56.1 g/kg MM. The final diets offered in the confinement system consisted of 300 g/kg corn silage, 427.8 g/kg GC, 263.3 g/kg DDG, and 35.8 g/kg MM (DM basis).

Results and Discussion: During the finishing phase, bulls that received GC and DDGM in pasture consumed more CP than bulls in the confinement system (P = 0.001). Nutrient digestibility was greater among the bulls in pasture than those in confinement ($P \leq 0.001$), likely because of the lower proportion of NDF consumed by bulls that expressed selective grazing behavior (P = 0.001). Daily weight gain was affected by pre-finishing history (P = 0.03) and finishing system ($P \leq 0.001$) and was lower after SBM supplementation for bulls on pasture (P = 0.009). The final BW ($P \leq 0.001$), hot carcass weight ($P = 0.005$), and fat thickness ($P \leq 0.001$) were greater in bulls finished in confinement, but carcass yield was greater in bulls from pasture ($P \leq 0.001$).

Implications and Applications: Preweaning supplementation affected the intake of nutrients in Nellore bulls finished on pasture postweaning but did not affect the intake of bulls finished in a confinement feedlot. Supplementation with DDGM in the preweaning phase (3 g/kg of BW) did not affect animal performance or carcass traits in either finishing system. Therefore, it is an option for replacing conventional supplements.

Key words: dried distillers grains, feedlot, Nellore breed, tropical pasture, zebu cattle

INTRODUCTION

Pre-finishing supplementation can increase grazing cattle gains, leading to increased BW at the beginning of the finishing phase, decreasing the time required for finishing bulls, and improving carcass traits and meat quality (Poppi et al., 2018; Hoffmann et al., 2021a). According to Carvalho et al. (2020), dietary supplementation with minerals, energy, and protein at different growth phases is indispensable when beef cattle grazed on tropical pastures are slaughtered at less than 24 mo of age. Animal performance response to supplementation is affected by the

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nutrients provided by the supplement to correct dietary limitations and meet quantitative and qualitative nutrient requirements, with concomitant effects on intake, digestibility, and nutrient metabolism (Mertens and Grant, 2020; Hoffmann et al., 2021a).

Dietary inclusion of less-expensive feeds and feed by-products, such as dried distillers grains (**DDG**), is now being considered as a replacement for conventional feed ingredients in sustainable beef production systems (Tedeschi et al., 2015; Hoffmann et al., 2021a,b). The shift in ingredient usage for cattle feed implies a more efficient use of natural resources and a reduction in the impact of livestock systems on society by avoiding competition with resources for human food (Tedeschi et al., 2015; Dubeux Jr. et al., 2017).

The use of DDG, a grain ethanol agro-industry by-product, is promising because it can meet the energy and protein requirements of diets fed to cattle during the finishing phase on pastures or in confinement (Buckner et al., 2008; Smith et al., 2016; Cardoso et al., 2020; Fonseca et al., 2020; Smith et al., 2020, 2021; Hoffmann et al., 2021b). This by-product has a great biological value (Tedeschi et al., 2009), as it is a good source of RUP, comprising 470 to 530 g/kg CP, increasing metabolizable protein flow to the small intestine of beef cattle grazing on tropical forage (Fonseca et al., 2020). Furthermore, corn DDG has a low starch content and highly digestible NDF, which can be used in confinement systems to reduce the risk of acidosis and improve ruminal health (Pecka-Kiełb et al., 2017). Previous studies evaluating the replacement of conventional protein sources, such as cottonseed meal and soybean meal, have showed that at a supplementation level of 3 g/kg of BW (on a DM basis), DDG is a viable protein alternative because it has the same potential for animal performance and can be used to intensify beef cattle production (de Araújo et al., 2021; Hoffmann et al., 2021a).

Although DDG has been used in confinement diets in temperate regions, primarily for *Bos taurus* (Smith et al., 2020, 2021), information on the application of DDG in finishing system diets of tropical regions in confinement or on pasture and its ability to improve beef cattle production efficiency is limited (Soares et al., 2015; Martins et al., 2018; Alhadas et al., 2021; Boas e Silva et al., 2020). Therefore, we hypothesized that cattle finishing performance is influenced by diet during the pre-finishing backgrounding phase and the finishing system. We aimed to evaluate the effects of the supplement type fed during the pre-finishing growth phase of grazing Nellore bulls on their gain performance during the subsequent finishing phase, either in confinement or on pasture.

MATERIALS AND METHODS

All procedures implemented in the present study followed the Ethical Principles in Animal Experimentation adopted by the National Council for the Control of Animal Experimentation, with protocol no. 12703/15, and were approved by the Committee on Ethics in the Use of Animals, São Paulo State University "Júlio de Mesquita Filho" (UNESP).

Experimental and Environmental Parameters

The study was conducted at the Forage and Grasslands sector of São Paulo State University "Júlio de Mesquita Filho" (FCAV/UNESP), Jaboticabal, São Paulo, Brazil, located at 21°15′22″S, 48°18′58″W, at an altitude of 595 m, in a subtropical AW-type climate (tropical climate with dry winter, based on the Köppen classification; Köppen and Geiger, 1928). Based on meteorological data from the Agroclimatological Station of FCAV/UNESP (Jaboticabal, São Paulo, Brazil; conventional meteorological station, EMC), average temperatures during the study ranged from 17.9 to 21.0°C, with minimum and maximum temperatures of 11.3°C and 25.6°C, respectively. The total rainfall was 135.2 mm, and the average relative humidity was 59.4% during the trial period.

