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Research Paper

Correlation between ingestive behaviour, intake and performance of grazing cattle supplemented with or without propolis extract (LLOS®)

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Abstract. This study aimed to evaluate the correlations between ingestive behaviour and intake of grazing cattle supplemented with or without of propolis extract (LLOS®), during the rainy season. Thirty-two uncastrated crossbred steers (269 ± 4.92 kg) about 20 month-old were used in a completely randomized design with 2 × 2 factorial arrangement of treatments, with 8 replicates. Two levels of supplementation were used (0.3 and 0.6% of body weight, DM basis), with or without the addition of LLOS®. In the treatments with LLOS®, the extract was added daily at 2 g/kg DM supplement. The significance of the correlation coefficient was tested using the "t" test at 5% probability. The parameters evaluated were: intake, ingestive behaviour and performance of animals. The time the animals spent eating at the trough showed a positive, but weak correlation with average daily gain (ADG). For the behavioral variables studied, only the time spent ruminating and eating at the trough showed a correlation with intake and performance. The time spent ruminating was negatively correlated with DMI, NDF intake (NDFI) and TDN intake (TDNI). The feed efficiencies of DM, CP, TCH and rumination efficiencies of DM, CP, NFC and TCH showed positive and moderate correlations with NDFI. There is a correlation between the intake of nutrients, DMI, performance, and animal behaviour, and monitoring animal behaviour can be of utmost importance for the understanding of metabolic and nutritional aspects related to cattle production, and can eliminate the need for the use of invasive tests that may be stressful to animals.

Keywords: Feed efficiency, rumination efficiency, average daily gain, ingestive behaviour.

INTRODUCTION

The pasture production system is one of the most viable alternatives for rearing cattle, due to the results promoted and to the lower investments regarding man labor and facilities. According to Stieven (2012), the Brazilian beef cattle industry sought animals with greater weight gain and better carcass and reproductive characteristics, aiming at lower production costs. In order to achieve these goals, supplementing grazing animals is a technique that has been increasingly adopted as an alternative to optimize production per area and maximize the profits of the production system.

The capacity of a feed being ingested by the animal depends on various factors that interact under different feeding situations, animal behavior and environment (Tonello et al., 2012). Thus, ingestive behavior of grazing ruminants can be characterized by uneven distribution of a succession of defined and discrete periods of activities commonly named ingestion, rumination and resting (Fischer et al., 2000).

The search for greater feed efficiency has increasingly grown, and its association with the study of the ingestive behaviour of grazing cattle has been one of the biggest obstacles in research. In view of this, the objective was to evaluate the correlations between the ingestive behavior and performance of cattle on pasture supplemented with or without addition of propolis extract (LLOS®) to the diet.

MATERIALS AND METHODS

The study was conducted on Princesa do Mateiro Farm, located in the municipality of Ribeirão do Largo, southeast of Bahia State, Brazil, whose climate is tropical humid (Köppen, 2005). Thirty-two crossbred cattle (5/8 Zebu × 3/8 European), with average age of 20 months and initial weight of 269 ± 4.92 kg were used. The design adopted was completely randomized, in a 2 × 2 factorial arrangement at eight replications. The factors were two levels of supplementation (0.3 and 0.6% of the body weight [BW], on a dry matter basis) and addition or absence of propolis extract (LLOS®) in the concentrate.

The experimental period was 126 days from December 2010 to April 2011 of which the first 14 days were used to acclimate the animals to the diet while the other remaining 112 days were used for data gathering .The data on estimate, intake, fecal output and digestibility were collected between the 37th and 41st days of the experimental period.

The animals received a dose (1 ml/50 kg BW) of vermifuge (Ivermectin 2.25% and Abamectin 1.25%) with "long-acting" power.

The concentrate was supplied daily, at 10h00, in uncovered 3.6 m plastic troughs, allowing the animals to have access from both sides. The animals had unlimited access to the water in each paddock. The initial (iBW) and final (fBW) body weights were obtained by weighing the animals after a water- and feed-deprivation period of 12 h, and during the experimental period the animals were weighed in 28-day periods so that the concentrate supply could be adjusted, since it was based on their body weight (%BW).

The diet was formulated according to the NRC (2001), considering roughage: concentrate ratio of 80:20. The concentrate supplement utilized in this study contained: 95.61% corn meal, 3.55% urea and 0.84% limestone. When the propolis extract (LLOS®) was added to the concentrate, 2 g of the product were included for every kg of dry matter of the concentrate supplement offered per day.

