Livestock Science 204 (2017) 122–128

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Does supplementation during previous phase influence performance during the growing and finishing phase in Nellore cattle?

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ARTICLE INFO

Keywords:
Bos Indicus
Energy
Nutritional strategies
Protein
Tropical grass

ABSTRACT

In Brazil, the beef cattle are widely raised in pasture post weaning, but the supplementation has been studied only in individual phases of the animal's growth curve. Therefore, the objective of this study was evaluated the nutritional interrelationship between the growing and finishing phases in the performance of Nellore bulls. Eighty-four weaned calves (body weight [BW] = 205 ± 4.7 kg; 8 months) raised on pasture during the growing phase (dry season, summer and autumn) and finished in feedlot were used. The experiment was conducted as a randomized block design with a 2 × 2 × 3 factorial arrangement of treatments. Factors included 1) two supplements levels in the dry season (protein [1 g/kg BW/day - PR1] or protein-energy [3 g/kg BW/day - PE] supplement); 2) two supplement levels in summer (mineral supplement [*ad libitum* - MS] or protein supplement [1 g/kg BW/day - PR2]); and three supplement levels in autumn (MS, PR2 or PE). The animals were finished with a common diet. The dry season supplementation affected the average daily gain (ADG) in the summer ($P < 0.05$). In summer, animals fed MS had a greater ADG when fed PR1 in the previous (dry) season than those receiving PE (0.696 vs. 0.581 kg, $P < 0.01$); while, no difference in ADG was observed when the animals received PR2 (0.815 kg, $P = 0.99$). In autumn, animals fed PR2 in the previous (summer) season exhibited 11.3% lower ADG than those supplemented with MS (0.503 vs. 0.567 kg, $P < 0.01$), regardless of the autumn supplementation. Dry season supplementation did not affect the ADG during finishing phase (0.909 kg, $P = 0.14$). The animals fed PR2 in the summer and PE in the autumn had tendency of lower ADG during the feedlot ($P = 0.06$) compared with animals fed MS, however, they were finished 20 days earlier ($P = 0.06$). In conclusion, to provide PE in the dry season, followed by MS in the summer is not recommended, because this strategy reduces the ADG. In addition, dry season supplementation does not affect the ADG during finishing phase, while supply supplements of greater nutritional value in autumn reduces feedlot period.

1. Introduction

Cattle production in the tropics mainly relies on pasture systems (Ferraz and Felício, 2010). Thus, there is rarely a balance on pasture systems between the supply and requirement of nutrients because of seasonal fluctuations in the quantity and quality of forage (Detmann et al., 2014). To overcome this condition, supplementation is used to improve the efficiency of pasture utilization and to optimize animal performance (Casagrande et al., 2011). However, the supplementation has been evaluated in individual periods such as the dry season, summer, or autumn in tropical conditions (Barbero et al., 2017; Detmann et al., 2014; Moretti et al., 2013).

The nutritional strategy promotes metabolic and physiological alterations, as well as changes in the composition of body weight gain, in the subsequent phase of the animal's growth curve (Keogh et al., 2015; Pesonen et al., 2014; Sainz et al., 1995;). Nevertheless, most studies have evaluated the effect of supplementation during the growing phase on the finishing performance of cattle, considering the growing phase to be nutritionally uniform under non-tropical conditions (Drouillard and Kuhl, 1999; McCurdy et al., 2010; Neel et al., 2007). In addition, *Bos indicus* cattle are mainly used in tropical systems (Ferraz and Felício, 2010), and their growth pattern differs from *Bos taurus* (Oliveira et al., 2011).

Within this context, the objective of this study was to understand the interrelationship of supplementation strategies provided to Nellore bulls during the growing phase, as well as the effects of the supplement strategies offered during the growing phase on the finishing performance of the animals. The hypothesis for this study was that the

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http://dx.doi.org/10.1016/j.livsci.2017.08.019
Received 27 April 2017; Received in revised form 23 August 2017; Accepted 25 August 2017
1871-1413/

nutritional strategy provided to the bulls in a previous phase will alter the subsequent performance, as well as carcass traits at the end of the finishing period. Furthermore, the adequate growth of the animal depends of the nutritional strategy provided in a certain phase and this one should be the same or greater in subsequent phases.

2. Materials and methods

The study was conducted in Colina, São Paulo, Brazil (20°43′5″S and 48°32′38″W). All procedures involving animals were conducted in accordance with the ethical guidelines adopted by the Brazilian Guidelines for the Care and Use of Animals for Scientific and Educational Purposes (CONCEA, 2013).