Pre-Finishing Growth Phase and Animal Feeding

Before the finishing phase, the bulls were reared during the rainy season (from October to March in Central Brazil) in a growth-phase experiment by Ferrari et al. (2021). Bulls were grazed on Marandu grass pastures [*Urochloa brizantha* (Hochst ex A. Rich) Stapf cv. Marandu] managed at 25-cm height, under continuous grazing and a variable stocking rate, using the put-and-take stocking approach (Mott and Lucas, 1952). This approach was chosen based on a 7-yr experiment that showed that this grazing height promoted greater forage production and animal performance per area (Santana et al., 2017).

We used 80 Nellore bulls (17 ± 2 mo old; 251 ± 13.2 kg initial BW), receiving 1 of the 4 supplement types: (1) only mineral mixture (**MM**) supplementation ad libitum; (2) supplementation with ground corn (**GC**), composed of 918.42 g/kg GC and 81.58 g/kg MM, at 3 g/kg of BW; (3) supplementation with GC and soybean meal (**SBM**), composed of 627.46 g/kg GC, 242.00 g/kg SBM, and 130.54 g/kg MM, at 3g/kg of BW; or (4) supplementation with GC and corn DDG, composed of 413.00 g/kg DDG, 466.72 g/kg GC, and 120.48 g/kg MM, at 3 g/kg of BW (**DDGM**). The inclusion of corn DDG was determined based on CP content. The chemical compositions of the 4 diets are presented in Table 1.

The bulls were supplemented every morning (1100 h), and the supplements were allocated in an uncovered feeder with a linear space of 0.3 m per animal. The amount of supplement was adjusted according to the BW of each animal every 28 d.

The pre-finishing experiment was evaluated over four 28-d periods, following a 21-d adaptation period, totaling 112 experimental days and 133 total days. The cattle were distributed in 12 paddocks, with 3 replicates (paddocks) per treatment. There were 2 paddocks with 1.3 ha within

Table 1. Composition of the supplements used during the pre-finishing phase provided to Nellore bulls grazed on pastures of *Urochloa brizantha* 'Marandu'[1]

		Supplement		
Component[2]	MM	SBM	GC	DDGM
Ingredient (g/kg, DM basis)				
DDG	—	—	—	413.00
Corn	—	627.46	918.42	466.72
Soybean meal	—	242.00	—	—
Mineral mix[3]	1,000	130.54	81.58	120.48
Chemical composition of supplements (g/kg, DM basis)				
Calcium	199.00	260.00	199.00	237.00
Phosphorus	40.00	100.00	40.00	100.00
Sulfur	52.00	52.00	62.00	88.00
Sodium	140.00	140.00	70.00	130.00
NDF	—	31.20	39.91	44.37
iNDF	—	4.34	3.84	5.69
NFC	—	31.32	64.00	34.65
TDN	—	68.22	73.71	70.07
EE	—	2.74	3.48	5.08
Starch	—	465.08	661.26	366.19
Ash	100.00	198.53	160.20	181.08
CP	—	16.05	7.08	16.02
RDP (g/kg, CP basis)	—	642.20	592.20	586.50
RUP (g/kg, CP basis)	—	35.78	40.78	41.35
Fractions of protein (g/kg; CP basis)				
A	—	180.90	232.70	134.10
B1	—	103.70	36.40	63.40
B2	—	658.20	575.00	714.50
B3	—	21.20	116.50	14.60
C	—	36.00	39.40	73.40

[1]MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains (DDG). Data were collected during the rainy season, from Dec. 2016 to Apr. 2017.

[2]iNDF = indigestible NDF; NFC = nonfibrous carbohydrates; EE = ether extract; fractions of protein: A = NPN, B1 = true protein rapidly degradable in the rumen, B2 = true protein with intermediate degradation rate in the rumen, B3 = true protein with slow degradation rate in the rumen, and C = unavailable or cell-wall-bound true protein..

[3]Warranty levels: monensin sodium salt 200 (80 g/kg of product).

each treatment and 8 bulls/paddock, and 1 with 0.7 ha, with 4 bulls/paddock, for a total of 20 bulls/treatment.

Finishing Phase

The finishing experiment was conducted during the dry season, corresponding to the period between May and September in Central Brazil. The experimental period was 133 d, from May 1 to September 10, 2016, with the first 21 d for adaptation to the diets and 4 evaluation periods of 28 d each for the pasture and confinement systems.

The bulls from the pre-finishing phase in the pasture were randomly and equally distributed in 2 different finishing systems: confinement or pasture, with a high-concentrate diet. For each pre-finishing treatment, 10 cattle were kept on pasture (n = 40), and 10 were housed in confinement (n = 40). Three paddocks from each pre-finishing treatment were used for pasture finishing (n = 12); two 1.3-ha paddocks contained 4 bulls, and one 0.7-ha paddock contained 2 bulls, to minimize possible environmental and stress effects.

The Nellore bulls in the pasture finishing system were weighed once at the beginning of the experimental period, after a 12-h feed and water fasting period (d 22, after a 21-d adaptation period), using an electronic digital scale (Indicator VF-B, Valfran). The mean initial BW of the bulls was 385 ± 30 kg. The pasture stocking rate was maintained at 2.5 animal units/ha (1 animal unit = 450 kg of BW) in all paddocks, using other bulls of the same

Table 2. Chemical composition of supplements and Marandu grass or corn silage in pasture or feedlot finishing systems