The animals were kept in a pasture production system, under intermittent grazing, on a *Brachiaria brizantha* cv. Marandu grass pasture. The experimental area was divided into 12 paddocks of 1.2 ha each. At the beginning of the experimental period, the animals were randomly allocated to a set of four paddocks during a 28-day period, and at seven days the groups of animals were moved to another paddock so that all groups passed through all paddocks.

The pasture was evaluated every 28 days both in the entry paddocks (new set of four paddocks) and in the exit paddocks (where the animals remained for a period of 28 days) to determine the availability and accumulation of dry matter on the pasture (kg $DM.ha^{-1}$). For this purpose on the first day of each period in each paddock containing 12 samples (0.25 m^2 metallic square) these were cut with gardening scissors following the procedure described by McMeniman (1997). Immediately after the cut, the samples were weighed on a digital scale and subsequently conditioned in a plastic bag and frozen at -10°C for subsequent analyses.

The forage samples from simulated grazing were obtained by observing the consumption of the experimental animals according to Johnson (1978), identifying the type of material consumed and collecting a similar sample to the feed ingested.

After pre-drying in a forced-ventilation oven for 72 h at 55°C, the samples of concentrate, forage and feces were ground to 1 mm in a Wiley mill to analyze the chemical composition. The analysis was carried at Laboratory of Chemical Methods and Separations of the Department of Rural and Animal Technology at Universidade Estadual do Sudoeste da Bahia (LABMESQ-UESB).

The non-fibrous carbohydrates corrected for the residual ash and protein (NFCap) were obtained by the equation (Hall, 2003): NFCap = 100 – [(%CP - %urea CP + %urea) + NDFap + %EE + %Ash]; the total carbohydrates (TCH), by the equation (Sniffen et al., 1992): TCH = 100 – (%CP + %EE + %Ash) and the total digestible nutrients (TDN), by the equation of Weiss (1999), but utilizing the NDF corrected for the residual ash and protein: TDN = %digestible CP + %digestible NDFap + %digestible NFC + (2.25 * %digestible EE).

The analysis of the dry matter (DM), ash, crude protein (CP) and ether extract (EE) contents in the samples of feeds and feces were performed according to the methodology described by the AOAC (1990). The organic matter (OM) was estimated by subtracting the ash content from the dry matter content.

The chemical composition of the forage (simulated grazing) and concentrate are given in Table 1. The dry-matter residual biomass (RBM) was estimated according to the double-sampling method, with the aid of a square of known area (0.25 m^2) cast randomly 60 times per paddock (Wilm et al., 1994). Having the values of the cut samples visually estimated, using the equation proposed by Gardner (1986), it was possible to calculate the amount of forage biomass available per paddock, expressed as kg $DM.ha^{-1}$. The average RBM in the experimental period was 515.73 kgDM/ha day.

The triple-pairing technique was employed to measure

Table 1. Chemical composition of *Brachiaria brizanta* grass (simulated grazing) and concentrate.

Ingredient (%)	Simulated grazing	Concentrate
Dry matter	20.03	87.62
Organic matter	98.84	98.73
Crude protein	11.46	21.78
Ether extract	1.99	0.20
Total carbohydrates	85.17	76.75
Estimated TDN	76.96	76.19
NFC	22.32	63.60
NDFap	58.09	1.75
Estimated pdNDF	42.63	1.54
Acid detergent fiber	34.76	9.96
Ash	1.16	1.27
Lignin	6.45	1.77

TDN total digestible nutrients, *NDFap* neutral detergent fiber corrected for the residual ash and protein, *pdNDF* potentially degradable neutral detergent fiber.