2.1. Experimental period, grazing area and feedlot

The experimental period comprised the growing and finishing phases of the Nellore bulls. The growing phase was divided into the dry season (from July 16 to December 11, 148 days), summer (from December 12 to March 12, 90 days), and autumn (from March 13 to June 26, 105 days). The summer and autumn periods corresponding to the rainy season. The growing phase was followed by the finishing phase (from June 27 up to reaching 500 kg of body weight [BW]).

During the dry season, the grazing area consisted of Marandu grass (*Brachiaria brizantha* cv. Marandu) divided into 12 paddocks (2.16–2.40 ha each). Each paddock had drinkers and feeding troughs for the supplements. In summer and autumn, 6 rotational stocking management systems of Tanzania grass (*Panicum maximum* cv. Tanzania) were used. Each rotational stocking system had a central area containing the drinkers and feeding troughs for the supplements and was divided into five paddocks of 1.3 ha each. The drinkers had a capacity of 1500 L and the linear feeding trough space per animal was 30 cm. During finishing phase, the animals were housed in collective pens (240 m^2) in a feedlot equipped with drinker and feed bunks.

2.2. Experimental animals, treatments, experimental design and feedlot diet

All experimental animals belonged to the herd of the farm and they were managed in the same way until weaning. Eighty-four bulls, newly weaned Nellore calves (BW = 205 ± 4.7 kg; 8 months) were used. The animals were weighed, dewormed with 1% Ivermectin (Ivomec, Merial, Paulínea, SP, Brazil), and identified individually with ear tags. In addition to the experimental animals, other animals were used when necessary to adjust the grazing pressure and to maintain the same forage supply in all paddocks.

Proposed treatments were designed to ideally provide different rates of gain to the animals during the growing phase. The selection and definition of the supplements were based on their representative use under tropical conditions (Detmann et al., 2014). The variations in the composition and levels of the supplements, as well as in the number of supplements in each seasons of the year, were due to the intrinsic characteristics of each season under tropical conditions (Table 1).

In the dry season, the experiment was conducted as a randomized block design with two supplements levels: protein (1 g/kg BW/day - PR1) or protein-energy (3 g/kg BW/day - PE) supplement. The experimental unit was the animal (42 animals per treatment). In the summer, the experiment was conducted as a randomized block design with a 2 × 2 factorial arrangement of treatments. Factors included 1) two supplements levels in the dry season (PR1 or PE supplement); 2) two supplement levels in summer (mineral supplement [ad libitum - MS] or protein supplement [1 g/kg BW/day - PR2]). The experimental unit was the animal (21 animals per treatment). In the autumn and feedlot, the experiment was conducted as a randomized block design with a 2 × 2 × 3 factorial arrangement of treatments. Factors included 1) two supplements levels in the dry season (PR1 or PE); 2) two supplement levels in summer (MS or PR2); and three supplement levels in autumn (MS, PR2 or PE). The experimental unit was the animal (7 animals per treatment). The randomization of animals in each season allowed us to comply with the nutritional strategy of each animal (Table 2). During the growing phase, the supplement was provided daily at 08:00 h.

In the feedlot, a common diet was formulated to achieve an estimated average daily gain (ADG) of 1.25 kg/day (NRC, 2000). The finishing total mixed ration contained sugarcane silage (400 g/kg), cottonseed meal (66.5 g/kg), soybean hull (365 g/kg), ground corn (109 g/kg), urea (17.7 g/kg), and mineral premix (41.8 g/kg). The total mixed ration was provided twice a day (08:00 h and 15:00 h) at equal amounts using a forage wagon (Rotomix Express, Casale, São Carlos, SP, Brazil) equipped with a scale. The orts of the previous day were collected and weighed to adjust the total mixed ration supply before

Table 1
Composition of the supplements offered in the dry season (from July 16 to December 11, 148 days), summer (from December 12 to March 12, 90 days), and autumn (from March 13 to June 26, 105 days).

Item	Supplement			
	MS	PR1	PR2	PE
	Ingredient, g/kg dry matter			
Cottonseed meal	–	419	290	317
Pelleted citrus pulp	–	80	288	562
Urea	–	124	17	34
Sodium chloride	–	115	39	37
Mineral premix	–	262	366	50
	Composition			
Crude protein, g/kg	–	500	300	250
NPN equivalent protein, g/kg	–	530	130	90
Estimated total digestible nutrients, g/kg	–	400	400	600
Calcium, g	155	50	77	23
Phosphorus, g	80	33	20	6
Sodium, g	130	15	30	13