Item[1]	Supplement	Forage[2]	Total diet
Pasture finishing system (g/kg, DM basis, pasture)			
DDG	337.6	—	—
Ground corn	611.2	—	—
Mineral mixture[3]	51.2	—	—
Chemical composition (g/kg, DM basis)			
Starch	464.7	—	325.3
OM	938.9	905.4	928.8
NDF	417.6	614.4	476.6
Crude energy (MJ/kg of DM)	184.4	174.1	181.3
EE	50.1	29.8	44.0
TDN	814.9	530.0	729.4
CP	185.0	123.3	166.5
RDP (g/kg, CP basis)	608.1	561.6	594.1
RUP (g/kg, CP basis)	391.9	438.3	405.8
Confinement finishing system (g/kg, DM basis, silage)			
Corn silage	300.0	—	—
Ground corn	427.8	—	—
DDG	236.3	—	—
Mineral mixture[3]	35.8	—	—
Chemical composition (g/kg, DM basis)			
Starch	325.3	300.0	317.7
OM	854.5	956.5	885.1
NDF	209.4	582.5	321.3
Crude energy (MJ/kg of DM)	417.0	178.1	345.3
EE	23.8	35.2	27.2
TDN	750.8	632.2	715.2
CP	148.0	85.3	129.2
RDP (g/kg, CP basis)	760.1	682.5	736.8
RUP (g/kg, CP basis)	239.9	317.5	263.1

[1]DDG = dried distillers grains; EE = ether extract; TDN = total digestible nutrients; CP = crude protein; RDP = ruminal degradable protein; RUP = rumen undegradable protein;.

[2]Roughage: forage in pasture system, and corn silage in confinement system.

[3]Composition of mineral mixture: Ca, 6.6 g/kg; Co, 96.6 mg/kg; Cu, 17.15 mg/kg; I, 0.77 mg/kg; Mn, 47.23 mg/kg; Na, 2.5 g/kg; S, 8.9 g/kg; Se, 22.14 mg/kg; P, 3.4 g/kg; Zn, 69.52 mg/kg; sodium monensin, 24.5 mg/kg; supplementation ad libitum.

genetic pattern only to adjust the stocking rate according to the put-and-take technique (Mott and Lucas, 1952) in a continuous stocking system.

The other 40 bulls, 10 from each of the 4 pre-finishing treatments, were distributed across 12 pens of 60 m^2 each in the confinement system. We used 3 pens/treatment (n = 12 pens), in which 2 pens contained 3 bulls, and 1 pen contained 4 bulls. The bulls were weighed at the beginning of the experiment after a 12-h feed and water fasting period (d 22, after a 21-d adaptation period), using an electronic digital scale (Indicator VF-B, Valfran), and had an average initial BW of 387 ± 20 kg.

Bulls finished on pasture were offered a concentrate supplement consisting of 337.6 g/kg DDG, 611.2 g/kg GC, and 56.1 g/kg MM (Table 2). In the pasture finishing system, supplements were provided ad libitum daily in an uncovered feeder, and the quantity of feed was adjusted to allow 3 to 5 g/kg orts, which were weighed daily and removed from the feeder before allocating the supplement again.

Before adaptation, all bulls were treated for endo- and ectoparasites using fluazuron pour-on for cattle tick control (Acatak, Elanco Animal Health) and albendazole sulfoxide as a vermifuge (Agebendazol, Agener Uniao). The 21-d adaptation period for the bulls in the confinement system followed a stair-step protocol in which the amount of concentrate was increased every 3 d. The adaptation diet consisted of a roughage-to-concentrate ratio of 72:28. The proportion of concentrate started and finished at 3 g/kg and 18 g/kg BW, respectively. The final diet had a

30:70 ratio, administered twice daily (two-thirds at 0700 h and one-third at 1600 h). Morning orts were weighed to adjust their quantity to daily orts of 3 to 5 g/kg. Final diets offered in the confinement (**CF**) system (Table 2) consisted of 300 g/kg corn silage, 427.8 kg/kg GC, 263.3 g/kg DDG, and 35.8 g/kg MM (DM basis).

The diets were formulated according to the National Academies of Sciences, Engineering, and Medicine (NASEM, 2016) and the Ruminant Nutrition System (Tedeschi and Fox, 2020a,b) nutrition models. In both finishing systems, the supplement provided had the same ingredients, but the forage sources in the pasture system (**PS**) and CF were Marandu grass pasture and corn silage, respectively. Corn silage was harvested at a two-thirds milk line and contained 32.4% DM, 3.73% total volatile fatty acids, 2.94% lactic acid, 2.48% acetic acid, and approximately 45% corn grain. Table 2 shows the chemical compositions of supplements and forage in PS and CF.

Forage Mass and Morphological Composition of Pasture

Forage mass (DM/ha) was measured every 28 d, and 80 points/ha of Marandu grass was determined randomly in the paddock using a graduated ruler (Barthram, 1985). Three representative grass samples of average height were collected from each paddock by cutting 5 cm above the soil of all herbage present in a 0.25-m^2 metal frame. All samples were split into 2 portions to determine the DM content and morphological composition (fractionated into leaves, stems and sheaths, and dead material). The grass samples were dried in a forced-air circulation oven at 55°C for 72 h, and the total DM and ratios (%) of morphological components were determined to estimate forage mass.

Nutrient Intake and Digestibility

Nutrient intake and digestibility were determined in 24 bulls, with 6 bulls/treatment and 2 bulls/paddock in PS. Supplement intake was determined as the average intake by bulls maintained in the paddock, according to the difference between feed supply and orts. Forage intake was estimated based on individual fecal production, using indigestible NDF (**iNDF**) as an internal marker (Norris et al., 2019) and chromium oxide (Cr_2O_3) as an inert external marker, which is the standard used for investigative purposes in Brazil and approved by the local and national Ethics Committees on the Use of Animals.

