Tropical Animal Health and Production (2018) 50:1411–1416
https://doi.org/10.1007/s11250-018-1574-y

REGULAR ARTICLES

Increasing levels of supplementation for crossbred steers on pasture during the dry period of the year

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Received: 13 November 2017 / Accepted: 14 March 2018 / Published online: 22 March 2018

Abstract
The aim of this study was to evaluate the effect of increasing concentrate supplementation levels on the intake, nutrient digestibility, and performance of crossbred steers during the dry period of the year. The experiment was developed on Princesa do Mateiro farm, in the municipality of Ribeirão do Largo, located in the southwest region of Bahia State, Brazil. Forty uncastrated male crossbred (½ Holstein-Zebu) steers with an average body weight (BW) of 232.55 ± 24.97 kg were distributed into four treatments in a completely randomized design with ten replicates. The animals were managed in an experimental area formed by *Brachiaria brizantha* cv. Marandu, in an intermittent grazing system. Treatments consisted of the following supplementation levels: 0.2% BW, with 60% crude protein (CP); 0.3% BW, with 40% CP; 0.4% BW, with 30% CP; and 0.5% BW, with 24% CP. The intakes of forage dry matter in kg/day and %BW and neutral detergent fiber corrected for ash and protein (NDFap) in %BW decreased linearly, whereas the intake of non-fibrous carbohydrates corrected for ash and protein in kg/day and average daily gain increased linearly. Therefore, the use of supplementation at 0.5% BW (24% crude protein) to provide gains of up to 0.500 kg/day is recommended for grazing steers during the post-weaning period in the dry season of the year.

Keywords Intake · Performance · Digestibility · Fiber · Pasture

Introduction

The dry matter intake is the crucial point of an animal's routine where it can obtain the nutrients required for maintenance and production, which makes it also the most important parameter in the evaluation of diets. The nutrient intake is the variable that most influences the performance of grazing cattle, and it is directly related to the ruminant's ability to capture, degrade, and absorb the feed and convert it into meat and/or milk.

Tropical forage production is greatly affected by soil-climatic, species-related, and pasture management-related factors. These interact amongst each other, making part of the environment-plant-environment interface. It is therefore important to know these interactions to better use the pasture aiming at the maximization of the produced forage, which is the basal nutritional resource of most cattle rearing systems.

The seasonality of forage production is a common characteristic of tropical forages, representing one of the bottlenecks of cattle production on pasture, characterized by reductions in the percentages of crude protein and nutrient digestibility, with a consequent effect of the reduced weight gain (Araújo et al. 2017). The nitrogenous compounds are the most deficient nutrients in tropical forages, which compromise the action of fiber-degrading microorganisms. In this regard, it should be stressed that, during the dry period, supplementation with nitrogenous compounds should be adopted to potentiate forage intake and the utilization of the basal energy (Detmann et al. 2014).

However, in studies conducted under tropical conditions, protein and energy supplements may have an interaction effect on the metabolism of nitrogenous compounds by amplifying the nitrogen assimilation in the rumen environments when provided together (Souza et al. 2010).

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The intensification of beef cattle husbandry raises questions as to its nutritional and biological applicability. There is a lack of studies on the biological and technical implications with respect to the production of grazing animals supplemented with different levels of crude protein. However, the application of this technique is not completely elucidated, and thus further research should be carried out on this topic.

This study was conducted to evaluate the effect of increasing levels of concentrate supplementation on the intake, nutrient digestibility, and performance of crossbred steers on *Brachiaria Brizantha* cv. Marandu pastures during the dry period of the year.

Material and methods

This study was conducted in strict conformity with the Brazilian legislation on experimentation involving the use of animals adopted by the National Council of Experimental Control (CONCEA) and was approved by the Ethics Committee In Animal Use (CEUA) of the State University of Southwest Bahia, located in Itapetinga-BA, Brazil, under approval no. 84/2015, of 04/15/2015.

The experiment was conducted on Princesa do Mateiro farm, located in the municipality of Ribeirão do Largo-BA, Brazil, and lasted 126 days comprised between 09/06/2014 and 11/29/2014. The experimental period was divided into four 28-day sub-periods where the first 14 days served as an adaptation of the animals to the diets.

Forty uncastrated male crossbred (½ Holstein-Zebu) steers with an average body weight of 232.55 ± 24.97 kg were distributed into 13 ha in an experimental area consisting of 12 paddocks of *Brachiaria brizantha* cultivar Marandu equipped with covered troughs accessed from both sides and water troughs.