MS = mineral supplement *ad libitum*; PR1 = dry season protein supplement offered at 1 g/kg body weight (BW) per day; PR2 = protein supplement offered at 1 g/kg BW per day (summer and autumn); PE = protein-energy supplement offered at 3 g/kg BW per day (dry season and autumn); NPN = non-protein nitrogen.
Composition MS, in g/kg: magnesium 10; sulfur 40; in mg/kg: copper 1350; manganese 1040; zinc 5000; iodine 100; cobalt 80; selenium 26; fluoride 800.
Composition premix PR1, in g/kg: magnesium 2; sulfur 66; in mg/kg: copper 2; manganese 15; zinc 40; iodine 260; cobalt 200; selenium 960; fluoride 19; monensin 15.
Composition premix PR2, in g/kg: magnesium 2; sulfur 20; in mg/kg: copper 345; manganese 265; zinc 1280; iodine 25; cobalt 20; selenium 6; fluoride 200; monensin 200.
Composition premix PE, in g/kg: magnesium 1; sulfur 3; in mg/kg: copper 40; manganese 30; zinc 148; iodine 3; cobalt 2; selenium 1; fluoride 60; monensin 80.

Table 2
Experimental design and supplementation strategies (dry season = July 16 to December 11, 148 days; summer = December 12 to March 12, 90 days; autumn = March 13 to June 26, 105 days; finishing = June 27 up to reaching 500 kg).

Dry season *n* = 84	Summer *n* = 84	Autumn *n* = 84	Finishing *n* = 84	Slaughter *n* = 84
PR1 *n* = 42	MS *n* = 21	MS *n* = 7	Feedlot *n* = 7	*n* = 7
		PR2 *n* = 7	Feedlot *n* = 7	*n* = 7
		PE *n* = 7	Feedlot *n* = 7	*n* = 7
	PR2 *n* = 21	MS *n* = 7	Feedlot *n* = 7	*n* = 7
		PR2 *n* = 7	Feedlot *n* = 7	*n* = 7
		PE *n* = 7	Feedlot *n* = 7	*n* = 7
PE *n* = 42	MS *n* = 21	MS *n* = 7	Feedlot *n* = 7	*n* = 7
		PR2 *n* = 7	Feedlot *n* = 7	*n* = 7
		PE *n* = 7	Feedlot *n* = 7	*n* = 7
	PR2 *n* = 21	MS *n* = 7	Feedlot *n* = 7	*n* = 7
		PR2 *n* = 7	Feedlot *n* = 7	*n* = 7
		PE *n* = 7	Feedlot *n* = 7	*n* = 7

MS = mineral supplement ad libitum; PR1 = dry season protein supplement offered at 1 g/kg body weight (BW) per day; PR2 = protein supplement offered at 1 g/kg BW per day (summer and autumn); PE = protein-energy supplement offered at 3 g/kg BW per day (dry season and autumn).

feeding the animals in the morning. Feed intake was adjusted daily based on the previous days' intake, maintaining orts at approximately 10% of the total provided, characterizing *ad libitum* intake. The 84 animals were kept in a feedlot in 6 pens, which had 14 head per pen. The allocation of the animals in the pens followed the strategies used in autumn to avoid stress.

2.3. Grazing method, forage characteristics, and exploratory data analysis of the pastures

In the dry season, continuous stocking was used as the grazing method. In summer, a rotational stocking system consisting of 6 days of occupation and 24 days of rest was applied, corresponding to grazing cycles of 30 days. In autumn, a rotational stocking system consisting of 7 days of occupation and 28 days of rest was used, corresponding to grazing cycles of 35 days. The stocking rate was variable in all grazing systems because of the proposed treatments. The put-and-take method (Mott and Lucas, 1952) was used to adjust the grazing pressure and to maintain the same forage supply in all paddocks. This management was adopted to permit a homogenous forage supply among the different nutrient supplementation levels, removing the influence of pasture on the response variables.

Forage samples collection was made at intervals of 42 days during the dry season, 30 days in summer, and 35 days in autumn at 9 sites per paddock, always at the end of the grazing cycles. Forage mass was determined using the double sampling method adapted from Sollenberger et al. (1995). To estimate the nutritional value of the pasture the hand-plucked samples were used (De Vries, 1995). These samples were dried at 55°C in a forced draft oven for 72 h, ground in a Willey mill (Thomas Model 4 Wiley, Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1-mm screen sieve, and stored for further chemical analysis.

The dry matter (method 934.01) and crude protein (method 978.04) content was measured according to recommendations of the AOAC (1995). The content of neutral detergent fiber and acid detergent fiber was determined by sequential analysis as described by Robertson and Van Soest (1981) using a fiber analyzer (TE-149, Tecnal, Piracicaba, SP, Brazil). Cellulose was solubilized with 72% sulfuric acid and lignin content was obtained as the difference (Goering and Van Soest, 1970). *In vitro* true digestibility of dry matter was determined as described by Van Soest and Robertson (1985).