We administered 10 g of Cr_2O_3 per day to each animal via the esophagus for 10 d. The first 7 d were regarded as adaptation, and feces were collected during the last 3 d (Hopper et al., 1978) at 0700 h, 1100 h, and 1500 h to form a composite sample for each bull (n = 6 bulls/treatment). The fecal recovery of Cr_2O_3 was determined as described by Williams et al. (1962), and fecal excretion (FE) was calculated using the following equation (Le Du and Penning, 1982):

$$\mathrm{FE(g/d)} = \frac{\text{provided } \mathrm{Cr_2O_3(g/d)}}{\text{concentration of } \mathrm{Cr_2O_3(g/kg\ of\ DM)}}.$$

To quantify iNDF, hand-plucked forage and feces samples were ground in a Willey mill with a 2-mm sieve, conditioned in Ankom F-57 filter bags (Ankom Technology), and allocated in situ into the rumen of cannulated bulls for 288 h, as described by Norris et al. (2019). We used 4 rumen-cannulated bulls (17 ± 2 mo old; 260 ± 7 kg), with the same genetic pattern, of which 2 were kept on pasture and 2 were allocated in a pen. All cannulated bulls were fed the same diet in each system. After removal from the rumen, the bags were washed, dried, and extracted with neutral detergent solution using an Ankom fiber analyzer (Model 200, Ankom Technologies).

In the confinement system, bulls' feed intake was measured daily in each pen by determining the differences between feed supply and orts. The diet and orts of each pen were sampled weekly, creating a composite sample at the end of each 28-d experimental period.

During the last 3 d of each 28-d experimental period, samples of 200 g of feces were collected from the confined bulls immediately after defecation, to determine digestibility. The samples were collected at alternate times: 1100 h and 1600 h, 0900 h and 1500 h, and 0700 h and 1400 h on the first, second, and third days of collection, respectively. A sample of feces was composed of samples collected over the days and times of collection for each bull (n = 10 bulls/treatment). The samples were identified and subsequently analyzed for iNDF content (Valente et al., 2011), to determine fecal excretion through an internal marker (Cochran et al., 1986), and other bromatological analyses, such as DM, OM, ether extract (**EE**), CP, NDF, and ADF, following AOAC (2012) methodologies.

In both systems, from the intake of nutrients from supplement or forage, or both, and their excretion in feces, the total apparent digestibility of each nutrient was calculated as follows:

$$\mathrm{DDM} = \frac{(\mathrm{TDMI} - \mathrm{FE})}{\mathrm{TDMI}},$$

where DDM = total apparent digestibility of DM (%); TDMI = total DMI (kg/d); and FE = fecal excretion (kg/d).

Analysis of Forage, Feed Samples, Orts, and Feces

Simulated grazing collections were performed using the hand-plucking method (Sollenberger and Cherney, 1995), to evaluate the chemical composition of the forage every 28 d. The samples were dried in a forced-air circulation oven at 55°C for 72 h and ground in a Willey mill with a 1-mm sieve for chemical analysis.

The diet and orts from each pen in the confinement system were sampled weekly (d 7, 14, 21, and 28 of each period) and combined into a single composite sample at the end of each 28-d experimental period (n = 4 samplings/period).

Samples of forage, feed, and orts were dried in an oven at 55°C for 72 h and then ground in a Willey mill with 2- and 1-mm sieves for iNDF and chemical component analyses, respectively. The chemical analysis included orts DM, OM, EE, and CP, conducted according to AOAC (2012), and NDF and ADF conducted according to Van Soest et al. (1991). Because of the high grain content of feed samples, 250 μL of α-amylase per gram of supplement and confinement feed samples was added to the filter bags for NDF analysis (AOAC, 2012).

Animal Performance and Carcass Characteristics

Nellore bulls were weighed after a 12-h feed and water fasting period after the adaptation period, at the beginning (d 21) and end of the experimental period (d 133) to determine their ADG. Intermediate weighing, without fasting, was also conducted at the end of each 28-d experimental period (d 49, 77, and 105) to adjust the supplement supply. After 133 d of the total experiment, CF and PS animals were slaughtered at a commercial slaughterhouse in São Paulo State, Brazil.

The carcass of each animal was divided into 2 half-carcasses, which were weighed to determine the hot carcass weight. Subsequently, carcass yield was determined as a function of fasting BW and hot carcass weight. Carcasses were chilled for 24 h, and samples of the 12th and 13th ribs were obtained from the longissimus thoracis et lumborum, to measure the fat thickness and loin eye area (Greiner et al., 2003). The loin eye area was traced on transparencies for later measurement on a planimeter, and the subcutaneous fat thickness was evaluated with the aid of a digital caliper at the point corresponding to three-quarters of the distance between the medial part of the spine and the lateral part of the loin eye area (Greiner et al., 2003).

Statistical Analyses

The bulls were distributed in a completely randomized block design, using a 4 × 2 factorial arrangement, with 4 pre-finishing growth phase supplementation treatments (MM, GC, SBM, and DDGM) and 2 finishing systems (PS and CF). Data were analyzed using SAS University Edition (SAS Institute Inc.). A mixed model was assumed and analyzed using PROC MIXED. The supplements, finishing systems, and interactions in the mixed model were considered fixed effects. Random effects included animal, paddock or collective pen, and periods (mainly to understand forage conditions), and the best covariance structure was selected using the corrected Akaike criterion. Paddocks and collective pens were considered the experimental units because bulls from the same pre-finishing treatment were maintained in that treatment during the finishing phase. Intake and digestibility were measured in groups of bulls in confinement, and each animal's performance and carcass traits comprised an experimental unit for both finishing systems. The data analytics procedures detailed by Tedeschi (2022) were followed, to ensure the robustness of the data. Normality was assessed using Student's residual tests, and $P > 0.05$ indicated normality (Cramer-von Mises tests). The Box-Cox transformation was used when a normal distribution was not established. This transformation was sufficient to reach a normal distribution. The means were compared using Tukey's test at a significance level of 0.05. P-values ≤ 0.05 were considered significant, and values between 0.05 and 0.10 constituted a trend.

