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REGULAR ARTICLES

Correlation between production performance and feeding behavior of steers on pasture during the rainy-dry transition period

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Abstract The aim of this study was to evaluate the correlation between production performance and feeding behavior of steers reared on pasture during the rainy-dry transition period. Twenty-two ½ Holstein-Zebu crossbred steers at an average age of 10 months and with an average initial body weight of 234.5 ± 16.0 kg were distributed in a completely randomized design with two types of supplementation and eleven replications. Pearson's linear correlation analysis was performed between behavioral variables and weight gain and feed conversion. Correlation coefficients were tested by the *t* test. The time expended feeding at the trough was positively correlated ($P < 0.05$) with average daily gain (ADG) and with the number of periods of permanence at the trough. Bite rate and the number of bites per day were positively correlated ($P < 0.05$) with ADG and negatively ($P < 0.05$) with feed conversion, unlike the number of bites per swallow, which was negatively correlated ($P < 0.05$) with ADG. There was a positive correlation ($P < 0.05$) between feed efficiency in dry matter and neutral detergent fiber and ADG. Feeding behavior characteristics have little association with the production performance of cattle on pasture receiving mineral or energy-protein supplementation.

Keywords Bovine · Feed efficiency · Grazing · Rumination · Weight gain

Introduction

The pasture represents the nutritional resource of greatest importance for cattle farming in Brazil, and according to Figueiras et al. (2015), grazed forage plants are largely influenced by climatic variables over the year that cause fluctuations in the quantity of herbage mass produced as well as in the quality of the herbage available to the animal.

During the period of transition from the rainy to the dry season of the year, tropical pastures suffer a decline in their leaf to stem ratio and an increase in the proportion of dead material, which are the parts least consumed by animals precisely because of their low nutritional value. When opportunities for selective grazing are reduced, a larger amount of mature herbage (with lower digestibility) is ingested, leading to a decrease in animal weight gain rates (Paulino et al. 2002).

The reduced animal performance during this period is attributed to the lower availability of herbage and low-dry matter intake by grazing animals, which in turn affects their intake of energy, protein, and minerals (Ítavo et al. 2007). Leaves are the plant component selected by cattle at the moment they seize the food, and when fed low-quality diets, these animals need to extend their grazing time, which may consequently interfere with their production performance.

The feeding behavior of grazing ruminants has been used to guide and underpin several discussions on intake and has consequently been associated with the performance of animals in experimentation (Santana Junior et al. 2013). The amount and how forage and other feedstuffs are available to animals

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determine different responses and alterations in their performance, which may imply behavioral changes due to the possible existence of correlations between performance and behavioral variables (Dias et al. 2014). The feeding behavior and animal performance data and their associations are useful for supplementation programs to increase the efficiency of animal production on pasture.

In this study, we hypothesize that the feeding behavior aspects are associated with production characteristics of steers reared on pasture. The aim of this study was to evaluate correlations between production performance and feeding behavior of dairy steers grazing on a *Brachiaria brizantha* cv. Marandu pasture during the rainy-dry transition period.

Materials and methods

The experiment was conducted on Princesa do Mateiro Farm, located in the municipality of Ribeirão do Largo, southwest Bahia State, Brazil.

Animals and experimental diets

Twenty-two Holstein-Zebu crossbred steers with an average age of 10 months and an average initial body weight of 234.5 ± 16.0 kg were used in this study. The experiment lasted 84 days in total, and before the experiment began, all steers were dewormed, weighed, identified, and divided into two groups. A completely randomized experimental design was adopted, with 2 supplementation types and 11 replications.

The following treatments were evaluated: (1) Protein/energy supplementation in the proportion of 0.4% body weight (balanced to meet the nutritional requirements for a gain of 600 g/day) and (2) mineral supplementation ad libitum.