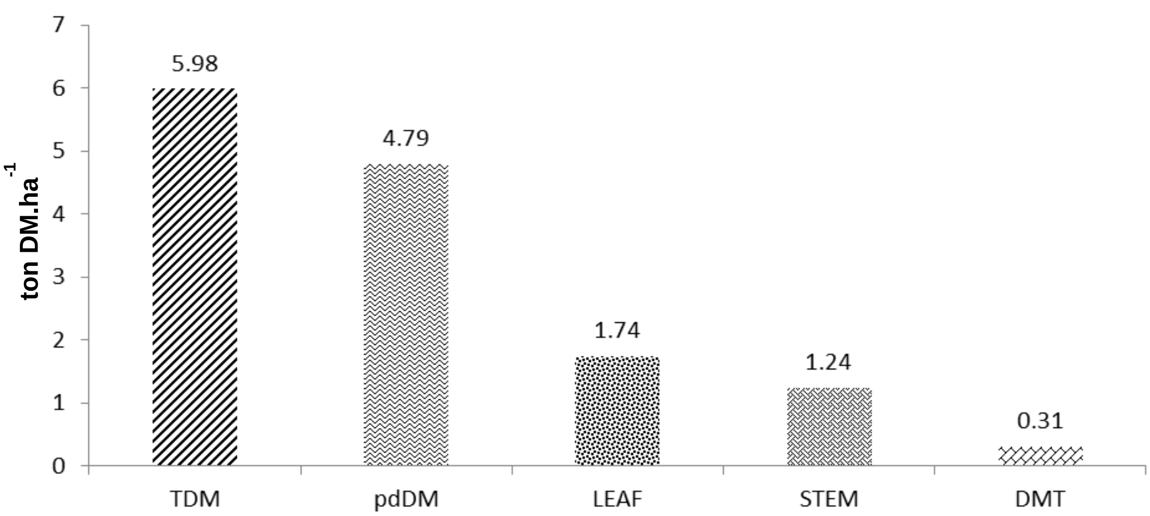

Figure 1. Availabilities of total dry matter (TDM), potentially digestible dry matter (pdDM), leaf, stem and dead material (DMT) of *Brachiaria brizantha*.

the biomass accumulation over time, considering the paddocks that remained ungrazed for 28 days as control (Moraes et al., 1990).

The average dry matter accumulation rate (DAR) was 32.76 kg DM/ha day and its estimate was given by the equation proposed by Campbell (1966): DARj $(G_i – F_{i-1})$ / n

In which: DARj - daily dry matter accumulation rate in period j, in kgDM/ha day; G_i - average final dry matter of the four deferred pastures at instant i, in kg DM; F_{i-1} - average initial dry matter present in the deferred paddocks at instant i –1, in kgDM / ha; n - number of days in the period.

The stocking rate (SR) was calculated considering the animal unit (AU) as 450 kg of BW (body weight); the average AU in the experimental period was 2.55 AU.ha^{-1}, and the average forage offer (FO) in the experimental period was 48.51 kg DM/100 kg BW day.

The potentially digestible dry matter content (pdDM) of the pasture was estimated according to the methodology described by Paulino et al. (2006): psDM = 0.98 * [(100 - %NDF) + (%NDF - %iNDF)]

The pdDM availability (pdDMa) per hectare was estimated by the equation according to Paulino et al. (2006): pdDMa = TDMa * pdDM; in which: pdDMa: potentially digestible DM availability, in kg.ha-1; TDMa: total DM availability, in kg.ha-1, and pdDM: potentially digestible DM, as percentage.

Figure 1 shows the availabilities of total dry matter, potentially digestible dry matter, leaf, stem and dead

Table 2. Mean daily intakes of grazing cattle supplemented with or without propolis extract (LLOS®).

Variables	Propolis (P)		Levels (L)		CV (%)	Significance		
	With	Without	0.3% BW	0.6% BW		P	L	P × L
TDMI (kg/day)	9.79	9.68	9.34	10.12	5.59	NS	*	NS
RHDMI (kg/day)	8.36	8.25	8.39	8.22	3.39	NS	Ns	*
TDMI (%PC)	2.80	2.78	2.72	2.86	12.69	NS	Ns	NS
RHDMI (%PC)	2.40	2.37	2.44	2.33	11.41	NS	Ns	NS
OMI (kg/day)	9.67	9.57	9.24	10.00	5.59	NS	*	NS
EEI(kg/day)	0.194	0.192	0.186	0.200	5.59	NS	*	NS
CPI (kg/day)	1.12	1.10	1.07	1.16	5.59	NS	*	NS
NDFapI (kg/day)	5.68	5.62	5.43	5.87	5.59	NS	*	NS
NDFapI (%BW)	1.62	1.62	1.58	1.66	12.69	NS	Ns	NS
NFCI (kg/day)	2.18	2.16	2.08	2.26	5.59	NS	*	NS
TDNI (kg/day)	7.14	7.31	6.77	7.67	6.72	NS	*	NS

* Significant ($P < 0.05$), NS not significant (F test)

material of *Brachiaria brizantha.*

To estimate the fecal production, we utilized LIPE® (purified, enriched lignin) as external marker, which was supplied daily at 07h00 at one capsule (single dose) per animal, with seven days for adaptation and regulation of the excretion of the marker and five days to collect the feces.

