

Influence of post-weaning management system during the finishing phase on grasslands or feedlot on aiming to improvement of the beef cattle production

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ABSTRACT

The effects of differing post-weaning management systems applied during the wet season were evaluated on the performance of 108 young Nelore (*Bos taurus indicus*) bulls finished on grasslands or feedlot system during the dry season. In Exp. 1, three grazing heights (15 cm, 25 cm, and 35 cm) of *Brachiaria brizantha* (Hochst ex A. Rich) Stapf Marandu were evaluated during the wet season with bulls receiving 0.3% of body weight (BW) in supplementary feed. In Exp. 2, supplementation levels were decreased as grazing heights were increased such as: (1) low height (15 cm) and high supplementation (0.6% BW) (LH-HS); (2) moderate height (25 cm) and moderate supplementation (0.3% BW) (MH-MS); or (3) high height (35 cm) with no supplementation (HH-NS). In both experiments, at the end of the wet season, a half of the bulls were finished on grasslands and receiving 1.0 kg/100 kg BW of dietary supplementation while the remaining bulls were placed in a feedlot system. A non-linear regression test was applied (linear plateau) to estimate the point of stabilization of DMI on feedlot. The experimental design was completely randomized in a factorial arrangement 3 (post-weaning system) × 2 (finishing systems), consisting of three replicates (lots of three bulls) per treatment ($n = 18$, each Exp.). In the Exp. 1, the post-weaning system using 35 cm of grazing height had greater BW ($P = 0.04$) through the finishing phase in comparison with bulls grazing 15 cm of grazing height. However, the ADG during the initial 21 days of the finishing phase was changed by grazing height used during the post-weaning phase ($P = 0.004$), and by finishing system ($P = 0.007$). The post-weaning system did not alter the carcass weight ($P = 0.63$), but the bulls finished on grasslands exhibited greater carcass weight ($P = 0.02$) than bulls finished on feedlot. In the Exp. 2, non-supplemented bulls (HH-NS) took a longer time ($\pm 10\%$) to DMI stabilization on feedlot ($P < 0.01$). There were no changes in the carcass weight caused by post-weaning system ($P = 0.84$), or by finishing system ($P = 0.14$). The evaluated systems combining increasing grazing height and decreasing supplementation level during the post-weaning phase can be used during the wet season according to the economic background or production target, once these systems do not influence the finishing phase.

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1. Introduction

Most of Brazil has favorable climatic characteristics during the summer for the production of tropical forages, and consequently, has

suitable conditions for beef cattle production on grasslands, allowing a range of grazing intensities strategies. However, climatic conditions during the winter limit the growth of forages and require strategies, such as the use of high supplementation or feeding in feedlots. The period of adaptation to the high proportion of concentrate in their diet is critical (Millen et al., 2009), and ruminal and metabolic changes may compromise dry matter (DM) intake and average daily gain (ADG).

There is no consensus in the literature concerning the parameters that indicate adaptation to feedlot diets. Furthermore, the effects of

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the diet provided prior the feedlot period on productive aspects in the finishing phase are not well defined. The use of proper statistical methodology to estimate parameters can be an important tool in these studies. Dietary management during the period prior finishing, especially regarding the supply of supplement, or lack of thereof, may be an important factor in the finishing phase, or even alterations in body composition of cattle (Pesonen et al., 2014).

Grazing height combined with dietary supplementation enhances cattle production during the post-weaning period (Barbero et al., 2015), but little is known about their influence in the finishing phase (Hersom et al., 2004). The hypothesis for the present study is that the practice of finishing beef cattle on either grasslands with supplementation or feedlot, are influenced by the post-weaning grazing system. The goal of this study was to determine if the beef-cattle post-weaning system on grasslands influence the time for balance of intake on a feedlot, ADG, final body weight (BW), weight, carcass weight, and carcass dressing of beef cattle finished on grasslands with supplementation or feedlot.

2. Material and methods

Two experiments were conducted simultaneously in the Forage Crops and Grasslands section of São Paulo State University, “Júlio de Mesquita Filho” (UNESP) (Jaboticabal, São Paulo, Brazil). The typical climate of the region is subtropical humid type, with dry winters and wet summers. The pastures used were planted with *Brachiaria brizantha* (Hochst ex A. Rich) Stapf Marandu (Marandu grass). The pastures were divided into 18 experimental paddocks. The bulls used in this experiment spent the post-weaning phase on grasslands during the wet season of 2012/2013, and were finished during the dry season of 2013 (April to August). The protocol used was approved by the Ethics, Bioethics, and Animal Welfare Committee of the UNESP, Jaboticabal (protocol number 022368/12).

2.1. Post-weaning in the wet season

2.1.1. Experiment 1

Fifty-four young Nelore (*Bos taurus indicus*) bulls, with an average initial age of 12 months and an average initial BW of 335 ± 6.3 kg, were separated into pastures featuring three grazing heights (15 cm, 25 cm, and 35 cm), under conditions of continuous grazing and with a variable stocking rate from January 2013 to April 2013. A feed supplement amounting to 0.3% BW (161 g crude protein [CP]/kg and 20.1 MJ gross energy [GE]/kg) was provided to each individual daily at 11h00m; the supplement was formulated based on a previous analysis of the forage that resulted in an ADG of 1.00 kg/day (Barbero et al., 2015). Stocking rates were 3199 (15 cm), 2290 (25 cm), and 1759 (35 cm) kg of BW/ha, and green leaves availability increased linearly with the increase in grazing height, as well as forage intake. The average daily gain also exhibited linear increases as grazing height increased. The average BW at the end of the post-weaning phase was 425 ± 4.5 , 431 ± 5.5 , and 437 ± 10.9 kg for the grazing heights of 15 cm, 25 cm, and 35 cm, respectively.