RESULTS AND DISCUSSION

Forage intake of grazing bulls averaged 2.01 kg of DM/d, which did not differ among the pre-finishing treatments ($P = 0.42$), and this was supported by forage allowance and the chemical and morphological composition of the pasture. During the finishing phase in the pasture, the average forage mass was 5.4 t/ha of DM, and was composed of 183.8, 124.4, and 701.5 g/kg of green leaf, stem, and dead material, respectively (Table 3). Forage chemical components, including OM, NDF, and EE contents, did not differ among pre-finishing treatments and were 906.7, 616.4, and 38.4 g/kg, respectively (Table 3). The CP content was lowest in MM compared with the SBM, GC, and DDGM treatments ($P < 0.001$; Table 3).

Nutrient intakes, including total DMI ($P = 0.001$), OM intake, CP intake, NDF intake, and nonfibrous carbohydrate intake ($P \leq 0.001$; Table 4), were greater in CF than on pasture. Also, comparing each pre-finishing treatment among finishing systems, nutrient intakes were consistently greater in confinement ($P < 0.05$). The confined cattle presented greater ADG than bulls finished in PS ($P \leq 0.001$), averaging 1.4 kg/d and 1.1 kg/d, respectively (Table 4). However, bulls fed MM and finished in PS had greater ADG (1.22 kg/d) than the other pre-finishing treatments in this finishing system ($P = 0.009$), which was not different from bulls fed MM in the CF system. The interaction effects of pre-finishing supplementation on finishing systems for nutrient intake and animal performance variables are shown in Figure 1.

Forage intake depends on nutritional and non-nutritional factors (Galyean and Gunter, 2016; Poppi et al., 1987). Non-nutritional factors include forage allowance and structure, animal selection, grazing time, bite size, and ingestion rate. However, nutritional factors are associated with the chemical composition and digestibility of forage, especially fiber, which causes physical satiation by filling the rumen and is also related to the passage rate (Poppi et al., 1987; Galyean and Gunter, 2016). In the present study, cattle had lower total DMI when finished in PS than when finished in CF. Animals in confinement were fed twice a day, which may have increased the TMR

Table 3. Forage mass, morphological composition, and chemical composition of Marandu grass pastures during the finishing phase

Item[1]	Supplement[2]				Experimental period					P-value[3]		
	MM	SBM	GC	DDGM	1	2	3	4	SEM	PF	EP	PF × EP
FM (t/ha)	5.30	5.40	5.40	5.40	6.60^{a}	6.00^{b}	5.30^{c}	3.60^{d}	4.371	0.97	<0.001	0.66
Green leaf (g/kg)	180.00	168.00	205.00	182.00	215.70^{ab}	256.60^{a}	157.20^{bc}	106.00^{c}	0.864	0.53	<0.001	0.85
Stem (g/kg)	129.00	122.00	118.50	128.00	178.60^{a}	114.30^{b}	133.70^{b}	69.20^{c}	0.357	0.62	<0.001	1.00
Dead material (g/kg)	694.00	702.00	712.00	698.00	606.00^{c}	677.00^{b}	712.00^{b}	831.00^{a}	0.806	0.58	<0.001	0.92
Chemical composition (g/kg DM)												
OM	910.80	906.70	605.00	604.60	906.60^{ab}	910.80^{a}	900.1^{a}	909.60^{ab}	130.412	0.31	0.04	0.62
NFD	622.30	631.10	595.50	616.70	652.70^{a}	582.90^{b}	610.2^{ab}	619.7^{ab}	59.850	0.22	0.002	0.70
CP	105.70^{B}	123.40^{A}	128.80^{A}	117.70^{AB}	137.70^{a}	144.0^{a}	95.90^{b}	100.0^{b}	22.434	0.01	<0.001	0.82
EE	24.20	32.50	25.20	31.70	28.60^{ab}	37.20^{a}	27.30^{ab}	20.6^{b}	13.595	0.06	<0.001	0.43

[a–d]Lowercase letters on the same line differ among periods when $P < 0.05$ by the Tukey test.

[A,B]Capital letters on the same line differ among pre-finishing treatment when $P < 0.05$ by the Tukey test.

[1]FM = forage mass; EE = ether extract.

[2]MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains.

[3]EP = experimental period; PF = pre-finishing growth phase.

intake, most likely due to the smaller particle size. A highly concentrated (70.0%) TMR provided a lower selection opportunity for animals (Mertens and Grant, 2020), thus increasing intake. Nonetheless, forage allowance in the pasture finishing system and the morphological and structural composition of the pasture increased the amount of selective grazing activity associated with its low nutritive value, which consequently reduced the passage rate of feed and decreased DM intake and digestibility, owing to the greater length of stay in the digestive tract (Poppi et al., 1987; Galyean and Gunter, 2016).

The ADG of 1.4 kg/d was reached with an intake of 5.79 kg/d of TDN and 1.17 kg/d of CP by bulls in the confinement system, whereas grazing bulls gained 1.17 kg/d with an intake of 6.96 kg/d of TDN and 0.961 kg/d of CP (Valadares Filho et al., 2016). The ADG in the present study was greater than those reported in previous studies examining supplementation and Nellore performance in Brazilian pastures (Barbero et al., 2017; Roth et al., 2017; Koscheck et al., 2020; Hoffmann et al., 2021b).

In our study, total DMI and CP intake were greater in confinement, which might account for the greater ADG compared with previous studies. Nutrient digestibility was greater in bulls finished on pasture. This can be explained by the diet of grazing bulls that could select forage, as it had a high proportion of forage mass (5.4 t/ha) and green leaves (184.0 g/kg). Selection was reduced for bulls in confinement that were fed 300.0 g/kg corn silage.