The feces were collected once daily, for five days, at every paddock, at five pre-established times (8h00, 10h00, 12h00, 14h00 and 16h00). Fecal output was estimated by determining the amount of LIPE® in the feces, by infrared spectroscopy, using the following formula adopted by Saliba et al. (2005):

$$FP = \left(\frac{\text{Amount of LIPE}^{®} \text{ supplied}_{(g)}}{(\text{Ai/totalDM}) \times 100} \right) \div DM_{(105°C)}$$

In which: FP - fecal production, in kg.day^{-1}, and A_i - logarithmic ratio of the absorption intensities of the wavelength bands 1050 cm^{-1}/1650 cm^{-1}.

The concentrate DM intake was estimated using the external marker chromic oxide (Cr_2O_3), which was supplied at 10 g per animal, mixed to the concentrate, for eight days, according to the methodology described by Valadares Filho et al. (2006), estimating fecal production by the equation:

$$CDMI = (FE * Cr_2O_3 feces) / (Cr_2O_3 \text{ concentrate})$$

Where: CDMI - concentrate dry matter intake; FP - fecal production, in kg; Cr_2O_3 - concentration of chromic oxide in the feces and concentrate.

The individual concentrate intake was estimated by dividing the total excretion of Cr_2O_3 by its respective concentration in the supplement.

To estimate the voluntary roughage intake (RHDMI), the internal marker present in the forage, indigestible NDF (iNDF), obtained according to Casali (2006) after ruminal incubation of 0.5 g of feed (forage and supplement) and feces, for 240 h, using bags manufactured with non-woven textile (TNT) grammage 100 (100 g.m^2), 5 × 5 cm. To determine the iNDF, the remaining material from incubation was subjected to extraction with neutral detergent.

The DM intake was calculated by the equation:

$$totalDMI = [\{(FE * CMF) – MC\} + CDMI] / CMR.$$

Where: FP - daily fecal production (kg.day^{-1}), obtained using LIPE®; CMF - concentration of the marker in the feces (g/kg); MC - quantity of marker in the concentrate; CDMI - concentrate DM intake, in kg supplement DM.day^{-1}; CMR - concentration of the marker in the roughage.

The feed conversion (FC) was determined based on the daily dry matter intake (kgMS.dia^{-1}) and animal performance (kgGain.day^{-1}): FC = DMI / ADG.

The average values of intake, performance and feed-conversion variables are shown in Table 2. The ingestive behavior of the animals was evaluated by previously trained assessors. The data were collected in two distinct periods lasting 24 h and with intervals of five minutes between observations, according to the methodology described by Silva et al. (2005). The studied variables were: grazing time, rumination time, time eating at the trough and idle time.

To obtain the number of rumination chews and the time spent ruminating each ruminal bolus of each animal, three observations were made in three different periods of the day (09h00 to 12h00, 15h00 to 18h00 and 19h00 to 21h00), according to Burger et al. (2000). To determine the number of daily boli, the total rumination time was divided by the average time spent ruminating

Table 3. Ingestive behavior of supplemented grazing cattle.

Variables	Propolis (P)		Levels (L)		CV (%)	Significance		
	With	Without	0.3%BW	0.6% BW		P	L	P×L
Grazing	463.33	477.92	453.33	487.82	11.33	NS	NS	*
Rumination	358.75	358.75	407.50	310.00	17.45	NS	*	NS
Idle	593.75	555.83	559.58	590.00	11.07	NS	NS	NS
Trough	24.16	47.50	19.58	52.08	27.72	*	*	NS
TCT	822.08	860.83	860.83	797.92	7.79	NS	NS	NS
BOLDAY	500.33	450.30	583.28	367.35	24.88	NS	*	NS
BITR	48.03	46.68	42.46	52.26	14.34	NS	*	*
BITDAY	22424.5	22748.1	19461.5	25711.1	22.17	NS	*	*
NGP	15.58	14.37	14.79	15.17	13.64	NS	NS	*
NIP	28.58	26.20	27.54	27.25	7.59	*	NS	NS
NRP	17.08	16.87	18.58	15.37	12.44	NS	*	NS
NTP	2.58	4.04	1.96	4.67	34.50	*	*	NS
TGP	31.59	37.36	33.64	35.31	14.37	*	NS	*
TIP	22.89	20.37	20.94	22.32	13.69	*	NS	NS
TRP	18.36	21.81	20.69	19.49	13.47	*	NS	NS
TTP	9.81	10.46	10.52	9.74	27.68	NS	NS	*
DMFE	1286.2	1240.7	1258.4	1268.5	13.99	NS	NS	NS
NDFapFE	713.88	648.19	726.48	635.59	19.93	NS	NS	NS
CPFE	167.04	158.55	1.57.61	167.97	15.92	NS	NS	NS
NFCFE	269.59	259.69	268.93	260.35	13.20	NS	NS	NS
TCHFE	1095.5	1056.7	1071.8	1080.3	13.99	NS	NS	NS
DMRE	1175.5	1127.8	936.4	1366.9	20.68	NS	*	NS
NDFapRE	951.41	848.68	815.74	984.35	28.08	NS	NS	NS
CPRE	223.49	214.31	175.67	262.13	21.16	NS	*	NS
NFCRE	523.77	486.07	3893.77	620.08	25.49	NS	*	NS
TCHRE	1463.0	1421.7	1198.9	1685.7	19.70	NS	*	NS