2.1.2. Experiment 2

Fifty-four young Nelore bulls with an average initial age of 12 months and an average initial BW of 336 ± 5.7 kg were used in this experiment. Grazing heights (15 cm, 25 cm, and 35 cm) under conditions of continuous grazing and with a variable stocking rate from January 2013 to April 2013 were combined with supplementation levels as follows: (1) low height (15 cm) and high supplementation (0.6% BW, 142 g CP/kg and 18.9 MJ GE/kg; LH-HS); (2) moderate height (25 cm) and moderate supplementation (0.3% BW, 161 g CP/kg and 20.1 MJ/kg GE; MH-MS), and (3) high height (35 cm) and no supplementation (HH-NS), as described by Barbero et al. (2015). Stocking rates were 3177 (LH-HS), 2290 (MH-MS), and 1782 (HH-NS) kg of BW/ha. Total

dry matter intake (9.85 ± 0.5 kg/bull/day) did not change according to treatments ($P = 0.28$), and the post-weaning strategies combining grazing height and supplementation level provided similar performance (1.13 ± 0.1 kg BW/bull/day). The average BW at the end of the post-weaning phase was 428 ± 7.2 , 432 ± 11.8 , and 430 ± 10.4 kg for the treatments LH-HS, MH-MS, and HH-NS, respectively.

2.2. Finishing in the dry season

2.2.1. Finishing on grasslands

At the beginning of the dry season, 54 bulls (431 ± 4.4 kg of BW) were finished on grasslands in which half of the bulls came from Exp. 1 (27) and the other half from Exp. 2 (27). The finishing phase occurred from April 21 to May 12, 2013 (21 days for adaptation) + 84 experimental days (until August 2013). The bulls received supplementation at a rate of 1.0 kg/100 kg BW (Table 1). Eighteen hectares were used (9 ha for each Exp.). To reduce potential environmental effects, post-weaned bulls were grouped as lots of three bulls each, totaling nine lots for both Exp. 1 and Exp. 2. These lots were formed so that each group would have a lot originating from each post-weaning system (i.e., treatment). Each group was then housed together in a paddock, with each lot (Exp. 1: $n = 9$, and Exp. 2: $n = 9$) considered to be the experimental unit (Fig. 1).

2.2.2. Finishing on feedlot

During the dry season, 54 bulls (429 ± 5.8 kg of BW) were confined in individual stalls and fed the same diet to evaluate the effect of the post-weaning system in which half of the bulls came from Exp. 1 (27) and other half came from Exp. 2 (27). The feedlot finishing period occurred from April 21 to May 12, 2013 (21 days for adaptation) + 84 experimental days (until August 2013). The feedlot-finishing diet consisted of sugarcane bagasse as roughage (20% on a DM basis) and a commercial concentrate (80% on a DM basis) (Table 2). The initial supply was 1.00 kg DM/100 kg BW, which was increased or decreased daily (15%) to obtain no >5% refusal of the total amount supplied, in order to reduce waste and selection of fractions, consuming only the formulated diet. Aiming to reduce environmental effects, experimental units were considered each group of three bulls each, totaling nine lots for both Exp. 1 and Exp. 2 (Exp. 1: $n = 9$, and Exp. 2: $n = 9$).

2.3. Forage samples

Grazing height was measured following the entry to exit of the bulls into experimental areas (every 28 days). Measurements were taken at the curvature of the upper leaves using a ruler graduated in centimeters, with 80 measurements conducted per hectare. To estimate forage mass, eight samples were taken per cut (described by: Shaw and TMannetje,

Table 1

Chemical composition of supplement and forage on pastures of Marandu grass in the finishing phase of beef cattle during the dry season.

	Supplement	Forage (Exp. 1)	Forage (Exp. 2)
Ingredient			
Mineral mix (g/kg DM)	107	–	–
Livestock urea (g/kg DM)	30.0	–	–
Ground corn (g/kg DM)	671	–	–
Soybean meal (g/kg DM)	192	–	–
Chemical composition			
Organic matter (g/kg DM)	780	903	907
Crude protein (g/kg DM)	220	133	135
Neutral detergent fiber (g/kg DM)	154	635	643
Acid detergent fiber (g/kg DM)	61.8	315	326
Gross energy (MJ/kg DM)	14.6	11.2	11.4
In vitro DM digestibility (g/kg DM)	826	529	538
In vitro OM digestibility (g/kg DM)	857	572	582

Dry matter (DM), and organic matter (OM). Supplementation of 1.0 kg/100 kg body weight.

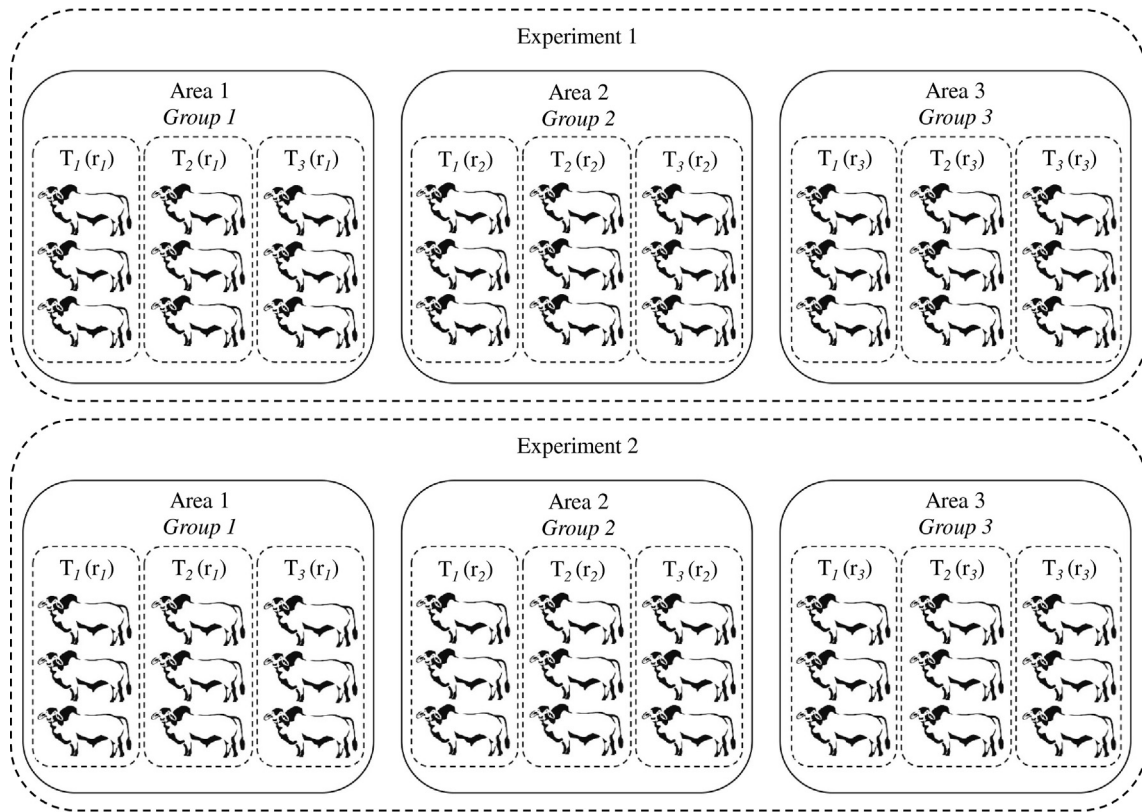


Fig. 1. Distribution of individual bulls into groups on pastures: area (three hectares), lot (three bulls), treatment (T), and replicate (r).