Exploratory data analysis of the pastures was performed. No differences in quantitative or qualitative forage characteristics were observed between the paddocks during the dry season, summer or autumn ($P > 0.05$) (Table 3). This lack of difference confirms the similarity of the pasture conditions, ruling out any confounding effect and inferring that the performance responses are due just to treatments.

2.4. Animal performance

Body weight and ADG during the growing phase were evaluated by weighing the animals at time zero (beginning of the growing phase – July) and at intervals of 42 days during the dry season, 30 days in summer, and 35 days in autumn, always at the end of the grazing cycles. In the feedlot, the bulls were weighed at intervals of 28 days. All weight measurements were obtained after fasting from solids for 16 h.

2.5. Slaughter procedure and carcass traits

The animals were slaughtered when they reached a BW of 500 kg. All slaughters were performed in a commercial slaughterhouse (20 km from the research facility) supervised by the Federal Inspection Service. Before slaughter, the animals were fasted from solids and liquids for 24 h. The kidney-pelvic-heart fat was collected and weighed during slaughter. At the end of the slaughter line, the carcasses were divided into 2 halves, weighed, and the hot carcass weight (HCW) was obtained, which was used to calculate the dressing percentage, in function of fasting BW. The carcasses were then chilled in the cold room for 24 h at 2°C. After chilling, the longissimus muscle area and backfat thickness were measured in the left half-carcass in a section of muscle between the 12th and 13th rib (Cañeque and Sañudo, 2005).

2.6. Statistical analyses

The calculation of the sample size in the finishing phase was obtained by means of the power analysis of the main variables analyzed in the experiment, with Power = 1-β, using 91.5% power with the confidence of $\alpha = 0.05$, thus a minimum number of 7 animals was defined per treatment.

Mixed models that included the supplementation levels and their interactions as fixed effects and initial BW (block) and residual as random effects were used. The animal was considered the experimental unit. The data were submitted for analysis of variance with repeated measures over time using the PROC MIXED procedure (repeated option) of the SAS. Different structures of the residual variance and covariance matrices were tested to determine the structure with the best fit for each trait. The matrices for each variable were chosen on the basis of the Bayesian information criterion. Means were compared by the Tukey's test. Significance statistic was established at $P \leq 0.05$ and trends were defined as $P > 0.05$ and $P \leq 0.10$.

Table 3
Quantitative and qualitative characteristics of pasture (dry season = July 16 to December 11, 148 days; summer = December 12 to March 12, 90 days; autumn = March 13 to June 26, 105 days; finishing = June 27 up to reaching 500 kg).

Item	Dry season		SEM	P-value	Summer		SEM	P-value	Autumn			SEM	P-value
	PR1	PE			MS	PR2			MS	PR2	PE		
Height, cm	37.94	40.82	1.87	0.26	76.16	77.78	1.22	0.40	65.59	64.02	64.92	2.51	0.91
forage mass, kg DM/ha	8497	8806	562	0.70	8397	8425	523	0.97	9173	8809	8300	590	0.63
LG allowance, kg DM/kg BW	1.05	0.99	0.10	0.67	6.45	6.17	0.21	0.41	7.63	7.05	7.00	0.84	0.85
	(g/kg of dry matter)												
Crude protein	84.7	87.9	1.8	0.22	138.5	139.3	3.2	0.88	172.1	172.7	171.4	8.7	0.99
Neutral detergent fiber	702.6	690.1	16.7	0.10	720.6	730.0	3.1	0.09	710.3	702.2	710.3	5.8	0.59
Acid detergent fiber	323.7	312.7	11.3	0.07	359.2	359.5	2.3	0.92	361.9	342.6	346.7	4.4	0.10
Lignin	49.4	47.2	2.5	0.29	55.9	60.3	2.3	0.25	62.6	54.5	57.2	7.2	0.74
In vitro NDF digestibility	526.9	545.6	12.1	0.27	476.0	481.6	12.1	0.76	597.1	601.5	612.5	22.6	0.89
In vitro DM digestibility	721.6	719.3	7.9	0.84	742.1	739.7	3.6	0.66	813.2	822.1	816.7	12.1	0.88

MS = mineral supplement *ad libitum*; PR1 = dry season protein supplement offered at 1 g/kg body weight (BW) per day; PR2 = protein supplement offered at 1 g/kg BW per day (summer and autumn); PE = protein-energy supplement offered at 3 g/kg BW per day (dry season and autumn); SEM = standard error of the mean; LG = leaf green; DM = dry matter; NDF = neutral detergent fiber.