In PS, animals that received MM in the pre-finishing phase presented a greater ADG than the others, characterizing a compensatory gain, which corresponds to the accelerated growth rate after a long period of feed restriction or low plane of nutrition (Fox et al., 1972; Ryan, 1990). However, in this study, the compensatory growth of bulls supplemented with MM can be explained by nutrient restriction during the pre-finishing phase, because the mineral supplement could not meet their energy and protein requirements. This resulted in a physiological response of compensatory growth in the subsequent phase when animals were fed an energy-protein balanced diet, meeting their needs. Thus, during the finishing phase, there was a compensation in the size and activity of the gastrointestinal tract organs of animals showing greater ADG compared with bulls fed with GC and DDGM. Similar compensatory growth was reported by Sampaio et al. (2017), who evaluated the nutritional interrelationship between the growth and finishing phases of crossbred cattle in tropical systems.

Regarding nutrient digestibility, DM digestibility, OM digestibility, CP digestibility, and NDF digestibility were greater in PS bulls than in CF bulls ($P < 0.05$; Table 5). There was no difference in the ether extract digestibility between pre-finishing treatments or finishing systems ($P > 0.05$). However, nonfibrous carbohydrate digestibility was greater in PS than in the CF system ($P = 0.03$). The dietary roughage-to-concentrate ratio allowed an intake of 4.78 kg/d of NDF, with digestibility of 498.1 g/kg and DM

Table 4. Effects of pre-finishing supplementation diets of finishing systems interactions on nutrients intake and animal performance

	Finishing system[2]													
	Confinement					Pasture					P-value[3]			
Variable[1]	MM	SBM	GC	DDGM		MM	SBM	GC	DDGM	SEM	FS	PF × FS	CF	PS
TDMI (kg/d)	12.76^{Ba}	13.76^{Aa}	12.99^{ABa}	13.61^{ABa}		8.91^{Ab}	7.61^{Bb}	9.52^{Ab}	9.00^{Ab}	0.881	0.001	0.002	0.03	0.001
TDMI (% of BW)	2.77^{Aa}	2.86^{Aa}	2.74^{Aa}	2.89^{Aa}		1.92^{ABb}	1.63^{Bb}	2.02^{Ab}	1.90^{ABb}	0.184	≤0.001	0.011	0.32	0.02
OMI (kg/d)	11.09^{Aa}	11.08^{Aa}	11.08^{Aa}	11.08^{Aa}		8.20^{Ab}	7.02^{Bb}	8.73^{Ab}	8.26^{Ab}	0.603	≤0.001	0.003	0.99	≤0.001
CPI (kg/d)	1.67^{Aa}	1.67^{Aa}	1.68^{Aa}	1.67^{Aa}		1.32^{Bb}	1.19^{Cb}	1.47^{Ab}	1.36^{ABb}	0.074	≤0.001	≤0.001	0.99	≤0.001
NDFI (kg/d)	4.79^{Aa}	4.79^{Aa}	4.78^{Aa}	4.77^{Aa}		3.28^{Ab}	2.66^{Bb}	3.58^{Ab}	3.37^{Ab}	0.312	≤0.001	0.012	0.99	0.001
NFCI (kg/d)	4.19^{Aa}	4.18^{Aa}	4.19^{Aa}	4.20^{Aa}		3.35^{Ab}	2.90^{Bb}	3.41^{Ab}	3.27^{Ab}	0.191	≤0.001	0.001	0.99	≤0.001
iBW (kg)	379^{Aa}	387^{Ab}	373^{Ab}	387^{Aa}	3	394^{Aa}	389^{Aa}	392^{Aa}	389^{Aa}	5.00	0.05	0.43	0.33	0.95
fBW (kg)	513^{Aa}	528^{Aa}	493^{Aa}	500^{Aa}	5	536^{Aa}	523^{ABa}	485^{Ca}	494^{BCa}	4.00	0.94	0.31	0.07	0.001
ADG (kg/d)	1.38^{Aa}	1.47^{Aa}	1.45^{Aa}	1.38^{Aa}		1.22^{Aa}	0.94^{Bb}	1.14^{Bab}	1.12^{Bab}	0.071	≤0.001	0.03	0.64	0.009

a,bLowercase letters on the same line differ among finishing systems when $P < 0.05$ by the Tukey test.

A–CCapital letters on the same line differ among pre-finishing histories in the same finishing system when $P < 0.05$ by the Tukey test.

[1]TDMI = total DMI; OMI = OM intake; CPI = CP intake; NDFI = NDF intake; NFCI = nonfibrous carbohydrate intake; iBW = initial body weight; fBW = final body weight.

[2]MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains.

[3]FS = finishing system; PF = pre-finishing history; CF = confinement; PS = pasture system.