1987) in average points per area (± 5.0 cm of residue), using a 0.25-m^2 circular frame. Samples were divided into dead material, stem + sheath, or green leaves, then dried in an oven ($55 \pm 5^\circ\text{C}$ for 72 h), following which they were weighed, to estimate the forage dry mass per hectare. Samples chosen for forage chemical composition analyses were harvested via the grazing-simulation method (described by: Sollenberger et al., 1995) from 20 or so points per hectare, with approximately 200 g of fresh matter collected per sampling effort. Samples destined for forage mass estimate analysis were collected as described above. Samples were dried in a forced-air oven ($55 \pm 5^\circ\text{C}$, for 72 h), ground in a mill (Thomas-Wiley Laboratory Mill Model 4, H. Thomas Co.), and taken to the laboratory for analyses.

2.4. Chemical composition

Dry matter, and organic matter (OM) were estimated according to procedures described in AOAC (1990) (AOAC 934.01 for DM, and AOAC 942.05 for OM). Crude protein content was estimated using a LECO® FP 528 device (Leco Corporation, Michigan, USA). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were estimated according to principles described by Mertens (2002) by using an ANKOM® device (Ankom Technologies, New York, USA). The *in vitro* digestibility was estimated using ANKOM® Daisy^{II} equipment and methodologies (Ankom Technologies, New York, USA). Gross energy was measured with an adiabatic bomb calorimeter (PARR Instrument Company 6300, Illinois, USA).

2.5. Dry matter intake

Dry matter intake (DMI) from grazing bulls was calculated by using three markers to estimate fecal excretion, DMI from supplement, and total DMI. To estimate fecal excretion, an external marker composed of isolated, purified, and enriched lignin deriving from *Eucalyptus grandis* (500 mg) was supplied orally for 6 days, with feces collected at 12 h intervals over the final 3 days. Feces were oven dried ($55 \pm 5^\circ\text{C}$ for 72 h), ground, and separated by animal. Fecal excretion was calculated based on the concentration of the marker, which was determined through infrared spectroscopy (Saliba et al., 2015).

A titanium dioxide (TiO_2) marker was used to estimate the DMI from the supplement concentrate (DMIS) (Titgemeyer et al., 2001). Ten grams of this marker was added to the supplementary feed and provided to each bull for 9 days; a grab sample of the bulls' feces were collected at 12-h intervals over the final 3 days. Feces were oven dried ($55 \pm 5^\circ\text{C}$ for 72 h), ground, and digested with sulfuric acid (H_2SO_4). The standard curve was created for concentrations of 0, 2, 4, 6, 8, and 10 mg of TiO_2 by atomic absorption spectrophotometry, with an ultraviolet waveband of

Table 2

Composition of the diet for beef cattle finished in the feedlot during the dry season.

Composition	
Ingredients	
Sugarcane bagasse (g/kg DM)	200
Soybean meal (g/kg DM)	135
Ground corn (g/kg DM)	475
Livestock urea (g/kg DM)	14
Mineral mix (g/kg DM)	176
Chemical composition	
Organic matter (g/kg DM)	787
Crude protein (g/kg DM)	139
Neutral detergent fiber (g/kg DM)	306
Acid detergent fiber (g/kg DM)	170
Gross energy (MJ/kg DM)	14.0
<i>In vitro</i> DM digestibility (g/kg DM)	730
<i>In vitro</i> OM digestibility (g/kg DM)	750

Dry matter (DM), and organic matter (OM).

410 nm (Myers et al., 2004). Dry matter intake from the supplement was calculated based on the concentration of TiO_2 , using the formula:

$$\text{DMIS} = ([\text{g TiO}_2/\text{g feces}] \times \text{fecalexcretion}) / [\text{g TiO}_2/\text{g supplement}]$$

Forage DMI was estimated using the indigestible-NDF marker (iNDF) obtained by rumen incubation (Nocek and English, 1986) for 240 h (Casali et al., 2008), using inoculum from young Nelore bulls. Forage DMI was calculated as:

$$\text{DMIF} = (\text{FE} \times [\text{IM}_{\text{Fe}}] - \text{DMIS} \times [\text{IM}_{\text{S}}]) / [\text{IM}_{\text{Fo}}]$$

where DMIF = DMI from the forage; FE = fecal excretion; DMIS = DMI from the supplement; and IM_{Fe} , IM_{S} , and IM_{Fo} = concentrations of the internal marker in the feces, supplement, and forage; respectively. Gross energy intake was calculated considering supplement intake and forage intake, and their respective gross energy contributions. Total DMI was defined as the sum of DMIF and DMIS. Dry matter intake from feedlot bulls was taken daily by the difference between supplied and refused into the feeders.