Table 4
Dry season and summer interactions on performance of Nellore bulls receiving different nutrient supplementations during the growing phase on pasture (dry season = July 16 to December 11, 148 days; summer = December 12 to March 12, 90 days; Autumn = March 13 to June 26, 105 days).

Item	Supplements				SEM	P-value		
Dry season	PR1		PE					
Summer	MS	PR2	MS	PR2		D	S	D × S
	Summer performance							
ADG, kg	0.698^b	0.825^a	0.584^c	0.823^a	0.025	< 0.01	< 0.01	0.02
BW 0, kg	261^b	258^b	276^a	277^a	5.86	< 0.01	< 0.01	< 0.01
BW 30, kg	286^b	282^b	296^a	300^a	6.15			
BW 60, kg	299^b	302^b	305^b	319^a	6.07			
BW 90, kg	323^b	332^b	328^b	351^a	6.22			
	Autumn performance							
ADG, kg	0.590^a	0.495^b	0.546^a	0.513^b	0.024	0.58	< 0.01	0.19
BW 0, kg	323^b	332^b	328^b	351^a	10.9	< 0.01	< 0.01	< 0.01
BW 35, kg	351^b	354^b	356^b	375^a	11.1			
BW 70, kg	374^b	373^b	374^b	395^a	11.2			
BW 105, kg	385^b	383^b	385^b	404^a	11.3			

MS = mineral supplement *ad libitum*; PR1 = dry season protein supplement offered at 1 g/kg body weight (BW) per day; PR2 = protein supplement offered at 1 g/kg BW per day; PE = protein-energy supplement offered at 3 g/kg BW per day; SEM = standard error of the mean; D = dry season; S = summer; D × S = interaction between the nutrient supplementations used in the dry season and summer; ADG = average daily gain; BW = body weight.
Summer: BW0 = Dec 12; BW 30 = Jan 11; BW 60 = Feb 11; BW 90 = Mar 12.
Autumn: BW0 = Mar 13; BW 35 = Apr 17; BW 70 = May 23; BW 105 = Jun 26.
[abc]Means within rows with similar superscripts are similar (P ≤ 0.05).

Table 5
Performance and carcass traits of feedlot-finished Nellore bulls receiving different nutrient supplementations during the growing phase on pasture (dry season = July 16 to December 11, 148 days; summer = December 12 to March 12, 90 days; autumn = March 13 to June 26, 105 days).

Item	Supplements												SEM	P-value					
Dry season	PR1						PE												
Summer	MS			PR2			MS			PR2				D	S	A	D × S	D × A	S × A
Autumn	MS	PR2	PE	MS	PR2	PE	MS	PR2	PE	MS	PR2	PE							
Initial body weight, kg	364	390	401	360	386	404	378	387	391	377	307	421	12.5	< 0.01	< 0.01	< 0.01	< 0.01	0.19	0.03
Final body weight, kg	513	521	519	493	505	516	510	507	504	500	520	523	9.23	0.97	0.47	0.04	< 0.01	0.79	0.07
Average daily gain, kg	1.06	0.97	0.90	0.90	0.85	0.90	0.95	0.92	0.82	0.90	0.87	0.85	0.05	0.14	0.06	0.09	0.24	0.79	0.24
Days on feed, days	140	136	133	150	140	125	140	132	141	141	133	120	9.01	0.43	0.50	0.01	0.23	0.65	0.06
Hot carcass weight, kg	286	292	290	273	279	282	278	284	278	283	295	288	5.89	0.81	0.60	0.01	< 0.01	0.63	0.74
Carcass dressing, %	55.8	56.0	55.8	55.5	55.4	54.6	54.6	56.1	55.2	56.5	56.0	55.0	0.53	0.85	0.80	0.17	0.04	0.84	0.13
LM area, cm^2	74.3	71.7	76.7	73.4	70.9	71.6	70.3	77.6	75.2	75.2	74.9	73.7	2.85	0.57	0.33	0.65	0.62	0.15	0.61
Backfat thickness, mm	5.90	4.60	5.10	4.90	6.00	6.10	5.90	6.70	5.50	5.90	6.50	4.90	0.73	0.28	0.82	0.58	0.37	0.23	0.56
Liver, g/100 kg HCW	18.6	18.2	17.5	18.1	18.4	19.1	18.0	18.5	17.3	17.3	17.4	18.2	0.59	0.21	0.63	0.96	0.42	0.98	0.12
KPH, g/100 kg HCW	15.8	14.5	15.1	14.8	18.0	14.8	15.5	15.6	16.5	16.0	14.9	14.3	1.27	0.94	0.95	0.82	0.30	0.65	0.34

MS = mineral supplement *ad libitum*; PR1 = dry season protein supplement offered at 1 g/kg body weight (BW) per day; PR2 = protein supplement offered at 1 g/kg BW per day (summer and autumn); PE = protein-energy supplement offered at 3 g/kg BW per day (dry season and autumn); SEM = standard error of the mean; D = dry season, S = summer, A = autumn, and their respective interactions; LM = longissimus muscle; HCW = hot carcass weight; KPH = kidney-pelvic-heart fat.