* Significant ($P < 0.05$), NS not significant (F test). GRAZING, RUMINATION, IDLE and TROUGH ($min.day^{-1}$). *TMT* total chewing time ($min.day^{-1}$), *BOLDAY* number of ruminated boli per day ($no.day^{-1}$), *BITR* bite rate ($no.min^{-1}$), *BITDAY* number of bites per day ($no.day^{-1}$), *NGP* number of grazing periods (no./period), *NIP* number of idle periods (no./period), *NRP* number of rumination periods (no./period), *NTP* number of periods at the trough (no./period), *TGP* time per grazing period (minutes/period), *TIP* time per idle period (minutes/ period), *TRP* time per rumination period (minutes/period), *TTP* time per period at the trough (minutes/ period).
Feed efficiency ($g.hour^{-1}$): *DMFE* of dry matter, *NDFapFE* neutral detergent fiber corrected for the residual ash and protein, *NFCFE* non-fibrous carbohydrates, *TCHFE* total carbohydrates
Rumination efficiency ($g.hour^{-1}$): of *DMRE* dry matter, *NDFapRE* neutral detergent fiber corrected for the residual ash and protein, *NFCRE* non-fibrous carbohydrates, *TCHRE* total carbohydrates

each bolus, as described previously.

The discretization of time series was performed directly on the data collection spreadsheets, by counting the discrete periods of grazing, rumination, idleness, and eating at the trough. The average duration of each of the discrete periods was obtained by dividing the daily times of each of these activities by the number of discrete periods of the same activity, as described by Silva et al. (2006).

The feed and rumination efficiencies were obtained according to the methodology of Bürger et al. (2000), as follows: DMFE = DMI / ET; NDFFE = NDFI / ET; DMRU = DMI / RUT; NDFRE = NDFI / RUT; TCT = ET + RUT.

Where: DMFE - dry matter feed efficiency; DMI - dry matter intake; ET - eating time; NDFFE - neutral detergent fiber feed efficiency; NDFI - neutral detergent fiber intake; DMRE - dry matter rumination efficiency; RUT - rumination time; NDFRE - neutral detergent fiber rumination efficiency; NDFI - neutral detergent fiber intake; TCT - total chewing time.

The mean values for feed and rumination efficiencies shown in Table 3. The correlation coefficient was tested by the "t" test at 5% of significance, utilizing statistical software SAEG (2001). The evaluated parameters were: intake, performance and ingestive behavior.

To evaluate the correlation between the variables, Pearson's linear correlation coefficient (r) was used. The correlation (r) assumes values between –1 (negative linear association) and 1 (positive linear association), and depending on the values, it can be classified into very

Table 4. Interpretation of the interaction (r) values.

Negative r	Correlation	Positive r
–0.19 to 0.00	Very weak	0.00 to 0.19
–0.39 to –0.20	Weak	0.20 to 0.39
–0.69 to –0.40	Moderate	0.40 to 0.69
–0.89 to –0.70	Strong	0.70 to 0.89
1.00 to –0.90	Very strong	0.90 to 1.00

Source: http://leg.ufpr.br/~silvia/CE003/node74.html

Table 5. Correlation between intake and behavior of supplemented grazing cattle.

