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Correlations between intake and ingestive behavior of supplemented pasture-finished steers

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ABSTRACT. The objective was to evaluate the correlations between intake and ingestive behavior of steers receiving supplementation and finished on pasture. The field phase was conducted at the Princesa do Mateiro Farm, municipality of Ribeirão do Largo, state of Bahia. For this experiment, 32 crossbred steers (Holstein X Zebu) in the finishing phase, with an average initial weight of 420 ± 7.54 kg, were distributed in a completely randomized design, with four treatments (0.2, 0.4, 0.6, and 0.8%) and eight repetitions. Grazing time (GT) did not correlate ($p > 0.05$) with total dry matter intake (TDMI). GT showed a moderate positive correlation ($p < 0.05$) with crude protein intake (CPI) and neutral detergent fiber intake corrected for ash and protein (NDFIap). Rumination time (RUM) showed a weak negative correlation ($p < 0.05$) with NFCI. Trough feeding time (TFT) showed moderate negative correlations with NDFIap and moderate positive correlations with NFCI ($p < 0.05$). The number of bites per day (NBD) showed a weak negative correlation with TDMI and a moderate negative correlation with CPI, NDFIap ($p < 0.05$). The correlations found demonstrate that supplementation of steers finished on pasture interferes with their ingestive behavior.

Keywords: Feeding; cattle; rumination; bite rate; grazing time.

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Introduction

To maximize the bio-economicity of grazing cattle production during the dry period of the year, it is necessary to optimize the available basal resources. In this context, supplementation of animals on pasture to supply limiting nutrients, especially crude protein, meets the growth requirements of rumen microorganisms, making it possible to increase the efficiency of forage dry matter intake, degradation of the fiber fraction, animal performance, and reduce the production cycle (Couto et al., 2019).

When using supplementation, the pattern of dry matter intake by ruminants may eventually be changed, as a secondary nutritional resource will be introduced to their feeding habits. According to Dias et al. (2014), factors such as general management and the environment can affect the digestibility of a given food and/or nutrient and this influence can be expressed in ingestive behavior, and consequently, in performance.

There is still a lack of scientific studies explaining the biological responses regarding the production of supplemented cattle on pastures, making it necessary to investigate the possible correlations between the variables of ingestive behavior and nutrient intake, which can significantly contribute to the understanding of factors that may interfere with the nutrition and production of animals on pastures (Figueiredo et al. 2018).

Given the above, the objective was to evaluate the correlations between intake and ingestive behavior of steers receiving supplementation and finished on pasture.

Material and methods

The research was approved by the Animal Use Ethics Committee of the State University of Southwest Bahia, under protocol 15/2012.

The field experimental phase was conducted at the Princesa do Mateiro Farm, municipality of Ribeirão do Largo, state of Bahia, located at 15° 26′ 46″ South latitude and 40° 44′ 24″ West longitude, and at 800 meters altitude. The total area used was 13 hectares of *Brachiaria brizantha* cv. Marandu, divided into ten paddocks of the same proportion under rotational stocking. The experimental period began in the dry season, on

September 3, 2011, ending on December 15 of the same year, totaling 102 days, 14 days for adaptation of the animals to the diet, and 88 days for data collection. For this experiment, 32 crossbred steers (Holstein X Zebu) in the finishing phase, with an average initial weight of 420 ± 7.54 kg, were used. The diets were formulated according to the National Research Council [NRC] (2000) to meet the nutritional requirements of the animals and to provide gains of 0.500 kg day^{-1}. The animals received supplementation at the following levels: 0.2, 0.4, 0.6, and 0.8%, consisting of ground corn grain (71.28%), soybean meal (23.2%), urea (3.11%), and mineral salt (2.2%). Each management paddock had plastic and fixed troughs, collective with double access, without cover, with a linear dimension of 80 cm/animal, for daily supply of the supplement at 10:00 am.

To reduce the influence of biomass variation between paddocks, the steers were kept in each paddock for seven days and, after this period, were transferred to another, in a randomly pre-established direction.