Protein/energy supplementation was provided daily (Table 1) at 10:00 in collective plastic troughs with double access. An intermittent stocking system was adopted in the pasture, which was formed by *Brachiaria brizantha* cv. Marandu grass, in a 7.7-ha area that was divided into six paddocks with equivalent areas. To avoid any effect of pasture, the animals from each treatment were alternated every 7 days between two paddocks within the period of 28 days.

Laboratory analyses

Simulated-grazing samples were harvested manually, after a previous period of careful observation of the height and parts of the plants being consumed by the animals. Subsequently, aliquots of pasture and supplement processed through 1-mm sieves (Table 2) were evaluated for the dry matter (DM; method INCT-CA G-003/1), organic matter (OM; method INCT-CA M-001/1), crude protein (CP; method INCT-CA N-001/1), ether extract (EE; method INCT-CA G-005/1), neutral detergent fiber corrected for ash and protein (NDFap; methods INCT-CA F-002/1, INCT-CA M-002/1, and INCT-CA N-004/1), ADF (method INCT-CA F-004/1), and indigestible NDF (method INCT-CA F-009/1), according to techniques described by Detmann et al. (2012). Non-fibrous carbohydrate (NFC) contents were estimated according to Detmann and Valadares Filho (2010). Total digestible nutrient (TDN) contents were obtained by the equation of Weiss (1999).

Table 1 Ingredients and composition of supplements

Ingredient (g/kg DM)	Protein/energy supplement	Mineral supplement
Corn	449.4	–
Soybean meal	454.4	–
Urea + AS[a]	49.9	–
Mineral mixture[b]	46.3	1000

[a] Urea + ammonium sulfate (9:1)

[b] Composition: calcium 235 g; phosphorus 160 g; magnesium 16 g; sulfur 12 g; cobalt 150 mg; copper 1600 mg; iodine 190 mg; manganese 1400 mg; iron 1000 mg; selenium 32 mg; zinc 6000 mg, 1120 mg; fluorine (maximum) 1600 mg, 1400 mg; iron 1000 mg; selenium 32 mg; zinc 6000 mg, 1120 mg; fluorine (maximum) 1600 mg

Pasture characteristics

The pasture was evaluated every 28 days. The DM availability (Fig. 1) was estimated according to the methodology described by McMeniman (1997). The potentially digestible DM (pdDM) of the pasture was calculated as described by Paulino et al. (2006), by the following equation:

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

where iNDF = indigestible neutral detergent fiber.

The equation below was used to calculate the pdDM availability (pdDMA):

$$pdDMA = TDMA \times pdDM$$

where pdDMA = potentially digestible DM availability, in kilogram per hectare; TDMA = total DM availability, in kilogram/hectare; and pdDM = potentially digestible DM, in percent values.

Pasture samples were harvested, weighed, and homogenized, and the forage components in composite samples (leaf, stem, and dead material) were separated (Fig. 1).

Feeding behavior

Feeding behavior was evaluated on the 35th and 42nd days of the experiment. Observations were performed every 5 min, according to the methodology described by Carvalho et al. (2007), over a 24-h period. The animals were evaluated by

Table 2 Chemical composition of the *Brachiaria brizantha* pasture and of the protein/energy supplement

Item (g/kg DM)	*Brachiaria brizantha*	Protein/ energy supplement
Dry matter[a]	285.2	878.5
Organic matter	908.9	897.6
Crude protein	100.0	480.0
Ether extract	24.6	27.2
Neutral detergent fiber[b]	697.2	227.0
Acid detergent fiber	401.2	87.7
Non-fibrous carbohydrates	155.4	158.4
Total digestible nutrients	519.9	600.0

[a] In gram per kilogram fresh matter

[b] Corrected for ash and protein

two trained observers, which switched shifts every 3 hours, positioned strategically so as not to disturb the animals.

We evaluated the following behavioral variables: grazing time, rumination time, idle time, and time feeding at the trough (Burger et al. 2000). Behavioral activities were considered mutually exclusionary, as defined by Pardo et al. (2003).