3. Results

3.1. Growing phase

There was interaction between dry season and summer supplementations (P = 0.02). The supplementation during the dry season did not influence the ADG in the summer for animals fed PR2, with a mean of 0.824 kg (P = 0.99). This gain was 29% greater (P < 0.01) compared to the ADG of animals that received MS in summer. In contrast, animals fed MS in summer exhibited greater ADG when they had received PR1 in the dry season compared to animals that received PE (0.698 vs. 0.584 kg, P < 0.01). Bulls receiving PE in the dry reason started the summer with a differential of 16 kg of BW compared to PR1 (277 vs. 261 kg, P < 0.01). At the end of summer period, the animals fed MS lose this differential, regardless of dry season supplementation (average = 326 kg, P = 0.17). In contrast, animals supplemented with PR2 in summer increased this differential to 19 kg (351 vs. 332 kg, P < 0.01) (Table 4).

There was no triple interaction between dry season, summer, and autumn supplementations for performance in autumn (P = 0.81). The dry season supplementation did not affect the performance of animals in autumn, with an ADG of 0.536 kg (P = 0.58). In contrast, animals supplemented with PR2 in summer decreased in 11.3% the ADG during autumn compared to animals receiving MS (0.504 vs. 0.568 kg, P < 0.01). There was an interaction between dry season and summer supplementations in autumn on BW (P < 0.01). At the end of the autumn period (end of the growing phase), animals fed PE in the dry season and PR2 in summer had a BW (404 kg) 4.9% higher than those fed PE in the dry season and MS in summer and a 5.1% higher than those supplemented with PR1 in the dry season and with MS or PR2 in summer (P < 0.01) (Table 4).

3.2. Finishing phase

There was no triple interaction between dry season, summer, and autumn supplementations for performance of finishing bulls (P > 0.86).

Body weight at feedlot entry was influenced by a combination of dry season and summer supplementations ($P < 0.01$) and of summer and autumn supplementations ($P = 0.03$). The difference in BW between the lowest and highest level of supplementation strategy was approximately 60 kg, supporting the justification of this study (Table 5).

The supplementation provided during the dry season did not affect the ADG during finishing phase, with a mean of 0.909 kg ($P = 0.14$). Animals that received PR2 in summer trend to gain 0.05 kg lower per day in the feedlot than those consuming MS ($P = 0.06$). Regarding the supplementation provided in autumn, animals that received PE tended to gain 0.084 kg lower per day in the feedlot than those receiving MS, while the PR2 level tended to promoted an intermediate ADG ($P = 0.09$) (Table 5).

An interaction between summer and autumn nutrient supplementations ($P = 0.06$) tended to affect the days on fed. Bulls receiving MS in summer and autumn or PR2 in summer and MS in autumn required more days on fed for finishing (on average = 143 days). In contrast, animals supplemented with PR2 in summer and PE in autumn required 20 less days on fed to reach the established slaughter BW (on average = 123 days). An intermediate behavior was observed for the other strategies (on average = 136 days) (Table 5).

The animals were slaughtered when their BW was higher than 500 kg. The body weight measurements were performed every 28 days to reduce stress, generating differences in slaughter BW. Thus, an interaction ($P < 0.01$) was observed between dry season and summer supplementations, as well as tend ($P = 0.07$) between summer and autumn supplementations, for the BW at final of finishing phase. However, as the slaughter was define by body weight, the variable more important is the days on fed, so this will be discussed (Table 5).

Hot carcass weight was influenced by the interaction between dry season and summer supplementations ($P < 0.01$). Animals supplemented with PR1 in the dry season had a greater HCW when they received MS in summer compared to those that received PR2 (289 vs. 278 kg). Animals that received PE in the dry season and PR2 in summer or PE in the dry season and MS in summer had an intermediate HCW (284 kg). An interaction between dry season and summer supplementations was observed for dressing percentage ($P = 0.04$). However, application of the means test showed no significant difference (Table 5).