Pasture samples were taken and weighed on a portable digital scale accurate to 5 g. Part of the samples were placed in plastic bags, identified, and frozen in a freezer at -10°C for later analysis of the chemical composition. The other part of the samples was manually separated into the components (leaf blade, stem, and dead material), which were weighed to obtain the percentage of each component.

For fecal output estimation, LIPE® (purified and enriched lignin) (Saliba et al., 2015) was supplied daily at 8 am, for seven days, in a single dose of one capsule per animal, including three days for adaptation and regulation of the marker excretion flow and five days for feces collection. The estimation of fecal output was made by determining the LIPE® content in feces, using an infrared spectrophotometer at the nutrition laboratory of the UFMG Veterinary School, using the formula described by Saliba et al. (2015):

FO = amount of LIPE® supplied (g) / ((Ai/MS total) *100

where: FO – fecal output; Ai – logarithmic relationship of absorption intensities of wavelength bands from 1,050 cm^{-1}/1,650 cm^{-1}.

The concentrate dry matter (DM) intake was measured using the average body weight of the animals multiplied by the percentage estimated for individual intake. To estimate voluntary forage intake, the internal indicator indigestible neutral detergent fiber (iNDF) was used. Forage, feces, and concentrate samples were incubated in the rumen of two fistulated animals for 240 hours (Casali et al., 2008) in TNT 100 bags (non-woven fabric), at a ratio of 20 mg of sample/cm^2. After removal from the rumen, the bags were washed and dried in a forced ventilation oven and the material was extracted with neutral detergent, as described by Detmann et al. (2012). The remaining material was considered the non-digestible part. DM intake was calculated as follows:

TDMI (kg day^{-1}) = [(FExCIFe) – IC] + CDMI / CIFo

where: TDMI = total dry matter intake; FE = fecal excretion (kg day^{-1}), obtained using LIPE; CIFe = concentration of the indicator in feces (kg kg^{-1}); CIFo = concentration of the indicator in the forage (kg kg^{-1}); IC = amount of the indicator present in the concentrate; and CDMI = concentrate DM intake.

For simulated grazing, the group of animals was observed at the time they were grazing, analyzing the pasture canopy height they consumed. Next, forage was collected in a way to maintain characteristics similar to the pasture the animals were ingesting, as described by Johnson (1978). Analyses of dry matter (DM), ash, crude protein (CP), ether extract (EE), neutral detergent fiber (NDFap), and acid detergent fiber (ADF) contents in concentrate, forage, and feces samples followed Detmann et al. (2012). Total carbohydrates (TC) were estimated according to Sniffen et al. (1992):

TC = 100 – (%CP + %EE + %Ashes)

Non-fiber carbohydrates corrected for ash and protein (NFCap) were calculated as proposed by Hall (2003):

NFCap = 100 – [% EE + %Ashes+ (%NDFap – %CP) + (%CP - %PBNNP + %NNP)]

Total digestible nutrients (TDN) were calculated according to Weiss (1999), using NDF and NFC corrected for ash and protein, and the following equation:

TDN (%) = PBD + FDNcpD + CNFcpD + 2.25EED

where: DCP = digestible CP; NDFapD = digestible NDFap; NFCapD = digestible NFCap; and EED = digestible EE. The total digestible nutrient content of foods and total diets were calculated according to equations described by the NRC (2001).

Table 1 lists the chemical compositions of the total diet used in the present experiment.

Table 1. Chemical composition of the total experimental diet.

Item	Values (%)
Dry matter (%)	49.37
Organic matter (%)	91.92
Crude protein (%)	10.80
Ether extract (%)	2.67
Total carbohydrate (%)	78.49
NFCap (%)	23.33
NDFap (%)	55.13
ADF (%)	40.53
Ashes (%)	8.05
iNDF (%)	15.04

NFCap = Non-fiber carbohydrates corrected for ash and protein; NDFap = Neutral detergent fiber corrected for ash and protein; ADF = Acid detergent fiber; iNDF = Indigestible neutral detergent fiber.