The number of rumination chews and the time expended on the rumination of each cud, by each animal, were obtained according to Polli et al. (1996). Total feeding time was determined as the sum of the grazing time and the time expended feeding at the trough. Total chewing time, in turn, was estimated as the sum of the grazing, rumination, and feeding (trough) times.

Bite rate was estimated as the time spent by the animal to perform 20 bites (Hodgson 1982). Bite mass was calculated by dividing the daily pasture intake by the total number of mouthfuls swallowed (Jamieson and Hodgson 1979). The results of biting and swallowing were recorded on six occasions throughout the day, following Baggio et al. (2009), with three evaluations performed during the morning and three in the afternoon, which were also used to determine the number of bites per day, as the product between bite rate and grazing time.

The variables grams of DM and NDF/meal were obtained by dividing the average individual intake of ach fraction by the number of feeding periods per day (in 24 h). Feed and rumination efficiencies, expressed in grams of DM per hour and grams of NDF per hour, were obtained by dividing the average daily intakes of DM and NDF by the total time spent feeding and/or ruminating in 24 h, respectively. The variables grams of DM and NDF/cud were obtained by dividing the average individual intakes of each fraction by the number of cuds ruminated per day (in 24 h).

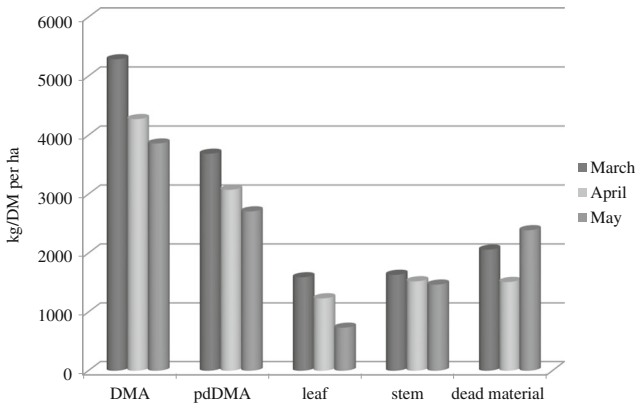

Fig. 1 Total dry matter availability (DMA), potentially digestible dry matter availability (pdDMA), leaf, stem, and dead material of the *Brachiaria brizantha* cv. Marandu pasture in the three experimental periods (March, April, and May)

Production performance

Animals were weighed to evaluate production performance at the beginning and end of the experiment, after a feed-deprivation period of 12 h, and every 28 days (without previous fasting) to adjust the supplement supply. Total weight gain and average daily gain were determined as the difference between final and initial weights, and this value was divided by the duration of the experimental period in days, respectively. Feed conversion was calculated as the ratio between daily dry matter intake and average daily gain.

Statistical analyses

Correlations were obtained by using production performance parameters (average daily gain and feed conversion) and feeding behavior characteristics (Tables 3 and 4) by Pearson's linear correlation analysis and *t* test. Data were processed by the System for Statistical and Genetic Analysis (SAEG), with correlations considered significant when $P < 0.05$.

Results and discussion

Because there was no effect of supplement type on the behavioral variables, data were analyzed as a function of their mean values. No significant correlation was observed ($P > 0.05$) between grazing time, idle time, rumination time, total feeding time, and total chewing time, and average daily gain or feed conversion (Table 5).

However, a positive correlation was observed ($P < 0.05$) between time feeding at the trough and average daily gain (Table 5), and there were also moderate positive correlations ($P < 0.05$) between average daily gain and the number of periods feeding at the trough and average time per period feeding at the trough (Table 6). These results are similar to those found by Dias et al. (2014), who evaluated correlations

Table 3 Average daily gain and feed conversion of steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item	Supplement type	
	Protein/energy	Mineral
Average daily gain (kg/day)	0.545	0.348
Feed conversion	15.14	21.04

between feeding behavior and performance of steers and reported that the supply of supplement to cattle reared on pastures results in an additional nutrient gain for rumen