The experimental design was completely randomized, with four treatments and ten replicates. Treatments consisted of three increasing levels of supplementation based on the animals' BW (Table 1), as follows: 0.2% BW, with 60% crude protein (CP); 0.3% BW, with 40% CP; 0.4% BW, with 30% CP; and 0.5% BW, with 24% CP. The animals were fed in a group where the supplement was supplied daily at approximately 10 h00. Diets were formulated according to the NRC (1996).

The chemical composition of forage and concentrate supplements can be seen in Table 2.

Concentrations of dry matter (DM), mineral matter (MM), crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber corrected for ash and protein (NDFap) were analyzed according to the methodology described by Aoac (1995). The ether extract (EE) content was analyzed using an Ankom® machine (XT15) following the methodology described by AOCS (2005).

Table 1 Centesimal composition of the supplements

Ingredient (g/kg)	Dietary supplement level (%BW)			
	0.2	0.3	0.4	0.5
Ground grain sorghum	49.22	68.86	80.06	86.33
Soybean meal	31.34	19.08	11.30	6.77
Urea	13.91	8.39	5.91	4.50
Mineral salt[1]	5.53	3.67	2.73	2.40

[1] Provides per kg: calcium 175 g; phosphorus 60 g; sodium 107; sulfur 12 g; magnesium 5000 mg; cobalt 107 mg; copper 1300 mg; iodine 70 mg; manganese 1000 mg; selenium 18 mg; zinc 4000 mg; iron 1400 mg; fluorine (maximum) 600 mg

The non-fibrous carbohydrate content corrected for ash and protein (NFCap) of forage and feces was calculated by the following equation, proposed by Weiss (1999), where all terms are expressed as %DM:

$$\text{NFCap} = 100 - \text{CP} - \text{EE} - \text{NDFap} - \text{MM}$$

where NFCap, non-fibrous carbohydrates corrected for ash and protein; CP, crude protein content; EE, ether extract content; NDFap, neutral detergent fiber corrected for ash and protein; and MM, mineral matter content. All terms are expressed as % of DM.

The supplements contained urea; for this reason, the NFCap content in them was obtained by using the equation proposed by Hall (2003), as displayed below:

$$\text{NFCap} = 100 - [(\text{CP\%} - \text{CP\%from urea} + \text{urea\%}) + \text{EE} + \text{NDFap} + \text{MM}]$$

where CP, crude protein content in the concentrate supplement; CP% from urea, protein equivalent of urea; urea%, urea content in the concentrate supplement; EE, ether extract content; NDFap, neutral detergent fiber corrected for ash and protein; and MM, mineral matter content. All terms are expressed as % of DM.

Total digestible nutrients (TDN) were calculated based on the equation suggested by NRC (2001), as shown below:

$$\text{TDN} = \text{DCP} + 2.25 \times \text{DEE} + \text{DNDFap} + \text{DNFC}$$

where DCP = digestible CP; DEE = digestible EE; and DNDFap = digestible NDFap.

The digestibility (*D*) of dry matter and nutrients was estimated by the formula described by Silva and Leão (1979):

$$D = [(\text{kg nutrient ingested} - \text{kg nutrient excreted})/\text{kg nutrient ingested}] \times 100.$$

To estimate fecal production, chromic oxide (Cr_2O_3) was used as an external marker. The marker was provided daily at 07.00 at a single dose of 10 g/animal/day inside paper cartridges that were administered orally for a period of 11 days, consisting of 7 days of adaptation of animals to management

Table 2 Chemical composition of forage and concentrate supplements and forage characteristics

Component[1]	Simulated grazing	Supplement (%BW)			
		0.2	0.3	0.4	0.5
Dry matter (%)	27.01	86.52	88.05	87.90	88.91
Mineral matter (%)	10.80	10.48	7.30	5.55	4.66
Crude protein (%)	7.26	60.00	40.00	30.00	24.00
Ether extract (%)	2.33	2.38	2.22	2.15	2.49
NDFap (%)	65.96	8.73	11.61	14.86	23.30
NFCap (%)	13.99	43.61	54.16	58.24	53.65
iNDF (%)	25.00	1.21	1.36	1.69	1.75
TDN (%)	45.37	69.45	63.22	61.12	59.30
Forage characteristics					
TDMA	1889.36 kg/ha	Forage allowance		10.71 kg DM/100 kg BW/day	
pdDMA	1545.38 kg/ha	Leaf to stem ratio		1.30	
GDMA	771.39 kg/ha				

[1] *NDFap* neutral detergent fiber corrected for ash and protein, *NFCap* non-fibrous carbohydrates corrected for ash and protein, *iNDF* indigestible neutral detergent fiber, *TDN* total digestible nutrients, *TDMA* total dry matter availability, *pdDMA* potentially digestible dry matter availability, *GDMA* green dry matter availability

procedures and regulation of chromium excretion in the feces and 4 days of collection. Subsequently, the fecal output was calculated according to Smith and Reid (1955), using the formula below:

$$\mathrm{FO} = \mathrm{OP}/\mathrm{CMF}$$

where FO = daily fecal output (g/day); OP = amount of chromic oxide provided (g/day); and CMF = concentration of chromic oxide in the feces (g/g DM).