Observations regarding ingestive behavior were made for 24 hours on experimental days 36 and 50. The animals were visually evaluated every five minutes, as described by Gary et al. (1970), by trained observers, who used digital stopwatches to determine the time spent on each activity and took notes on an ethogram. The times spent in grazing, rumination, feeding in the trough, and other activities were observed. Feeding and rumination times were calculated as a function of dry matter intake (DMI) and neutral detergent fiber intake (NDFi) (min kg^{-1} DM or NDF). The time spent by animals in selecting and seizing forage, including the short periods spent walking to select forage, was considered grazing time (Hancock, 1953). Rumination time corresponded to the processes of regurgitation, remastication, reinsalivation, and redeglutition.

Trough feeding time was the time spent by the animal consuming supplement, while time in other activities (resting, drinking, interacting) included all activities, except for those mentioned above. The discretization of the time series was done directly in the data collection spreadsheets, with the counting of discrete periods of feeding, ruminating, and other activities. The average duration of each of the discrete periods was obtained by dividing the daily times of each activity by the number of discrete periods, as described by Silva et al. (2008). Total feeding time (TFT) and total chewing time (TCT) were determined by the equations below:

TAF = GT + TF

where: GT (minutes) = grazing time; TF (minutes) = trough feeding time;

TCT = GT + RUM + TF

where: GT (minutes) = grazing time; RUM (minutes) = rumination time; TF (minutes) = trough feeding time.

The number of chews was counted and the time spent ruminating each cud was determined, for each animal, using a digital stopwatch. To obtain chewing averages and time, observations of three cuds were made at different times of the day (from 9 am to 12 pm and from 4 pm to 7 pm), according to Burger et al. (2000). To obtain the daily number of cuds, the total rumination time was divided by the average time spent ruminating each cud, described previously.

The bite rate (BR) of the animals in each group was estimated through the time the animal took to perform 20 bites (Hodgson, 1982). The results of bite and deglutition observations were recorded on six occasions during the day, according to Baggio et al. (2009), with three assessments in the morning and three in the afternoon. The data was also used to determine the number of bites per day (NBD), which is the product of bite rate and grazing time. The variables: number of cuds per day (CUD (n)), time per chewing (TCud (n)), and number of chews per cud (CCud (n)) were calculated using the equations below:

CUD = RUM / TCud

where: CUD (number per day); RUM (seconds per day) – rumination time; TCud (seconds) – time per chewing;

CCud = BOL * CCud

where: CCud (number per day); CUD – number of cuds per day; CCud – number of chews per cud.

The correlations were estimated using Pearson's linear correlation analysis and processed by the SAEG Program – Statistical and Genetic Analysis System (VERSION 9.1) and considered significant when $p < 0.05$.

Results and discussion

Grazing time (GT) did not correlate ($p > 0.05$) with total dry matter intake (TDMI) (Table 2). This lack of correlation is probably a result of the structure of the forage canopy and the high forage availability, with values for total dry matter, potentially digestible dry matter (DMpd), green dry matter (DMg), green leaves, stem, and dead matter of 4,180; 3,295;1,865; 970; 895; 2,315 kg ha^{-1}, respectively. Logically, increases in grazing time are related to pastures with low forage availability, which increases the time cattle spend in selecting more nutritious parts of the plant to meet their nutritional requirements. The present study is not in line with the results found in the literature, in which some authors report the presence of a correlation between these variables, showing that the result is important for developing equations for predicting animal intake and performance (Gontijo Neto et al., 2006).

Table 2. Correlation between intake variables, grazing time, rumination time, trough feeding time, time in other activities, and total feeding time of supplemented steers finishing on pasture.

Variable	GT		RUM		TF		AO		TFT	
	r	P	r	P	R	P	r	P	r	P
TDMI	0.01	0.43	0.16	0.10	-0.13	0.14	-0.02	0.40	-0.01	0.45
CPI	0.43	0.00	0.43	0.00	-0.45	0.00	-0.41	0.00	0.34	0.00
NDFIap	0.46	0.00	0.49	0.00	-0.55	0.00	-0.52	0.00	0.34	0.00
NFCI	-0.53	0.00	-0.39	0.00	0.56	0.00	-0.57	0.00	-0.42	0.00

TDMI – Total dry matter intake; CPI – Crude protein intake; NDFIap – Intake of neutral detergent fiber intake corrected for ash and protein; NFCI – Non-fiber carbohydrate intake; GT – Grazing time; RUM – Rumination time; TF- Through feeding time; OA – Time in other activities; TFT - Total feeding time.