Variables	T		G		R		I	
	r	P	r	P	r	P	r	P
RHDMI (kg.day^{-1})	-	-	-	-	-	-	-	-
CDMI (kg.day^{-1})	0.6862	0.0001	-	-	–0.4318	0.0176	-	-
NDFI (kg.day^{-1})	0.5585	0.0023	-	-	–0.3993	0.0266	-	-
TDNI (kg.day^{-1})	0.7425	0.0000	-	-	–0.4505	0.0136	-	-
TDMIBW (kg.day^{-1})	-	-	-	-	-	-	-	-
RHIBW (kg.day^{-1})	-	-	-	-	-	-	-	-
ADG (kg.day^{-1})	0.3699	0.0376	-	-	-	-	-	-
*FC	-	-	-	-	-	-	-	-

Times spent: *T* eating at the trough, *G grazing*, *R* ruminating, *I* idle. *RHDMI* roughage intake, *CDMI* concentrate intake, *NDFI* neutral detergent fiber intake, *TDNI* total digestible nutrients intake, *TDMIBW* total dry matter intake as a function of body weight, *RHIBW* roughage intake as a function of body weight, *ADG* average daily gain, **FC* feed conversion, in kg dry matter intake per kg body weight.

weak, weak, moderate, strong and very strong (Table 4).

RESULTS AND DISCUSSION

The time spent by the animals at the trough (T) to consume the concentrate presented a positive, moderate correlation with the intakes of concentrate dry matter (CDMI) and NDF (NDFI) (Table 5). Thus, the time to consume the concentrate increased proportionally to the quantity available at the trough. In the present study the low and moderate supplementation levels (0.3 and 0.6% BW), the positive correlation with NDF intake was probably due to the additive effect.

The time the animals remained eating at the trough showed positive, strong correlation (r = 0.7425) with TDN intake (Table 5). In case of animals supplemented on pasture, the greater density of nutrients from the concentrate reflects in greater TDN intake. With the ADG, the time spent at the trough presented positive but weak correlation, that is, the performance is not necessarily associated with the quantity of concentrate offered at the trough, depending mostly on good forage offer to reach satisfactory animal performance. According to Pardo et al. (2003), the lower fiber intake by the animals consequently minimizes the time they spent ruminating. Greater concentrate intakes are associated with lower NDF intake and higher TDN intake.

The intakes of concentrate dry matter (CDMI), NDF (NDFI) and total digestible nutrients (TDNI) presented negative correlation with the rumination time (Table 5). The other parameters assessed, such as: roughage intake (RHI), roughage intake as a function of body weight (RHIBW), total dry matter intake as a function of body weight (TDMIBW) and feed conversion (FC) did not show correlation with the behavioral variables evaluated in the present study (Table 5). Similarly, the time animals grazed and remained idle did not correlate with any of the variables intake, performance or feed-conversion (Table 5).

Regarding the total chewing time (TCT), this variable presented negative, weak correlation with concentrate intake (CDMI) and total digestible nutrient intake (TDNI) (Table 6).

The results of the present study confirm with that of findings of Gomes et al. (2012), showing that if the amount of nutrients ingested from the concentrate increases, the particle size and consequently the time required for the chewing activity will increase as well.

A negative, correlation was observed between NDF intake (NDFI) and the number of ruminated boli per day (NBOL) (Table 6). Given that increase in NDF intake would stimulate increase in the chewing activity, there is no plausible explanation for verifying negative correlation, as we did in this study. We also found a negative, moderate correlation between TDN and NBOL (Table 6).

Table 6. Correlations between bites and swallowing and intake of supplemented grazing cattle.

	TCT		NBOL		BITR		BITDAY	
	r	P	r	P	r	P	r	P
RHDMI	-	-	-	-	-	-	-	-
CDMI	–0.3449	0.0494	-	-	0.5302	0.0038	0.4153	0.0218
NDFI	-	-	–0.3726	0.0365	0.5813	0.0014	0.4981	0.0105
TDNI	–0.3261	0.0600	–0.4059	0.0245	0.5648	0.0020	0.4676	0.0106
TDMIBW	-	-	-	-	0.4067	0.0243	0.3804	0.0334
RHIBW	-	-	-	-	-	-	-	-
ADG	-	-	-	-	-	-	-	-
FC	-	-	-	-	-	-	-	-

TCT total chewing time, *BOLDAY* number of ruminated boli per day, *BITR* bite rate, *BITDAY* number of bites per day.

Table 7. Correlations between the discrete periods of ingestive behavior and intake of supplemented grazing cattle.

	NGP		NIP		NRP		NTP	
	r	P	r	P	r	P	r	P
RHDMI	-	-	-	-	-	-	-	-
CDMI	-	-	-	-	-	-	0.5394	0.0033
NDFI	-	-	-	-	–0.4129	0.0225	0.4491	0.0139
TDNI	-	-	-	-	–0.4561	0.0125	0.5891	0.0012
TDMIBW	-	-	-	-	-	-	-	-
RHIBW	-	-	-	-	-	-	-	-
ADG	-	-	-	-	-	-	0.3562	0.0438
FC	-	-	-	-	-	-	-	-

Number of: *NGP* grazing periods, *NIP* idle periods, *NRP* rumination periods, *NTP* periods eating at the trough.