Table 5 Linear correlations between the feeding behavior activities and performance of steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item (min)	Average daily gain		Feed conversion	
	r	*P*	*r*	*P*
Grazing time	–	–	–	–
Idle time	–	–	–	–
Rumination time	–	–	–	–
Time feeding at the trough	0.63	**	–	–
Total feeding time	–	–	–	–
Total chewing time	–	–	–	–

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 4 Feeding behavior-related aspects steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item	Supplement type	
	Protein/energy	Mineral
Grazing time (min)	618.86	653.75
Idle time (min)	413.86	395.00
Rumination time (min)	376.36	385.00
Time feeding at the trough (min)	30.90	6.25
Total feeding time (min)	649.76	653.75
Total chewing time (min)	1026.12	1045.0
Number of grazing periods	13.36	10.12
Number of idle periods	15.40	13.81
Number of rumination periods	23.50	19.62
Number of periods feeding at the trough	2.36	0.81
Time per grazing period (min)	48.21	69.58
Time per idle period (min)	24.55	28.42
Time per rumination period (min)	18.16	20.87
Time per period feeding at the trough (min)	13.63	7.26
Bite rate (*n*/s)	0.70	0.53
Bite mass (kg/DM)	0.31	0.29
Bites per swallow (*n*)	22.96	28.45
Time per swallowed mouthful (s)	59.01	52.47
Number of bites per day	26,848.57	20,896.02
Rumination chews per cud (*n*)	53.00	53.15
Rumination chews per day (*n*)	25,059.68	23,077.02
Time per ruminated cud (s)	52.80	54.76
Cuds ruminated per day (*n*)	480.73	441.48
Dry matter intake (g/meal)	535.63	662.01
Neutral detergent fiber intake (g/meal)	138.20	180.52
Feed efficiency in dry matter (kg DM/h)	0.800	0.580
Feed efficiency in neutral detergent fiber (kg NDF/h)	0.458	0.358
Rumination efficiency in dry matter (kg DM/h)	1.352	1.086
Rumination efficiency in neutral detergent fiber (kg NDF/h)	0.779	0.673
Rumination in grams of dry matter (g DM/cud)	17.529	14.134
Rumination in grams of neutral detergent fiber (g NDF/cud)	10.163	8.761

Table 6 Linear correlation between the number and time per period of feeding behavior activities and performance of steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item	Average daily gain		Feed conversion	
	r	*P*	*r*	*P*
Number of grazing period	–	–	–	–
Number of idle periods	–	–	–	–
Number of rumination periods	–	–	–	–
Number of periods feeding at the trough	0.42	*	–	–
Time per grazing period (min)	–	–	–	–
Time per idle period (min)	–	–	0.45	*
Time rumination period (min)	–	–	–	–
Time per period feeding at the trough (min)	0.75	***	− 0.49	*

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

microorganisms, providing substrate for their growth and fiber use, which consequently elevate the average daily gain.

There was a moderate positive correlation ($P < 0.05$) between average time per idle period and feed conversion (Table 6). The increase in average time per idle period may indicate that the animals met their energy requirements, decreasing their grazing activity.

The average time per period at the trough was negatively correlated ($P < 0.05$) with feed conversion (Table 6). With the supply of a protein/energy supplement, there was an increase in the intake of nutritional components of better quality and better digestibility, which leads to better feed conversion.

Tropical grasses are seldom considered a balanced diet for grazing cattle, because they have nutritional limitations that influence intake and digestibility (Detmann et al. 2014). According to Brandão et al. (2016), the use of protein/energy supplements for animals reared on pasture allows for an association between the non-fibrous components and the nitrogen compounds in the rumen, improving microbial growth and the utilization of fiber and increasing the digestibility of nutritional components.