The intake of dry matter from the forage (FDMI) was determined using the internal marker indigestible NDF (iNDF), obtained after ruminal incubation for 288 h, following the methodology and equation described by Detmann et al. (2012):

$$\mathrm{FDMI} = \{[(\mathrm{FO} \times \mathrm{MFe}) - \mathrm{MS}]/\mathrm{MFo}\}$$

where FDMI = forage dry matter intake, in kg/day; FO = fecal output, in kg/day; MFe = concentration of the marker (iNDF) in the feces, in kg/kg; MS = concentration of the marker (iNDF) in the concentrate supplement, in kg/kg; and MFo = concentration of the marker (iNDF) in the forage, in kg/kg.

The intake of dry matter from the supplement (SDMI) was estimated using the titanium dioxide marker (TiO_2), which was provided in the amount of 15 g/animal/day, mixed with the concentrate, for 11 days, and supplied directly in the trough at 10 h00, in accordance with the procedure described by Valadares Filho et al. (2006). Subsequently, SDMI was calculated by the equation shown below:

$$\mathrm{SDMI} = (\mathrm{EF} \times \mathrm{TiO_2}\ \mathrm{feces})/\mathrm{TiO_2}\ \mathrm{supplement}$$

where TiO_2 feces and TiO_2 supplement correspond to the concentration of titanium dioxide in the feces and supplement, respectively.

Having the forage DM intake and supplement DM intake data, it was possible to estimate the total DM intake.

The animals remained 28 days in four pre-defined paddocks. Every 7 days, they were rotated across the paddocks to control possible paddock effects on the treatments (availability of pasture, location of drinker and troughs, relief, shading, etc.), and the treatment followed the group of animals.

The potentially digestible dry matter (pdDM) of the pasture was estimated according to the methodology of Paulino et al. (2006a):

$$\mathrm{pdDM} = 0.98\ (100 - \%\mathrm{NDF}) + (\%\mathrm{NDF} - \%\mathrm{iNDF})$$

where 0.98 = true digestibility coefficient of the cell content.

The equation below was used to calculate the potentially digestible DM availability (pdDMA):

$$\mathrm{pdDMA} = \mathrm{TDMA}^{*}\ \mathrm{pdDM}$$

where pdDMA = potentially digestible DM availability, in kg/ha; TDMA = total DM availability, in kg/ha; and pdDM = potentially digestible DM, in percentage terms.

For the calculation of forage allowance (FA) (kg DM/100 kg BW day), it was necessary to know the residual dry matter biomass (RBM) and the daily accumulation rate of DM (DAR).

The residual dry matter biomass (RBM) was estimated by the double sampling method (Wilm et al. 1994).

Daily accumulation rate (DAR) of DM was estimated by the equation proposed by Campbell (1966):

$$\mathrm{DAR} = (\mathrm{Gi} - \mathrm{Fi} - 1)/n$$

where DAR = daily accumulation rate of DM in the period, in kg DM/ha/day; Gi = final average dry matter of the four empty paddocks at instant i, in kg DM/ha; Fi − 1 = initial average dry matter present in the empty paddocks at i − 1, in kg DM/ha; and n = number of days in period j.

Forage allowance (FA) was calculated according to Prohmann et al. (2004):

$$\mathrm{FA\ (kg\ DM/100\ kg\ BW\ day)} = \{(\mathrm{RBM} \times \mathrm{area} + \mathrm{DAR} \times \mathrm{area})/\mathrm{totalBW}\}{*}100$$

where FA = forage allowance, in kg DM/100 kg BW/day; RBM = total residual biomass, in kg DM ha/day; DAR = daily accumulation rate, in kg DM ha/day; and BW = animal body weight, in kg.

Leaf to stem ratio was estimated by dividing the amount of leaf by the amount of stem, in kilograms.

The animals were weighed at the beginning and end of the experiment and also every 28 days (always after a 12-h feed-deprivation period) to adjust the supply of supplement. Average daily gain (ADG) was determined as the difference between final body weight (FBW) and initial body weight (IBW) divided by the duration of the experimental period, in days. The main limitation for the calculation of average daily gain (ADG) was its variability between the animals in the period, which can statistically interfere with an increase in the coefficient of variation.