This correlation is a direct reflection of the increase in the energy concentration of the diet. As the energy content of a diet and TDN intake increase, the NDF contents, particle size, and consequently number of ruminated boli per day, will decrease.

The intakes of concentrate (CDMI), NDF (NDFI), TDN (TDNI) and total dry matter as a function of body weight (TDMBW) had positive, moderate correlations with the bite rate (BITR). It was observed that increase in concentrate intake stimulated increase in the bite rate, which leads us to consider the possibility that this increase in nutrient intake is directly related to the greater selectivity of the animals, thereby promoting reduction in the amount of forage grasped per bite. According to Berchielli et al. (1994), the variations in bite mass do not cause differences in intake, due to the compensation of the bite rates. This tendency is observed when relating the number of bites per day (BITDAY) to the intakes of concentrate (CDMI), NDF, TDN and TDMBW (Table 6).

When the concentrate intake promotes an additive effect to forage intake or on the animal selectivity, the number of bites per day may be affected. This may occur due to both the quantitative increase in intake and by improvement in the quality of the ingested forage. Higher NDF intakes may be a reflection of increase in the number of bites per day when the mass of these bites is not reduced, or when this reduction in bite mass is compensated by increase in the number of bites.

Concerning the number of periods, those spent on rumination (NRP) showed negative, moderate correlation with NDF and TDN intakes (Table 7). Thus, if TDN increases, the animals will probably ruminate for longer, but fewer periods. Therefore, as TDN intake decreases, the NRP increases.

The number of periods spent eating at the trough (NTP) had positive, moderate correlations with the intakes of concentrate, NDF and TDN, and positive, weak correlation with ADG (Table 7). The supply of supplement requires a larger number of periods at the trough to eat it. The ingestion of more concentrate implies greater average daily gains. However, for NDF intake to increase, it is crucial that there be an additive effect on intake, in which the concentrate will stimulate increase in forage intake.

The number of grazing (NGP) and idle (NIP) periods did not show correlation with any of the intake, performance or feed-conversion variables (Table 7).

The time spent per grazing period (TGP) showed positive, weak correlation with the intakes of roughage (RHI), neutral detergent fiber (NDFI) and total digestible

Table 8. Correlations between the times per periods of behavioral activities and intake, performance and feed conversion of supplemented grazing cattle.

Variables	TGP		TIP		TRP		TTP	
	r	P	r	P	r	P	r	P
RHDMI	0.3579	0.0430	-	-	-	-	-	-
CDMI	-	-	-	-	-	-	-	-
NDFI	0.3539	0.0449	-	-	-	-	-	-
TDNI	0.3705	0.0374	-	-	-	-	-	-
TDMIBW	-	-	-	-	-	-	-	-
RHIBW	-	-	-	-	-	-	-	-
ADG	-	-	-	-	-	-	-	-
FC	-	-	-	-	-	-	-	-

Times spent per: *TGP* grazing period, *TIP* idle period, *TRP* rumination period, *TTP* period eating at the trough.

Table 9. Correlations between intake, average daily gain and feed conversion with the feed efficiencies of supplemented grazing cattle.

Variables	DMFE		NDFFE		CPFE		NFCFE		TCHFE	
	r	P	r	P	r	P	R	P	r	P
RHDMI	-	-	-	-	-	-	-	-	-	-
CDMI	-	-	-	-	0.5495	0.0027	-	-	0.3691	0.0379
NDFI	-	-	-0.3838	0.0321	-	-	-	-	-	-
TDNI	–0.5239	0.0043	-	-	-	-	-	-	-	-
TDMIBW	0.4387	0.016	-	-	0.5563	0.0024	-	-	0.4387	0.016
RHIBW	0.3847	0.0317	-	-	0.5259	0.0042	-	-	0.3847	0.0317
ADG	-	-	-	-	0.438	0.0161	-	-	-	-
FC	-	-	-	-	-	-	-	-	-	-

Feed efficiency of: *DMFE* dry matter, *NDFFE* neutral detergent fiber, *CPFE* crude protein, *NFCFE* non-fibrous carbohydrates, *TCHFE* total carbohydrates.

nutrients (TDNI) (Table 8). The longer time of permanence per period in the grazing activity may promote increase in roughage intake. Thus, due to the greater roughage intake, there is greater ingestion of neutral detergent fiber from the forage material.