Moderate positive correlations ($P < 0.05$) were observed between bite rate and the number of bites and average daily gain. Additionally, these behavioral parameters also displayed low negative correlations ($P < 0.05$) with feed conversion (Table 7), meaning the steers required lower bite rates to gain the same amount of weight, and that feed conversion might have been satisfactory even with a lower number of bites. In this study, a decrease was observed in leaf to stem in the pastures ratio over time (Fig. 1), which might have had a direct impact on bite-related aspects of the steers. Dias et al. (2014) stated that the bite rate is affected by structural characteristics of the pasture, such as height, leaf to stem ratio, and density. Thus, bite rate and the number of bites per day can influence forage intake.

There was a moderate positive correlation ($P < 0.05$) between bite mass and feed conversion because lambs needed to eat more to gain 1 kg of live weight, indicating a lower feed conversion. The low negative correlation ($P < 0.05$) between the number of bites per swallow and average daily gain (Table 7) was because the animals had increased their number of bites in order to swallow a satisfactory amount of forage, which might have been compromised by the greater selectivity during grazing. As stated by Berchielli et al. (2011), variations in bite mass do not lead to differences in intake, because of the compensation from the bite rates.

The improved use of the consumed feed resulting from supplementation is demonstrated by the positive correlation ($P < 0.05$) obtained between the feed efficiencies in DM and NDF and the average daily gain (Table 8). According to Silva et al. (2014), the time spent by animals at the trough has a moderate positive correlation with the intakes of DM and NDF, and the necessary time increases proportionally to the amount of feed available.

Rumination efficiency is an important mechanism to evaluate the use of low-digestibility feedstuffs (Nicory et al.

Table 7 Linear correlation between bite-related aspects and performance of steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item	Average daily gain		Feed conversion	
	r	*P*	*r*	*P*
Bite rate (*n*/s)	0.58	**	− 0.36	*
Bite mass (kg/DM)	–	–	0.42	*
Bites per swallow (*n*)	− 0.37	*	–	–
Time per mouthful swallowed (s)	–	–	–	–
Number of bites per day	0.61	**	− 0.42	*

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 8 Correlation between feed and rumination efficiencies and performance of steers on *Brachiaria brizantha* pastures in the rainy-dry transition period receiving protein/energy or mineral supplementation

Item	Average daily gain		Feed conversion	
	r	*P*	*r*	*P*
Dry matter intake (g/meal)	–	–	–	–
Neutral detergent fiber intake (g/meal)	–	–	–	–
Feed efficiency in dry matter (kg DM/h)	0.51	**	–	–
Feed efficiency in neutral detergent fiber (kg NDF/h)	0.41	*	–	–
Rumination efficiency in dry matter (kg DM/h)	–	–	–	–
Rumination efficiency in neutral detergent fiber (kg NDF/h)	–	–	–	–
Rumination in grams of dry matter (g DM/cud)	–	–	–	–
Rumination in grams of neutral detergent fiber (g NDF/cud)	–	–	–	–

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

2015). No significant correlations were observed ($P > 0.05$) between performance and rumination efficiency in DM and NDF; in addition, no correlation was found ($P > 0.05$) for rumination in grams of DM or NDF, either.

In this study, dry matter intake was 8.11 and 6.34 kg/day for the animals receiving the protein/energy supplement and the mineral supplement, respectively. Dry matter intake is positively related to the digestibility of NDF. In this way, as the feed and rumination efficiencies of the fibrous fraction are improved, nutrient intake also increases (Berchielli et al. 2011). Dry matter intake is the most important variable affecting the animal performance, and it is inversely related to the fiber content of the diet (Mertens 1994), because it may limit intake due to the physical filling of the rumen. Dias et al. (2014) found that the feeding behavior has a direct influence on the production performance of crossbred steers weaned on pasture during the rainy season, and that rumination efficiency improved when the animals were supplemented, which led to a better use of the feed consumed.

Overall, except for the time and number of periods feeding at the trough, which were positively correlated with the average daily gain of the steers, the main characteristics related to the feeding behavior of grazing cattle during the rainy-dry transition period are not correlated with their production performance.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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