Feed conversion (FC) was determined as a function of intake and animal performance, according to the equation below:

$$\mathrm{FC} = (\mathrm{total\ DM/ADG})$$

where total DM = daily total dry matter intake, in kg; and ADG = average daily gain, in kg.

Results were interpreted using the SAEG software (*Sistema de Análises Estatísticas e Genéticas*; SAEG 2000).

Results

There was no effect of supplements on total DM intake in kg/day or as a percentage of body weight (%BW) (Table 3). However, the DM intake from the forage expressed in both ways and the intake of NDFap as %BW decreased linearly.

The intakes of NFCap, CP, EE, and TDN in kg/day were not influenced by the tested levels. The increasing supplementation levels reflected in a linear increase in NFCap intake (kg/day).

No effect of supplementation levels was detected on the digestibility coefficients of total DM, CP, EE, or NFCap (Table 4); the exception was the digestibility coefficient of NDFap.

The supplementation levels had no influence on the final live weight (FLW) or feed conversion (FC) of the animals. Only their average daily gain (ADG) was affected, increasing linearly.

Discussion

The reduction of voluntary intake demonstrated the occurrence of the substitution effect between supplementation

Table 3 Intakes of dry matter and nutrients by cattle supplemented on pasture during the dry period

Item[1]	Supplement level (%)				Eq[4]	CV^2%	P^3	
	0.2	0.3	0.4	0.5			L	Q
Total DM (kg/day)	5.46	5.84	5.76	5.52	$\hat{Y} = 5.64$	16.75	0.999	0.311
Total DM (%BW)	2.13	2.17	2.19	2.09	$\hat{Y} = 2.14$	9.01	0.932	0.236
Forage DM (kg/day)	4.84	4.92	4.53	3.99	1	16.38	0.008	0.201
Forage DM (%BW)	1.88	1.82	1.73	1.51	2	8.81	0.001	0.113
Supplement DM (kg)	0.580	0.920	1.190	1.500				
NDFap (kg/day)	3.24	3.35	3.16	2.98	$\hat{Y} = 3.18$	16.28	0.195	0.512
NDFap (%BW)	1.26	1.24	1.21	1.13	3	8.14	0.003	0.437
CP (kg/day)	0.68	0.71	0.67	0.64	$\hat{Y} = 0.67$	25.05	0.778	0.739
EE (kg/day)	0.12	0.13	0.13	0.13	$\hat{Y} = 0.12$	17.40	0.984	0.745
NFCap (kg/day)	0.94	1.19	1.33	1.36	4	24.82	0.002	0.273
TDN (kg/day)	2.94	3.30	3.14	3.11	$\hat{Y} = 3.12$	35.98	0.984	0.823

[1] *BW* body weight, *NDFap* neutral detergent fiber corrected for ash and protein, *CP* crude protein, *EE* ether extract, *NFCap* non-fibrous carbohydrates corrected for ash and protein, *TDN* total digestible nutrients

[2] (%) = coefficient of variation (%)

[3] Significant probability at the level of 5%. *L* linear, *Q* quadratic

[4] Regression equation: [1] $\hat{Y} = -2.94X + 5.60$ $R^2 = 0.810$; [2] $\hat{Y} = -1.2X + 2.15$ $R^2 = 0.912$; [3] $\hat{Y} = -0.42X + 1.35$ $R^2 = 0.901$; [4] $\hat{Y} = 1.4X + 0.715$ $R^2 = 0.890$

Table 4 Total apparent digestibility coefficients (%) of dry matter and nutrients by cattle supplemented on pasture during the dry period

Item[1]	Supplement level (%)				Eq[4]	CV[2]%	P^3	
	0.2	0.3	0.4	0.5			L	Q
DM	51.58	48.91	47.37	45.81	$\hat{Y} = 48.42$	20.09	0.179	0.992
CP	56.54	52.32	48.71	48.22	$\hat{Y} = 51.45$	26.42	0.146	0.903
EE	66.96	57.41	61.86	61.46	$\hat{Y} = 61.92$	15.75	0.521	0.146
NDFap	48,99	47.76	41.85	40.27	1	21.56	0.024	0.999
NFC	62.64	62.43	63.95	65.01	$\hat{Y} = 63.51$	20.59	0.884	0.994

[1] *DM* dry matter, *CP* crude protein, *EE* ether extract, *NDFap* neutral detergent fiber corrected for ash and protein, *NFC* non-fibrous carbohydrates

[2] Coefficient of variation %

[3] Significant probability at the level of 5%. *L* linear, *Q* quadratic

[4] Regression equation: [1] $\hat{Y} = -32.07X + 55.94$ $R^2 = 0.926$

levels (Table 3). Only the substitution effect was seen, in which case the animal substitutes the intake of forage for supplement, which improves the quality of the consumed diet because of the higher availability of energy, leading it to be more selective and seek forage parts of better nutritional value. As a consequence, the animal performance is improved. In grain-producing regions, the substitution effect could be interesting, given the lower cost of ingredients.