2.6. Animal production

Bulls were weighed at the beginning (0 days) and end of the adaptation period (21 days), and again at the end of the experimental period ($21^\circ + 84$ days), after fasting for 12 h prior to both weighing events. Intermediate weighing sessions were carried out only in the bulls finished on grasslands every 28 days (without fasting) to adjust the supplementation level. It was calculated the gross energy intake per kg of BW gain. Cattle were slaughtered in a commercial abattoir, following the slaughter line of the establishment. Immediately after slaughter, the hot carcass weight (kg) was determined in order to calculate the carcass dressing weight relative to the final BW. These variables were calculated as follows:

$$\text{BW gain (kg)} = \text{final BW} - \text{initial BW};$$

$$\text{ADG} = \text{BW gain (kg)} / \text{days};$$

$$\begin{aligned} \text{Gross energy intake/BW gain} \\ = \text{Mega joule (MJ) of gross energy intake/kg of BW gain} \end{aligned}$$

$$\text{Carcass dressing} = (\text{kg}_{\text{carcass}} / \text{kg}_{\text{final BW}}) \times 100$$

2.7. Economic results

Concentrate expenses were calculated multiplying the price per kg by the total concentrate intake (daily intake \times days of experiment). Feedlot diet expenses were calculated considering the total diet price per kg (roughage + concentrate). To compare the economic effects of concentrate use, it was calculated only feed expenses, excepted forage costs grazed by bulls from grasslands systems. The income from each production system was calculated multiplying the BW gain (kg) by the commercial price of the bulls in State of São Paulo, Brazil at the experimental season (US\$1.49/kg BW; US\$1.00 = R\$2.28 Brazil). Profit was obtained by the difference between income and expenses.

2.8. Statistical analyses

A non-linear regression test (linear plateau) on daily DMI was conducted during the adaptation period in the bulls finished on the feedlot, for estimation of the time of DMI stabilization (Fig. 2). The experimental design was completely randomized in a factorial arrangement 3×2 (three post-weaning systems \times two finishing systems), consisting of three replicates per treatment (lots of three bulls) ($n = 18$), each experiment. The error-normality and homoscedasticity assumptions for

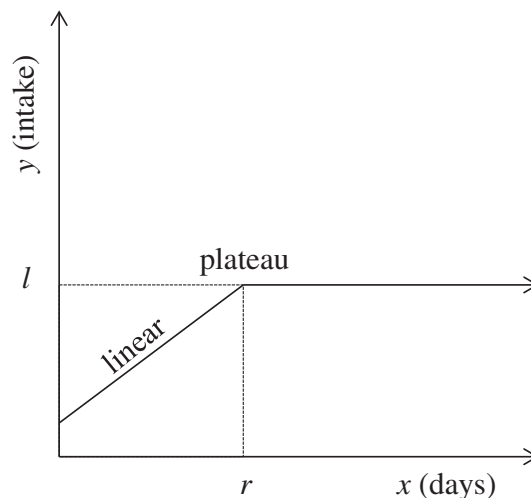


Fig. 2. Model used to estimate the time (days) for stabilization of dry matter intake by beef cattle during the adaptation period to the feedlot. $Y_{ij} = U \times (X_i < r) \times (r - X_i) + l + \varepsilon_{ij}$. Where: Y_{ij} = dependent variable (i = treatment, and j = replication); U = no biological interpretation; X_i = time; r = breaking point; l = intake estimated at the plateau; and ε_{ij} = random error.

analysis of variance were tested, and Tukey's test ($P < 0.05$) was used to compare the means of the treatments, using the MIX PROC procedure of SAS® software (Statistical Analysis System, SAS Institute, 2008 Inc., Cary, North Carolina). In both experiments, was used the following mathematical model:

$$Y_{ijk} = \mu + \text{PW}_j + \text{FS}_k + (\text{PW}_j \times \text{FS}_k) + \varepsilon_{ijk}$$

where: Y_{ijk} = dependent variable i subject to post-weaning system j at finishing system k , μ = overall mean, PW_j = effect of post-weaning system $j = 1, 2$, and 3 , FS_k = effect of finishing system $k = 1$ and 2 , $\text{PW}_j \times \text{FS}_k$ = interaction between post-weaning j and finishing system k , and ε_{ijk} = residual experimental error.

3. Results

3.1. Experiment 1

The average stocking rate over the experimental period was 3.18 ± 0.02 animal unit (animal unit = 450 kg)/ha. Forage characteristics exhibited averages of: green leaves = 2025 ± 275 kg DM/ha, NDF = 635 ± 11.8 g/kg of DM, CP = 133 ± 7.71 g/kg of DM, IVDMD = 529 ± 35.2 g/kg of DM, IVOMD = 572 ± 38.49 g/kg of DM and GE = 11.2 ± 0.67 MJ/kg DM. The bulls from 35 of grazing height during the post-weaning phase exhibited greater initial BW than bulls from 15 cm of grazing height post-weaning system ($P = 0.04$), however, there were no differences during the finishing system ($P = 0.70$) or interactions ($P = 0.44$). The ADG during the adaptation period was changed by the post-weaning system ($P = 0.004$), finishing system ($P = 0.07$), but there was no interaction ($P = 0.08$; it was observed a tendency to higher ADG by the bulls from 25 cm of grazing height during the post-weaning phase, finished on grasslands with supplementation). Over the initial 21 days that the bulls were adapting to the finishing conditions, bulls exhibited no more differences on final BW due to the post-weaning system ($P = 0.05$), finishing system ($P = 0.10$) or interactions ($P = 0.11$) (Table 3).

All bulls exhibited a significant response ($P \leq 0.05$) as seen in the non-linear regression test (linear plateau) for DMI as a function of days adapting to the feedlot, indicating that DMI stabilized over time. The grazing height utilized in the post-weaning phase did not change the time required to stabilize DMI ($P = 0.12$) on feedlot (Fig. 3). The post-weaning system did not change the final BW ($P = 0.68$). The

Table 3

Finishing phase of beef cattle from three post-weaning systems (15, 25 or 35 cm of Marandu grass grazing height), combined with finishing system on grassland with supplementation or feedlot.