4. Discussion

This study identified nutritional interactions between the different phases of an animal's growth curve. The variation in BW gain reflects seasonal fluctuations in forage production and nutrient supplementation under tropical conditions (Detmann et al., 2014). Therefore, additional data on pasture supplementation considering a tropical multiphase pattern rather than a single-phase model during the growing phase are needed. Using the tropical multiphase pattern, we can apply nutritional strategies that permit to obtain BW gains consistent with the genetic potential of the animals. These gains are necessary for intensification of the production system, without losses in the gains obtained in the early phases of growth. Thus, to understand the influence of nutritional level on the different phases of animal growth, we discuss performance according to the rate of gain (ADG per 100 kg BW), minimizing the effect of different BW. This value reflects the metabolic status because it is associated with the amount of nutrients consumed by the animal (Ferrell, 1988).

In the dry season, an ADG of 0.368 kg for animals that received PR1 and an ADG of 0.501 kg for animals that received PE are in agreement with results reported in the literature (Fernandes et al., 2016; Moretti et al., 2013). The rate of gain in the dry season was 0.157 and 0.210 kg per 100 kg BW for animals receiving PR1 and PE, respectively. An increase in animal performance is generally observed after the transition from dry to rainy season because of an improvement in forage quality. In the present study, performance varied according to the interaction between supplementation levels these seasons. Animals supplemented with PR1 in the dry season exhibited a nutritional boost in summer, with a 52% increase in the rate of gain when receiving MS (0.157–0.238 kg per 100 kg BW) and a 77% increase when receiving PR2 (0.157–0.278 kg per 100 kg BW). In contrast, different effects were observed when the animals received PE in the dry season. Animals that started to receive MS in summer maintained the rate of gain of the dry season (mean of 0.200 kg per 100 kg BW), while those supplemented with PR2 increased the rate of gain by 26%. Animals receiving PE in the dry season and MS in summer demonstrated a constant rate, while animals receiving the other combinations exhibited an increasing rate. The constant rate of gain of animals that received PE in the dry season and MS in summer highlights the need to increase the rate of gain from one phase to the other to avoid loss in the BW gain difference obtained in the previous phase.

In any situation, growth and/or body weight gain is determined by the extent to which the diet is able to meet the nutritional requirements of the animal. The nutrient intake of animals supplemented with MS in summer may have been lower in relation to the dry season. This intake plus greater initial maintenance requirements of these animals (Carstens et al., 1991), may have reduced the efficiency of nutrient utilization (Fox et al., 1972) and, consequently, their BW gain. Thus, in the absence of a stimulus to increase the rate of gain from one phase to the other, the energy required for the maintenance of vital functions is not decreased and a higher proportion of nutrients are allocated to body maintenance (Keogh et al., 2015). Among animals with an increasing rate of gain, those receiving PR1 in the dry season and MS or PR2 in summer did not reach the BW of animals that received PE in the dry season (that started summer heavier) and PR2 in summer. The increase in the rate of gain in animals that received PR1 in the dry season and MS or PR2 in summer was probably due to initial adaptation to the superior nutritional plan (Hornick et al., 2000). This adaptation is due to changes in the composition/intake of the diet and to the lower initial maintenance energy requirements of these animals (Carstens et al., 1991).

In autumn, animals fed PR2 in summer gained less weight compared to those that received MS, and they loss 38% of the differential of 15 kg in the BW gain observed at the end of summer. When there was a reduction in the rate of gain between phases, the greatest impact on performance was observed for animals receiving the greater nutritional level in the previous phase (in autumn, animals that received MS and PR2 in the rainy season exhibited a reduction in the rate of gain of 32% and 45%, respectively). Animals fed PE in the dry season and MS in the summer maintained the rate of gain of the previous phase. In sequence, the nutrients provided in autumn was not sufficient to continue to promote a constant rate of gain or an increase in the rate of gain (PE in the dry season and MS in summer = 0.173 kg per 100 kg BW, reduction of 18%). The reduction in the rate of gain (decrease in metabolism) is a mechanism to maintain the growth rhythm of the previous phase. A greater rate of gain, boosts the metabolic rate, thus increasing maintenance energy costs (Baldwin and Sainz, 1995). In contrast, in autumn, animals that consumed PR1 in the dry season and MS or PR2 in summer increased their rate of gain by 29% and 33%, respectively, and this increase was sufficient to annul the BW gain difference in relation to animals that received PE in the dry season and MS in summer. Only animals that received PE in the dry season and PR2 in summer were able to maintain a BW gain difference of 18 kg at the beginning of summer, probably due the increase of rate of gain of these animals.

Although the nutrient supplementations in autumn did not interact with the previous ones (dry and summer season), each supplementation alone exerted an effect on the BW gain at the end of the growing phase. This may be explained by 2 reasons. First, the animals had a high rate of gain at the end of summer (mean of 0.241 kg per 100 kg BW). Second, a 39% reduction in the overall mean rate of gain was observed in autumn, regardless of the level of supplementation. This season is characterized by a more marked decline in the quantity and quality of forage, reducing the nutritional supply derived from pasture. Thus, the lower the forage quality, the greater is the response amplitude obtained by the administration of different types of supplements and/or levels of supplementation (Poppi and MacLennan, 2007), especially when there is a reduction in the rate of gain.