A moderate positive correlation ($p < 0.05$) was found between GT and the intake of crude protein (CPI) and neutral detergent fiber corrected for ash and protein (NDFIap). In addition to the structure of the forage canopy, food intake by cattle on pastures is influenced by factors related to the chemical composition of forage and the amount of supplements provided. Therefore, these results are explained by the composition of the total diet, which led to an increase in the intake of NDF and CP.

GT showed a moderate negative correlation ($p < 0.05$) with the intake of non-fiber carbohydrates (NFCI), which was related to forage, which contains higher concentrations of NDF to the detriment of NFC, thus resulting in a linear reduction in the intake of this nutrient by cattle kept under these conditions.

Moderate positive correlations ($p < 0.05$) were found between rumination time (RUM) and CPI and NDFIap. Strong correlations between RUM and NDFIap were expected, however, when introducing concentrated foods into the diet for ruminants on pasture, biological responses become complex, involving factors that are not only related to pasture but to the interaction between the animal and the total diet given. Martini et al. (2017) state that when the animals' diet consists of forage, there is a tendency towards a higher intake of NDF, therefore, the intake of this component will result in longer time spent on rumination.

RUM showed a weak negative correlation ($p < 0.05$) with NFCI, which is a result of the intake of concentrate present in the diet. As the consumption of foods rich in NFC increases, rumination time is reduced; in addition, supplements contain smaller particle sizes, which causes reductions in the time spent on chewing.

Trough feeding time (TF) showed moderate negative correlations ($p < 0.05$) with CPI. In the present experiment, a substitution effect of forage for the supplement was verified, therefore, the longer time spent on feeding in the trough resulted in lower CPI, considering that the CP of the supplement was the same; the reduction of CPI is related to reduced forage intake. The presence of moderate negative correlations was found between TF and NDFIap and moderate positive correlations between TF and NFCI ($p < 0.05$). With the inclusion of supplementation in the diet, there was an increase in nutrient intake, especially NFC, concomitantly with a reduction in NDF intake, due to the composition of the supplement provided.

The time spent on other activities (OA) showed moderate negative correlations ($p <0.05$) with CPI, NDFIap, and NFCI. The intake of nutrients from supplements did not allow an increase in the time spent on other activities. According to Mendes et al. (2014), animals fed diets with high levels of concentrate tend to rest more, while those fed diets with low or no concentrate supplementation spend more time grazing and ruminating, which reduces time for other activities. Furthermore, Lima et al. (2020) reported that increases in the times of other activities of animals receiving supplementation may be linked to a longer digestion time because the intake of concentrate tends to improve the ruminal environment and concomitantly the animal's ability to digest the diet (Detmann et al., 2014).

Total feeding time (TFT) showed a weak positive correlation (p < 0.05) with CPI and NDFIap. This is in accordance with Silva et al. (2015), who observed correlations between TFT and NDFI and reported that this result probably occurred due to the forage passage rate, whose limitation is the physical effect caused by the NDF content present in the diet. Therefore, the higher the passage rate, the greater the food intake. The TFT showed a moderate negative correlation (p < 0.05) with the NFCI, showing that the increase in supplement intake promotes a decrease in grazing time and a consequent reduction in TFT since this variable is the result of the times the animals spend on grazing and feeding in the trough.

Total chewing time (TCT) did not correlate (p > 0.05) with TDMI (Table 3). TMT is the sum of grazing, rumination, and trough times. In this context, it is possible to explain the lack of correlation since GT, RUM, and TF presented the same results.

Table 3. Correlation between intake variables and total chewing time, bite rate, and number of chews, of supplemented steers finishing on pasture

Variable	TCT		BR		NC	
	R	P	R	P	R	P
TDMI	0.02	0.41	-0.15	0.12	-0.05	0.34
CPI	0.41	0.00	-0.47	0.00	-0.02	0.42
NDFIap	0.52	0.00	-0.55	0.00	0.11	0.19
NFCI	-0.57	0.00	0.59	0.00	0.20	0.05

TDMI – Total dry matter intake; CPI – Crude protein intake; NDFIap – Neutral detergent fiber intake corrected for ash and protein; NFCI – Non-fiber carbohydrate intake; TCT – Total chewing time; BR – Bite rate; NC – Number of chews.