Item	Post-weaning system ^(PW)			Finishing system ^(FS)		SEM	P-value		
	15 cm	25 cm	35 cm	Grassland	Feedlot		PW	FS	PW × FS
Adaptation period (initial 21 days)									
Initial body weight (kg)	425 ^b	431 ^{ab}	437 ^a	432	430	4.51	0.04	0.70	0.44
Final body weight (kg)	434	442	440	442	434	5.77	0.05	0.10	0.11
Average daily gain (kg/bull/day)	0.37 ^b	0.55 ^a	0.14 ^c	0.48 ^d	0.23 ^e	0.08	0.004	0.007	0.08
Finishing phase (84 days)									
Dry matter intake (kg/bull/day)	9.75 ^{ab}	9.39 ^b	10.2 ^a	10.6 ^d	8.92 ^e	0.24	0.03	<0.0001	0.74
Gross energy intake (MJ/bull/day)	130 ^{ab}	124 ^b	136 ^a	135	134	12.2	0.01	0.85	0.56
Final body weight (kg)	510	518	514	513	514	6.15	0.68	0.25	0.65
Average daily gain (kg/bull/day)	0.91	0.91	0.88	0.85	0.95	0.04	0.93	0.24	0.76
Gross energy intake (MJ/kg BW gain)	178	180	168	177	174	18.9	0.93	0.92	0.22
Carcass weight (kg)	272	272	265	279 ^d	260 ^e	3.95	0.63	0.02	0.43
Carcass dressing (%)	53.3	52.5	51.5	54.4 ^d	50.6 ^e	0.30	0.60	0.0002	0.26

Post-weaning system (^{abc}), and finishing system (^{de}). Means without a common superscript letter differ by Tukey test ($P < 0.05$). Standard error of mean (SEM).

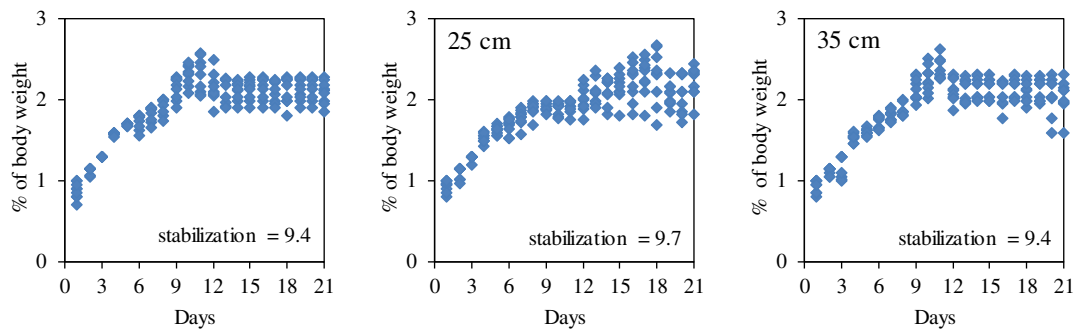
post-weaning system did not change the ADG ($P = 0.93$), carcass weight ($P = 0.63$), and carcass dressing ($P = 0.60$), but it changed the DMI ($P = 0.03$), where bulls from 35 cm exhibited higher DMI than bulls from 25 cm of grazing height during the post-weaning phase.

Gross energy intake was higher when bulls were grazing at 35 cm than bulls grazing at 25 cm of grazing height during the post-weaning ($P = 0.01$; Table 3). No differences were observed on gross energy intake by finishing system ($P = 0.85$), or interactions ($P = 0.56$). There are no changes on gross energy intake per kg of BW gain (MJ/kg BW gain) during finishing phase by post-weaning system ($P = 0.93$), finishing system ($P = 0.92$), or interactions ($P = 0.22$). The finishing system did not change the final BW ($P = 0.25$; Table 3), ADG ($P = 0.24$). However, carcass weight ($P = 0.02$), carcass dressing ($P = 0.0002$), and DMI ($P < 0.0001$) were greater for bulls finished on pasture than bulls finished on feedlot. There were no interactions between the grazing height used during the post-weaning phase and finishing

system on grasslands or feedlot for final BW ($P = 0.65$), ADG ($P = 0.76$), carcass weight ($P = 0.43$), carcass dressing ($P = 0.26$), or DMI ($P = 0.74$).

Total BW gain per bull during the finishing phase on feedlot was 85 ± 10 kg. The price (US\$) per kg of supplements utilized during the post-weaning phase was \$0.24 (0.3% BW; Table 4). The expenditures, including supplements, during the post-weaning phase were $9.7 \pm 0.65\%$ relative to the total amount spent on feed until slaughter. During the finishing phase on grasslands system, the total BW gains per bull were 82.0 ± 1.73 . Given that the price per kilogram of supplements fed to bulls during the post-weaning phase, already mentioned, and \$0.30/kg during the finishing phase, the total expenditure for supplements during the post-weaning phase were $14.8 \pm 0.27\%$, relative to the total amount spent until slaughter. The average daily expenditures for supplements were $\$0.30 \pm 0.01$ per bull during the post-weaning phase and $\$1.43 \pm 0.01$ in the finishing phase on grassland. Incomes

Experiment 1 (P -value = 0.12)



Experiment 2 (P -value = 0.01)

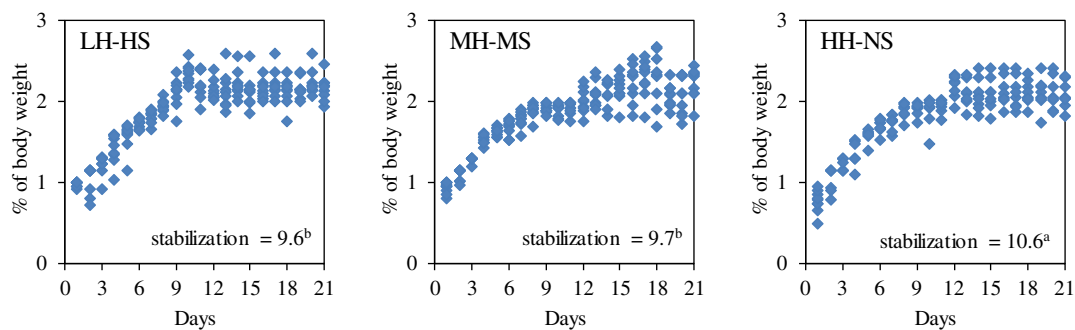


Fig. 3. Time (days) to stabilization of the dry matter intake during the adaptation period by beef cattle on feedlot according to post-weaning system (Exp. 1): 15, 25, and 35 cm of Marandu grass grazing height, or combinations between increasing grazing heights and decreasing supplement levels (Exp. 2): low height and high supplementation (LH-HS), moderate height and moderate supplementation (MH-MS), and high height and no supplementation (HH-NS). Means without a common superscript letter differ by Tukey test ($P < 0.05$).

Table 4
Diet expenses (except forage), income and profit by beef cattle post-weaning systems during the wet season, finished on grassland with supplementation or feedlot during the dry season.