In relation to finishing phase, since the growing phase precedes the feedlot, it was expected that bulls receiving a greater nutritional level in a constant way (PE in the dry season-PR2 in summer and PR2 in summer-PE in autumn) would enter the finishing period with a greater BW, a fact that was indeed observed. This fact led to the reduction in the days on fed during the finishing phase and this should improve production efficiency. Furthermore, waste production and the emission of greenhouse gases, such as methane, are reduced when the animals need less time to reach the slaughter (Chizzotti et al., 2011). Thus, intensifying the growing phase, takes advantage of the time of greater efficiency in tissue deposition of the animal and reduces the feedlot period, a process that requires diets with greater energy density and more expensive.

Another observation is that animals receiving PR1 in the dry season and MS in summer presented lower BW at the time of feedlot entry, but probably they were depositing muscle rather than fat. This behavior is likely because a lower rate of gain during growth seems to have a greater impact on fat accumulation without compromising muscle development (Sainz et al., 1995). This suggestion is supported by the greater HCW of these animals (PR1 in the dry season and MS in summer), as well as by the lack of a difference in liver and kidney-pelvic-heart fat weights between the different nutrient supplementations. On the other hand, evaluation of the summer/autumn interaction showed that a greater nutritional supply (PR2 in summer and PE in autumn) resulted in heavier bulls at slaughter and with fewer days on fed (the animals were slaughtered 20 days earlier), following the same BW pattern at the time of feedlot entry. In contrast to the dry/summer interaction, this interaction shows that animals receiving a greater nutritional supply in the last 2 phases of growth start the finishing phase prepared for fat deposition and they are finished in less time. This fact highlights the importance of studying the nutritional plan of animals.

There was no interaction between nutrient supplementations during the growing phase and feedlot ADG of the animals. However, animals that received PR2 either in summer or in autumn exhibited lower ADG during finishing compared to the other strategies. The rate of gain of animals that received MS in summer was similar to the feedlot rate of gain (0.214 vs. 0.209 kg per 100 kg BW, 2.3% lower), while the rate of gain of animals that received PR2 was reduced in the feedlot (0.267 vs. 0.195 kg per 100 kg BW, 27% lower). In contrast, in autumn, animals receiving MS exhibited a 108% increase in the rate of gain during finishing (0.105 vs. 0.218 kg per 100 kg BW), animals receiving PR2 exhibited a 32% increase in the rate of gain (0.150 vs. 0.199 kg per 100 kg BW), and animals receiving PE maintained the rate of gain (0.184 vs. 0.189 kg per 100 kg de BW, 2.7% higher). The use of PE, followed by the finishing diet, allowed continuous growth of the animals. In contrast, a combination of MS and pasture in autumn may have led to feed restriction, promoting compensatory gain during the finishing phase. Another interesting aspect of this compensatory gain is that the HCW of animals that received MS in autumn was lower. This may indicate a compensatory growth of these animals in the feedlot, which is represented by an increase in viscera size and not by a gain in HCW, i.e., unreal compensatory gain.

It is also important to understand that the feedlot ADG was below what was initially proposed (0.910 vs. 1.25 kg). The provided diet consisted of 134 g/kg of crude protein, 646 g/kg of neutral detergent fiber, and 684 g/kg of in vitro true digestibility, which allowed the predicted gain. However, it rained 38% of the 168 feedlot days, with a rainfall index of 789 mm. This climate condition compromised the feedlot performance of the animals.

Further studies designed primarily to elucidate the dynamics of muscle tissue deposition and of the different fat deposits, as well as of other non-carcass components, are necessary. A better understanding of the behavior of these tissues in response to changes in the rate of gain across the different phases of growth is important, particularly of the effects of nutrient supplementation during growth on finishing of animals in tropical production systems.

5. Conclusion

Providing protein-energy supplement in the first dry season of the animal should only be used within a nutritional plan that considers a higher rate of weight gain in the subsequent phase. The greater negative impact on performance in autumn due supplementation in the previous phase is because of the reduction on forage quality. The greater nutritional level in autumn allows a reduction in the feedlot period.

Acknowledgement

Financial support provided by *Bellman Nutrição Animal* (A Trouw Nutrition Company) and São Paulo Research Foundation [FAPESP; grant numbers #2011/02937-4, #2016/01961-2, and #2013/10340-3].

Conflict of interest

Author declares that there is no conflict of interest.

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