TCT showed a moderate positive correlation (p < 0.05) with NDFIap. According to Missio et al. (2010), TCT is increased linearly with the increase in physically effective NDF in ruminant diets. TCT showed a moderate negative correlation with NFCI (p < 0.05) due to increased supplement intake, which contains high levels of NFC that do not stimulate rumination, and consequently reduces TCT. The authors also found a linear decrease in the time spent chewing with increasing levels of concentrate in the diet, which can be mainly attributed to the reduction in the NDF content of the diet.

The bite rate (BR) did not correlate (p > 0.05) with the TDMI. BR for animals on pasture is characterized as a basic unit for obtaining nutrients and is a component that encompasses grazing activity.

Therefore, the result found can be explained as a result of the statistical behavior between TDMI and GT, directly affecting the results between BR and TDMI. BR of grazing ruminants is directly related to the sward structure, concerning its height, availability, nutritional value, accessibility of plant components preferred by the animal, and the material mass that can be collected with a bite, where cattle may present high BR with small volumes of swallowed cuds, or low BR with large volumes of swallowed cuds. In this context, characterizing their relevance for forage intake, and the importance of the ingestive behavior of cattle on the pasture offered, which may interfere with management practices that best suit the forage used.

BR had a moderate negative correlation with CPI and NDFIap (p < 0.05). The selectivity, characteristic of cattle, was reduced with the advent of supplementation, which provides readily available nutrients to meet their nutritional demands, thus causing a moderate reduction in BR. BR presented a moderate positive correlation with NFCI (p < 0.05). This is justifiable because, with increasing supplement intake by animals, there was a linear increase in NFCI.

The number of chews (NC) did not correlate with any intake variable (p > 0.05). This is controversial since when consuming concentrate foods from the diet, a reduction in NC is expected due to the low proportions of NDF, which would stimulate rumination. Santana Júnior et al. (2013) and Dias et al. (2014) evaluated supplemented animals on pasture and also did not detect a correlation between the number of chews and the analyzed intake variables.

The number of bites per day (NBD) showed a weak negative correlation with TDMI, and a moderate negative correlation with CPI, NDFIap (p < 0.05) (Table 4).

NBD is a product of bite rate and grazing time. The increase in supplement intake caused a reduction in forage intake, which explains the negative correlation between these variables. NBD showed a moderate positive correlation with NFCI (p < 0.05), which corroborates the increase in the intake of concentrate containing high levels of NFC.

Among the variables analyzed, bite time (BT) showed a weak negative correlation (p < 0.05) with NDFIap. BT is a variable associated with the time the animal spends grazing until swallowing the material harvested from the pasture. As the basal diet is the main source of NDF, this result is possibly associated with a lower forage intake because the animal remained in the trough for longer to consume the supplement supplied.

Table 4. Correlation between intake variables and the number of bites, bite time, and number of cuds per day of supplemented steers finishing on pasture.

Variable	NBD		BT		CUD	
	R	P	R	P	R	P
TDMI	-0.22	0.03	-0.18	0.07	0.08	0.25
CPI	-0.42	0.00	-0.16	0.08	0.36	0.00
NDFIap	-0.56	0.00	-0.31	0.00	0.31	0.00
NFCI	0.43	0.00	0.13	0.14	-0.26	0.01

TDMI – Total dry matter intake; CPI – Crude protein intake; NDFIap – Neutral detergent fiber intake corrected for ash and protein; NFCI – Non-fiber carbohydrate intake; NBD - Number of chews per bite; BT - bite time; CUD – Number of cuds per day.

The number of cuds per day (CUD) showed a weak positive correlation ($p < 0.05$) with CPI and NDFIap. The intake of concentrate allows the formation of smaller cuds with greater weight to be chewed but with a lower amount of fiber. CUD showed a weak negative correlation with NFCI, showing that the higher the NFCI, the lower the number of cuds to be ruminated.

Conclusion

The correlations found indicate that supplementation of steers finished on pasture interferes with aspects of ingestive behavior.

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