Item	Post-weaning system (Exp. 1) ^a			A			Finishing system	
	15 cm	25 cm	35 cm	LH-HS ^b	MH-MS ^c	HH-NS ^d	Grassland ^e	Feedlot ^f
Concentrate price (US\$/kg)	0.24	0.24	0.24	0.22	0.24	0.42	0.3	0.22 ^g
Concentrate intake (kg/bull/day)	1.24	1.27	1.27	2.62	1.27	0.05	4.78	10.2 ^g
Total concentrate intake (kg/bull)	104	107	107	220	107	4.03	502	1071 ^g
Body weight gain (kg)	90.7	96.6	101	93.2	96.6	94.9	84.6	85.5
Spent with concentrate (US\$/bull)	25.0	25.6	25.6	48.4	25.6	1.69	151	236 ^g
Income (US\$/bull)	135	144	150	139	144	141	126	127
Profit (US\$/bull)	112	121	128	98	122	140	–25	–108

Income considering US\$ 1.49/kg of BW gain.

^a Marandu grass grazing height during the post-weaning phase (wet season), with supplementation (0.3% BW).

^b LH-HS = low height (15 cm), high supplementation (0.6% BW).

^c MH-MS = moderate height (25 cm), moderate supplementation (0.3% BW).

^d HH-NS = high height (35 cm), no supplementation (mineral mix).

^e Finishing phase grazing Marandu grass (dry season), with supplementation (1% BW).

^f Finishing phase on feedlot (dry season).

^g Total diet including roughage and concentrate (20/80% of DM, respectively).

and profits during the post weaning and finishing phase are exhibited on Table 4.

3.2. Experiment 2

The average stocking rate over the experimental period was 3.20 ± 0.01 animal unit/ha. Forage characteristics exhibited averages of: green leaves = 1870 ± 254 kg DM/ha. Herbage chemical composition showed the values: NDF = 643 ± 5.86 g/kg of DM, CP = 135 ± 9.29 g/kg of DM, IVDMD = 538 ± 41.6 g/kg of DM, IVOMD = 582 ± 45.4 g/kg of DM and GE = 11.4 ± 0.69 MJ/kg DM. The bulls initial BW was not different among the post-weaning systems ($P = 0.71$; Table 5). Similarly, no differences in final BW ($P = 0.95$), and ADG ($P = 0.10$) were also found. In addition, initial BW in the feedlot ($P = 0.52$) and final feedlot BW ($P = 0.87$) were not different. However, there was an interaction tendency ($P = 0.06$) by bulls from post-weaning system MH-MS to exhibit higher ADG when finished on feedlot. There were no interactions between post-weaning system and finishing system on initial BW ($P = 0.92$), final BW ($P = 0.90$), and ADG ($P = 0.21$) during the adaptation period (initial 21 days).

Daily DMI during the feedlot adaptation period of all bulls exhibited a significant response ($P \leq 0.05$) in the non-linear regression test (linear plateau) for DMI as a function of days adapting to the feedlot, indicating that intake stabilized over time. Bulls from HH-NS post-weaning system spent 10% longer than the others post-weaning systems ($P = 0.01$; Fig. 2). Final BW was not changed by post-weaning system ($P = 0.53$),

finishing system ($P = 0.47$), and there was no interaction ($P = 0.98$). Average daily gain was greater in the bulls from HH-NS than MH-MS post-weaning system ($P = 0.04$), however, there were no changes due to finishing system ($P = 0.40$), or interaction ($P = 0.06$).

Gross energy intake was higher by bulls from HH-NS than bulls from LH-HS grazing system during the post-weaning ($P = 0.05$; Table 5). No differences were observed on gross energy intake by finishing system ($P = 0.22$), or interactions ($P = 0.11$). There are no changes on gross energy intake per kg of BW gain (MJ/kg BW gain) during finishing phase by post-weaning system ($P = 0.11$), finishing system ($P = 0.85$), or interactions ($P = 0.12$). Post-weaning system did not change the carcass weight ($P = 0.84$), carcass dressing ($P = 0.18$), and DMI ($P = 0.10$). The finishing system did not alter carcass weight ($P = 0.14$), but it did influence carcass dressing percentage ($P = 0.02$), and DMI ($P < 0.0001$), where were observed greater values by bulls finished on grasslands receiving supplementation during the dry season in comparison with bulls finished on the feedlot. There were no interactions on carcass weight ($P = 0.98$), carcass dressing ($P = 0.71$), and DMI ($P = 0.17$) between post-weaning systems and finishing systems (Table 5).

Total BW gain per bull during the finishing phase on feedlot was 86 ± 9.5 kg. The price (US\$) per kg of supplements utilized during the post-weaning phase, considering consumption, was \$0.42 (mineral mix), \$0.24 (0.3% BW), and \$0.22 (0.6% BW) (Table 4). The expenditures, including supplements, during the post-weaning phase were 18.4% (LH-HS), 9.8% (MH-MS), and 0.9% (HH-NS) (Exp. 2) relative to the total amount spent on feed until slaughter. During the finishing

Table 5
Finishing phase of beef cattle from three post-weaning systems (increasing Marandu grass grazing height and decreasing supplementation levels), combined with finishing system on grassland with supplementation or feedlot.

Item	Post-weaning system (^{PW})			Finishing system (^{FS})		SEM	P-value		
	LH-HS ^a	MH-MS ^b	HH-NS ^c	Grassland	Feedlot		PW	FS	PW × FS
Adaptation period (initial 21 days)									
Initial body weight (kg)	428	432	430	431	429	5.57	0.71	0.52	0.92
Final body weight (kg)	442	441	435	444	435	4.59	0.95	0.87	0.90
Average daily gain (kg/bull/day)	0.66	0.45	0.22	0.60	0.29	0.09	0.10	0.06	0.21
Finishing phase (84 days)									
Dry matter intake (kg/bull/day)	9.43	9.71	10.0	10.4 ^d	9.07 ^e	0.19	0.10	<0.0001	0.17
Gross energy intake (MJ/bull/day)	125 ^b	130 ^{ab}	133 ^a	131	128	7.91	0.05	0.22	0.11
Final body weight (kg)	520	509	516	518	513	5.04	0.53	0.47	0.98
Average daily gain (kg/bull/day)	0.94 ^{ab}	0.81 ^b	0.97 ^a	0.89	0.93	0.03	0.04	0.40	0.06
Gross energy intake (MJ/kg BW gain)	135	160	137	151	154	14.4	0.11	0.85	0.12
Carcass weight (kg)	275	281	274	278	268	2.78	0.84	0.14	0.98
Carcass dressing (%)	52.8	55.2	53.1	53.7 ^d	52.2 ^e	0.23	0.18	0.02	0.71

Post-weaning system (^{a,b,c}), and finishing system (^{d,e}). Means without a common superscript letter differ by Tukey test ($P < 0.05$).