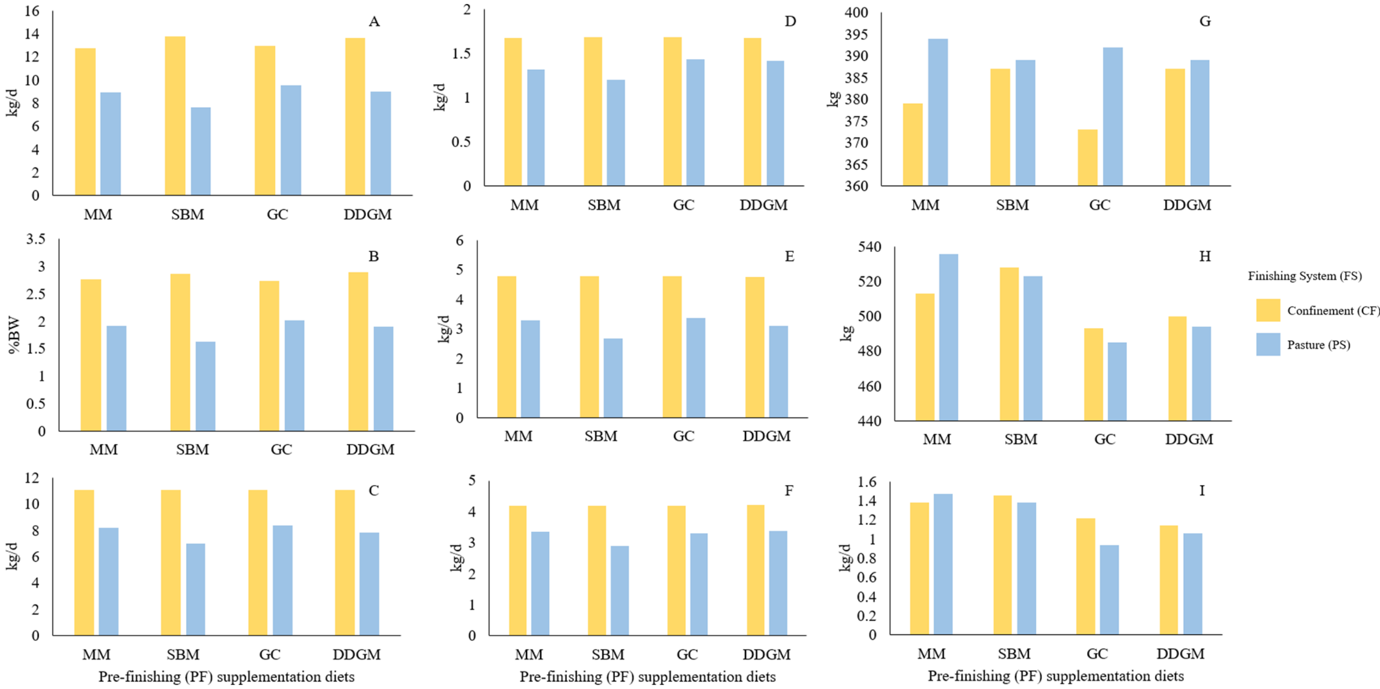

Figure 1. Interaction effects from pre-finishing (PF) supplementation into finishing systems (FS) for nutrient intake and animal performance variables. (A) Total DMI (TDMI, kg/d); (B) TDMI (% BW); (C) OM intake (kg/d); (D) CP intake (kg/d); (E) NDF intake (kg/d); (F) nonfibrous carbohydrate intake (kg/d); (G) initial BW (kg); (H) final BW (kg); (I) ADG (kg/d). MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains.

and OM digestibilities of 620.4 and 601.1 g/kg, respectively, in confinement.

However, a lesser or greater capacity for nutrient utilization defines its digestibility. According to Reis et al. (2013) and Mertens and Grant (2020), digestibility is directly dependent on the characteristics of the feedstuff and not on animals. In this study, nutrients were more digestible in PS than in CF because of the lower fiber intake by grazing bulls. In addition, grazing bulls presented selective behavior, consuming a high proportion of leaves with low

Table 5. Effects of pre-finishing supplementation diets on pasture and finishing system on nutrients digestibility

Digestibility[1] (g/kg)	Pre-finishing[2]				Finishing system[3]			*P*-value[4]		
	MM	SBM	GC	DDGM	CF	PS	SEM	PF	FS	PF × FS
DMD	677.8^{A}	615.5^{B}	641.3^{AB}	629.5^{AB}	625.0^{b}	657.0^{a}	0.43	0.05	0.05	0.34
OMD	697.5^{A}	620.8^{B}	648.8^{AB}	633.7^{B}	601.1^{b}	699.4^{a}	0.45	0.008	≤0.001	0.44
CPD	664.4^{A}	587.0^{B}	627.4^{AB}	602.9^{AB}	542.1^{b}	698.7^{a}	0.49	0.02	≤0.001	0.92
NDFD	610.3^{A}	515.0^{B}	590.2^{AB}	519.6^{B}	498.1^{b}	619.5^{a}	0.34	0.003	≤0.001	0.36
EED	524.3	569.7	594.0	522.7	543.9	561.4	1.20	0.64	0.44	0.09
NFCD	817.7^{A}	744.6^{AB}	727.6^{B}	78.18^{AB}	748.1^{b}	787.7^{a}	0.71	0.01	0.03	0.09

[a,b]Lowercase letters on the same line differ among finishing systems when $P < 0.05$ by the Tukey test.

[A,B]Capital letters on the same line differ among pre-finishing histories in the same finishing system when $P < 0.05$ by the Tukey test.

[1]DMD = DM digestibility; OMD = OM digestibility; CPD = CP digestibility; NDFD = NDF digestibility; EED = ether extract digestibility; NFCD = nonfibrous carbohydrate digestibility.

[2]MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains.

[3]CF = confinement ; PS = pasture system.

[4]PF = pre-finishing growth phase; FS = finishing system.

Table 6. Effects of pre-finishing supplementation diets on pasture and finishing system on carcass traits

	Pre-finishing[2]				Finishing system[3]			*P*-value[4]		
Variable[1]	**MM**	**SBM**	**GC**	**DDGM**	**CF**	**PS**	**SEM**	**PF**	**FS**	**PF × FS**
HCW (kg)	280.1	288.3	292.1	287.3	293.1[a]	281.3[b]	2.22	0.24	0.005	0.56
CY (g/kg)	556.1[B]	565.4[A]	569.4[A]	564.5[A]	558.3[b]	569.4[a]	1.61	0.03	<0.001	0.50
LEA (cm^2)	71.7	74.8	76.1	76.4	74.2	75.5	0.94	0.24	0.45	0.78
FT (mm)	4.1	4.6	4.5	3.9	5.2[a]	3.4[b]	0.24	0.27	≤0.001	0.68

[a,b]Lowercase letters on the same line differ among finishing systems when $P < 0.05$ by Tukey test.