With respect to the correlation between the rumination and feed efficiencies with performance, intake and feed conversion, the results can be viewed in Tables 9 and 10.

The average daily gain (ADG) showed positive, weak correlations with the rumination efficiencies of dry matter (DMRE) and crude protein (CPRE), and moderate correlation with the feed efficiency of protein (CPFE) and rumination efficiency of non-fibrous carbohydrates (NFCRE). Such results allow us to conclude that greater rumination and feed efficiencies, in a situation in which the feeds are offered with no restrictions, will result in better animal performance.

When the concentrate intake (CDMI) was correlated with the feed efficiencies of CP and TCH and with the rumination efficiencies of DM, CP, NFC and TCH, positive, moderate correlation was observed for both variables, except for TCHFE, which showed positive, weak correlation with CDMI. Marques (2008) reported that the rumination efficiency is increased when the supplementation level of the diet is elevated. Such assertion corroborates the results found in the present study. This occurs due to the physical characteristics of the feeds and also due to the density of nutrients.

For the roughage intake as a function of body weight (RHIBW), negative, weak correlation was observed with DMFE (Table 9) and negative, moderate correlation with NDFRE (Table 10). Usually, with increase in supplement intake, NDF intake reduces proportionally. These results corroborate Cruz et al. (2012), who evaluated the ingestive behavior of supplemented and unsupplemented cattle, and obtained a negative, moderate correlation between the NDF rumination efficiency and RHIBW (r = -0.55).

The total dry matter intake as a function of body weight (TDMIBW) presented negative, moderate correlation with the feed efficiency of DM (DMFE) (Table 9) and the rumination efficiency of NDF (Table 9). These results were probably caused by the higher intake of concentrate and roughage. The intake of NDF (NDFI) showed positive, moderate correlation with the feed efficiency of DM, CP and TCH (Table 9) and rumination efficiency of

Table 10. Correlations between intake, average daily gain and feed conversion with the rumination efficiencies of supplemented grazing cattle.

Variables	DMRE		NDFRE		CPRE		NFCRE		TCHRE	
	r	P	r	P	r	P	r	P	r	P
ADG	0.3756	0.0353	-	-	0.3889	0.0302	0.457	0.0124	-	-
FC	-	-	-	-	-	-	-	-	-	-
RHDMI	-	-	-	-	-	-	-	-	-	-
CDMI	0.651	0.0003	-	-	0.6786	0.0001	0.6893	0.0001	0.6064	0.0008
RHIBW	-	-	-0.4939	0.071	-	-	-	-	-	-
TDMIBW	-	-	-0.4161	0.0216	-	-	-	-	-	-
NDFI	0.63	0.0005	-	-	0.6497	0.0003	0.6264	0.0005	0.6092	0.0008
TDNI	0.6597	0.0002	-	-	0.6824	0.0001	0.6625	0.0002	0.6339	0.0004

Rumination efficiency of: *DMRE* dry matter, *NDFRE* neutral detergent fiber, *CPRE* crude protein, *NFCRE* non-fibrous carbohydrates, *TCHRE* total carbohydrates.

DM, CP, NFC and TCH (Table 10). This is due to the ingestion of concentrate, which contains greater amounts of NFC and CP in its composition, which optimizes the utilization of these nutrients.

The total digestible nutrient intake (TDNI) had positive, weak correlation with the feed efficiencies of DM and TCH and positive, moderate correlation with the feed efficiency of CP (Table 9) and with the rumination efficiencies of DM, CP, NFC and TCH (Table 10). Greater TDN intakes imply greater feed efficiency of dry matter, total carbohydrates and crude protein, which are present at a high percentage in the concentrate, compared with the forages. Similar effect occurs with the rumination efficiencies, because concentrates reduce the rumination time, making it more efficient.

CONCLUSIONS

The animal expresses, in its ingestive behavior, the metabolic changes promoted by greater or lower intake of a certain nutrient. The existence of correlation between nutrient intake, performance and animal behavior is unmistakable evidence that, if properly evaluated, animal behavior is a tool of extreme relevance for the understanding of the metabolic and nutritional aspects related to cattle production, thereby eliminating the need for invasive trials which, in many cases, do not meet the current welfare requirements to which we should subject the animals. Further studies related to behavior should be conducted to find out other parameters to understand better the intake and performance of grazing cattles.

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