Standard error of mean (SEM).

^a LH-HS = low height (15 cm), high supplementation (0.6% BW).

^b MH-MS = moderate height (25 cm), moderate supplementation (0.3% BW).

^c HH-NS = high height (35 cm), no supplementation

phase on grasslands system, the total BW gains per bull were 87.3 ± 3.51 kg. The total expenditure for supplements during the post-weaning phase were 24.4% (LH–HS), 14.5% (MH–MS), and 1.51% (HH–NS), relative to the total amount spent until slaughter. The average daily expenditures for supplements were \$0.49 (LH–HS), \$0.26 (MH–MS), and \$0.02 (HH–NS) (Exp. 2) per bull during the post-weaning phase and $\$1.43 \pm 0.01$ in the finishing phase on grassland. The incomes and profit are exhibited on Table 4.

4. Discussion

The height of the grass (Casagrande et al., 2011) and level of supplementation (Silva et al., 2009) in pasture can influence the amount of forage consumed by cattle. As such, variations in the roughage/concentrate ratio should be taken into account, and so should their influence on DMI, especially when higher proportions of concentrate are abruptly introduced, which can disrupt rumen conditions (Owens et al., 1998). Our results showed that the post-weaning system influenced DMI in both experiments during the finishing phase; however this influence was found to be greater on grassland system than the feedlot system. Although the proportion of concentrate provided during the finishing phase did increase, the roughage/concentrate ratio to the bulls finished on grasslands with supplementation was $55/45 \pm 0.5$, considered to be appropriate for efficient rumen functioning (Brown et al., 2006).

In the first experiment, the post-weaning system did not affect adaptation to the feedlot; however, in the second experiment, bulls that were not supplemented in the post-weaning phase (HH–NS) took longer to stabilize their intake in the feedlot compared to those that received supplements. The increase in the proportion of concentrate in the diet results in increased rumen propionate production, acidifying the rumen (Allen et al., 2009). According to Russell and Wilson (1996), the decline in pH caused by changes in the diet also generates numerous alterations in the microorganism populations in the rumen.

Bulls supplemented in the post-weaning phase may possess rumen conditions already adapted to the greater concentrate intake in the feedlot. This would explain the longer time needed for stabilization of DM during the adaptation period by the non-supplemented bulls in the post-weaning phase. Owens et al. (1998) showed acidosis during the adaptation period to high-concentrate diets as one of the major problems in feedlot systems. However, the ability of cattle to adapt to large amounts of concentrate was demonstrated by Schwaiger et al. (2013). Although variations in the time needed for stabilization of DMI were detected, the impacts on cattle feedlot-finishing systems may not have visible impacts.

Abrupt changes in cattle production system are causes of stress in bulls. Paranhos da Costa et al. (2012) emphasized the importance of animal wellbeing on performance. Managing the daily supply of supplements in the post-weaning phase may also influence the conditioning of these bulls to human presence, easing the adaptation to facilities and management of the feedlot. Additionally, there are factors related to previous rumen environment and a longer time necessary for the stabilization of DMI, as previously mentioned. Lower ADG exhibited by the non-supplemented bulls in the post-weaning system (Exp. 1) at the beginning of the feedlot period could also be associated with stress, caused by changes on installations and diet.

The average CP intakes for the bulls finished on grasslands in the both experiments were 1.8 ± 0.05 kg/day (Exp. 1) and 1.78 ± 0.02 kg/day (Exp. 2), with both values close to those predicted by NRC (1996) for the ADG observed in this study. The ratio between CP and digestible OM consumed was 245 g CP per kg digestible OM, which is above the limit for maximum nitrogen use efficiency proposed by Detmann et al. (2014). After the adaptation period, the post-weaning strategies did not influence the ADG during the dry season in the Exp. 1; therefore, the grazing height during the wet season can be utilized according to the objectives of production to optimize exploitation of the forage resources, thereby improving bull performance and increasing

productivity per area without influencing performance in the finishing phase.

The grazing height used during the post-weaning phase did not change the ADG (Exp. 1) during the finishing phase, but the finishing system has changed, with greater values by grasslands finishing system than feedlot, while in the Exp. 2, bulls from HH–NS post-weaning system exhibited greater ADG than MH–MS, and the finishing system did not change the ADG. Due to these differences on the ADG during the finishing phase, bulls from every evaluated post-weaning systems or finishing systems exhibited no differences on the final BW. Thus, even if there were differences between the BW caused by the post-weaning systems, these were eliminated during the finishing phase in the dry season, and the bulls in different treatments in the post-weaning phase were slaughtered with the same BW weight in both experiments.

According to Pesonen et al. (2014), the nutritional plan can change the body composition of cattle. Increases on the concentrate level in relation to roughage has been associated with reduction of the rumen size and proportion to total body weight, changing the carcass dressing; where animals fed diets with higher roughage levels tend to exhibit lower carcass dressing. However, greater weight gain rate can promote greater muscle deposition and greater carcass gain. The grazing height (Exp. 1), and the combination of grazing heights and supplementation level (Exp. 2) did not change the carcass weight and the carcass dressing. However, the greater carcass weight and consecutively the carcass dressing exhibited by bulls finished on grasslands (Exp. 1), can be associated with the greater ADG during the adaptation period (initial 21 days) to the finishing phase in this system.

According to NRC (1996), the passage rate through of the digestive tract it is directly related to intake rate and fiber contents. Bulls finished on feedlot received a roughage/concentrate ratio at 20:80% on DM basis, while bulls finished on grasslands with supplementation 55/45 (Exp. 1), and 54/46 (Exp. 2). In the Exp. 2, it is possible that the diet had a greater passage rate through the digestive tract during the fasting after the last weighing session by the bulls finished on feedlot than bulls finished on grassland, what could explain the difference between carcass dressing percentage, without altering the carcass weight.