[A,B]Capital letters on the same line differ among pre-finishing histories in the same finishing system when $P < 0.05$ by Tukey test.

[1]HCW = hot carcass weight; CY = carcass yield; LEA = loin eye area; FT = fat thickness.

[2]MM = mineral mix; SBM = multiple supplements with soybean meal; GC = energy supplement with cornmeal; DDGM = multiple supplements with dried distillers grains.

[3]CF = confinement; PS = pasture system.

[4]PF = pre-finishing growth phase; FS = finishing system.

NDF content, the digestibility of which was greater than that of the diet with corn silage provided to the confined bulls. The TMR supplied to the feedlot system restricted the animals' selective intake. Although the digestibility of nutrients was greater in PS, CF animals presented a greater intake of nutrients, especially digestible nutrients, which increased ADG compared with pasture-finished animals.

Tropical pastures submitted to appropriate grazing management during the rainy season, as reported by Hoffmann et al. (2021a), Ferrari et al. (2021), and Barbero et al. (2015) and sampled in the dry season using the hand-plucking technique (Halls, 1954), presented values of 123.3 g/kg CP and 614.4 g/kg NDF, which were close to the values reported by Hoffmann et al. (2021b) and Barbero et al. (2017). In this study, due to the selective behavior, bulls from pasture consumed forage with more digestible NDF content compared with the confinement bulls. In contrast, bulls from confinement consumed a lower amount of NDF provided by the whole-plant corn silage, which contained greater indigestible NDF content than forage from Marandu pasture. Silage fermentation results in a decrease in soluble carbohydrates to produce organic acids, which reduces forage nutritive value, considering that only lactic acid is an energy source for rumen microorganisms, and acetic, propionic, and butyric acids are used directly in animal metabolic processes (Van Soest, 1994; Tedeschi and Fox, 2020a).

The bulls' final BW did not differ among the pre-finishing growth phase treatments ($P = 0.72$; Table 4) but differed among finishing systems, being greater in CF (525 ± 4 kg) than in PS (493 ± 4 kg; $P \leq 0.001$). Bulls in PS had lower ($P < 0.01$) final BW, carcass weight, fat thickness, and carcass yield ($P < 0.01$) than those in CF (Table 6). Carcass yield was lower ($P = 0.0253$) in bulls fed MM during the pre-finishing phase and finished in confinement. However, the loin eye area did not differ among treatments of the pre-finishing phase or finishing system ($P > 0.05$; Table 6).

Carcass yields for pasture-finished cattle were acceptable, despite having lower ADG than cattle finished in confinement. The final BW is linked to hot carcass weight (Smith et al., 2020, 2021). Because hot carcass weight is the main component of commercial relationships between producers and slaughterhouses (Baba et al., 2016), in the Brazilian system, carcasses must reach 230 kg to avoid penalization with carcass discounts. All treatments in the present study generated carcass weights that exceeded those reported by Baba et al. (2016). Carcass yield was greater for bulls finished in the pasture because they had the autonomy to modulate their forage intake. By contrast, bulls finished in confinement consumed 300 g/kg of roughage in a diet with 30:70 roughage-to-concentrate ratio, with small variations as a result of possible selection, and this intake affected the size of the gastrointestinal tract (Vieira et al., 2017).

Ruminant nutrition affects carcass proportions, noncarcass components, and gastrointestinal size during the prefinishing and finishing phases (Koscheck et al., 2020). These changes can be attributed to nutrient digestibility (Nogalski et al., 2018), smaller forage intake during supplementation ad libitum, and selective behavior. In addition, bulls finished on pasture had lower ruminal content because of the high concentrate intake and low NDF intake from pasture, which affected digestive tract development and led to increased carcass yield and gains (Koscheck et al., 2020; Hoffmann et al., 2021b).

Slaughterhouses in the Brazilian system demand carcasses with 3 to 6 mm of subcutaneous fat. Less than 3 mm of fat results in meat darkness during chilling, which can affect the visual aspects, compromising commercialization and increasing water loss by cooling (Donicht et al., 2011). More than 6 mm of fat can negatively affect the producer in terms of carcass trimming during the slaughter process and before weighing the carcass, as well as the slaughterhouse because of the increase in operational costs involved in the process (Boito et al., 2018). Animals from both finishing systems had an adequate fat thickness to meet the Brazilian system requirement of 3 to 6 mm. However, further research is required to examine the influence of varying dietary RDP and RUP levels across production pre-finishing and finishing phases when different finishing systems are used.

APPLICATIONS

Feeding Nellore bulls with SBM during the pre-finishing growth phase resulted in reduced nutrient intake and ADG when finishing on pasture, but did not affect bulls finished in confinement. The pasture finishing system provided greater nutrient digestibility than confinement. Supplementation with DDG at 3 g/kg of BW during pre-finishing affected animal performance and carcass traits when considering the same finishing system. The BW, hot carcass weight, and fat thickness were greater in confined animals, but carcass yield was greater in animals on pasture. Thus, depending on production goals, DDG, a nonedible human feed co-product, can be used as a dietary ingredient. The efficiency of the pasture finishing system could not be determined because bulls from confinement were supplemented twice a day, which may have stimulated their intake and interfered with performance responses.

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