As a consequence of the lower forage DM intake, the intake of NDFap as %BW also decreased. This is related to the fact that the animals receiving higher levels of dietary supplementation consumed less forage, whose NDFap concentration is higher than that of concentrate supplements.

Similar levels of NDFap from the supplement were observed (Table 2), contributing to the similar intake of this chemical component in kg/day. Despite the substitution effect, CP intake did not differ across the treatments. The intake of TDN remained similar, as the concentrations of digestible nutrients that make up that variable also remained constant, except NFCap.

As the crude protein content in the supplements was reduced, the amount of sorghum increased as a result of the increasing supplementation levels (Table 1). Sorghum is a feedstuff rich in starch, a substrate highly fermentable in the rumen. Starch promotes a large production of volatile fatty acids (VFA), which in turn are responsible for increasing the energy used for maintenance and weight gain, which contributed to the performance response.

The increase in NFCap intake may be attributed to the growing level of supplement offered, with higher uptakes of NFCap from the concentrate.

The lack of differences for total DM intake (kg/day and %BW) explains the responses of the digestibility coefficients of DM, CP, EE, and NFCap (Table 4). The use of different supplementation levels was not able to influence the digestion and absorption of nutrients, probably because of interactions that occurred in the rumen. As a consequence, the digestibility of some nutrients remained unchanged.

Using concentrates in diets for grazing steers results in competition between amylolytic and fibrolytic bacteria, due to the greater participation of soluble carbohydrates, with amylolytic microorganisms developing faster because of their greater efficiency of utilization of the nitrogen present in the rumen. Thus, diets with higher levels of concentrate promote a greater proliferation of amylolytic over cellulolytic microorganisms, which in turn are responsible for the disruption of the plant cell wall that was not fully disrupted in the rumen, hence the low utilization of fibrous nutrients and consequent

Table 5 Performance of cattle supplemented on pasture during the dry period

Item[1]	Supplement level (%)				Eq[4]	CV[2]%	P^3	
	0.2	0.3	0.4	0.5			L	Q
IBW	232.80	232.90	232.50	232.00	–	–	–	–
FBW	264.00	265.10	263.30	274.10	$\hat{Y} = 266.62$	12.36	0.772	0.884
ADG	0.371	0.383	0.366	0.501	1	29.28	0.032	0.111
FC	15.03	17.17	17.02	12.72	$\hat{Y} = 15.48$	38.74	0.561	0.098

[1] *IBW* initial body weight, *FBW* final body weight, *ADG* average daily gain, *FC* feed conversion

[2] Coefficient of variation

[3] Significant probability at the level of 5%. *L* linear, *Q* quadratic

[4] Regression equation: [1] $\hat{Y} = 0.373X + 0.274$ $R^2 = 0.562$

impaired digestibility. According to Paulino et al. (2006b), depending on its extent, the negative associative effects such as that of substitution imply reductions in the digestibility of NDF and in roughage intake.

Feed conversion was influenced by the lack of an effect of supplementation levels on total DM intake (kg/day and %BW) (Table 5).

Average daily gain was affected by the substitution effect of forage for supplement, along with NFCap intake (Table 3), contributing to a higher nutrient uptake and leading to increased performance. The NFCap represent fraction A, composed of soluble sugars and rapidly degraded organic acids; and fraction B1, made of starch, pectin, and glucose, which are rapidly fermented. Thus, more energy becomes available for the growth of rumen microorganisms, enabling greater adherence and a longer colonization time and consequently a further extended digestion (Van Soest 1994). The ruminal fermentation of NFCap promotes the formation of volatile fatty acids (VFA), and the main precursor of the glucose synthesis is propionic acid, responsible for an increase in weight gain. The reduction of the digestibility coefficient of NDFap (Table 4) did not compromise the animal performance.

Therefore, the use of supplementation at 0.5% BW (24% crude protein) to provide gains of up to 0.500 kg/day is recommended for grazing steers during the post-weaning period in the dry season of the year.

Funding This study was financially supported by the Research Support Foundation of the State of Bahia (FAPESB) (grant no. 432/2014).

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