During the post-weaning phase, gross energy intake per kg of BW gain was 140 ± 2.99 MJ/kg BW gain (Exp. 1) and 147 ± 10.5 MJ/kg BW gain (Exp. 2). The forage resources provided $84 \pm 7\%$ (Exp. 1), and $78 \pm 5\%$ (Exp. 2) of gross energy intake (Barbero et al., 2015). During the finishing phase, it was 159 MJ/kg BW gain (grassland system), and 177 MJ/kg BW gain (feedlot). Though the post-weaning system or finishing system did not change the energy efficiency (MJ/kg BW gain), there was greater energy efficiency (average of 15%) during the post-weaning phase on grassland systems than during the finishing phase. Still must be considered that only 48% of gross energy consumed came from forage resources during the finishing phase on grassland system. Reduction on the bulls finishing period while exploring forage resources during the post-weaning phase can be an effective strategy to improve beef cattle production.

The post-weaning systems evaluated in this study represent a significant part of the beef-cattle production systems in Brazil. Post-weaning systems that generate greater rates of productivity during the wet season can be efficient regarding the use of forage resources, provided that the exploitation of greater production per area does not compromise ADG and influence the finishing phase. At large production scales, technologies like ultrasonography can help to inform the decision-making process based on the composition of the carcass, but such technologies are usually not available to or feasible for small-scale farmers.

Davies et al. (2009) discussed the increase in costs caused by an increase in the feedlot time, when long periods are necessary to reach slaughter weight. These authors concluded that bulls with greater ADG require less time for finishing, and consequently generate lower production costs. Reducing the feedlot period would have direct impacts on the costs per kilogram of carcass produced, given that daily feeding represents the largest share of the production costs. However,

increments in the feed cost for providing better performance should be considered. Another strategy to shorten the feedlot period is to exploit the ADG in the post-weaning phase, resulting in heavier bulls at the end of this period and consequently, heavier bulls at the beginning of the feedlot-finishing phase.

During the finishing phase on feedlot in both experiments, the largest portion of BW ($53 \pm 4.0\%$ in Exp. 1, and $52 \pm 3.0\%$ in Exp. 2) was deposited in the post-weaning phase during the wet season. The value per kilogram of diet during the feedlot period was \$0.22, 14.8% of the price per kg of BW (\$1.49/kg BW). This means that a feed conversion of 6.8 kg of diet/kg BW produced would be necessary to equal the amount spent on feeding. The average feed conversion during the feedlot-finishing phase was 10.7 ± 0.34 (Exp. 1) and 12.4 ± 1.25 (Exp. 2) kg diet/kg BW. Even if the feedlot-finishing diet is considered low-cost, given the inclusion of sugarcane bagasse as roughage, the high feed conversion negatively affects the production system by elevating the cost per kg of BW produced. Therefore, it is clear that independently of the post-weaning system utilized, it was the period of greatest productive and economic efficiency, because the exploitation of forage resources in the wet season, coupled with the supplementation strategies, provided a higher fraction of BW deposited until slaughter and lower expenditure for feed compared with the feedlot-finishing phase during the dry season.

During the finishing period on grasslands in both experiments, the bulk of BW gain ($53.7 \pm 1.54\%$ in Exp. 1, and $51.8 \pm 1.27\%$ in Exp. 2) occurred when post-weaning phase coincided with the wet season. The ratios between the amounts disbursed for supplements and the resulting BW (per kg) during the post-weaning phase were 0.28 ± 0.01 (Exp. 1) and 0.52 (LH–HS), 0.27 (MH–MS), and 0.02 (HH–NS) (Exp. 2), whereas in the finishing period on grassland with supplementation, this ratio was 1.78 ± 0.06 , which was higher than the quoted price of US\$1.49/kg of BW over the entire experimental period. It is thus clear that regardless of the post-weaning system employed, the growing period during the post-weaning phase was the period of greatest productive and economic efficiency, because the exploitation of forage resources during the wet season, coupled with the supplementation strategies, provided both a greater fraction of BW deposited until slaughter and lower supplement costs (US\$/kg BW produced) compared with the finishing period on grassland during the dry season.

Exploiting the production potential of grasslands in the post-weaning phase during the wet season, and thereby producing heavier bulls at the beginning of the finishing period, is of great relevance to the viability of beef-cattle production systems in Brazil. The beef-cattle post-weaning systems evaluated here had a lower cost of production per kilogram of BW produced than those in the finishing phase did; moreover, no significant changes in the production indices included in the analysis were observed. Studies on the effects caused by the combination of the post-weaning system and finishing phase of beef cattle are important, aiming at greater efficiency of production systems. Dietary supplementation increased expenses on production system, but it can be a beneficial when climate conditions compromises forage growth and stocking capacity. The economic efficiency of the combination between post-weaning and finishing systems are dependent of factors as climate conditions and economic background.

This study addressed the exploitation of beef cattle post-weaning systems on tropical grasslands during the wet season. The post-weaning period is more efficient compared with the finishing phase in both productive and economic aspects. Production systems utilizing high stocking rates to increase production per area and body weight by the end of the wet season are beneficial, since of that post-weaning system used do not affect the productive variables during the finishing phase. The post-weaning systems utilized in this study can be adopted during the wet season according to the economic context and objective of production because they do not influence the carcass weight in the grassland with supplementation or feedlot system during the dry season.

5. Conclusions

Bulls that did not receive supplementation during the post-weaning phase took a longer time to DMI stabilization on feedlot during the finishing phase. The finishing system alters the carcass weight of the bulls from different grazing heights during the post-weaning phase, but the combination of increasing grazing heights and decreasing supplement levels during the post-weaning phase did not alter the carcass weight by bulls finished on grasslands with supplementation or feedlot. Increasing grazing heights combined with decreasing supplementation levels during the post-weaning phase on the wet season can be adopted according to the economic context and the production objectives because they do not change the carcass weight of beef cattle finished on pastures and receiving supplementation or feedlot during the dry season.

Conflict of interest

We declare that there is not conflict of interests in this project or about the article submission to publication. All the financial sources were mentioned. Additionally, there is no financial or other relationship with other people or organizations that may inappropriately influence the author's work.

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