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# Correlation between Ingestive Behavior and Digestibility Coefficients of Supplemented Grazing Steers, with or without Addition of Propolis Extract (LLOS®)

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors RS and GC designed the study and performed the statistical analysis, Authors APS, FS and TL wrote the first draft of the manuscript. Authors LZ and SF preparation of propolis extract, authors AS and VC managed the analyses of the study. Author GA managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

The objective of this study was to evaluate the correlation between ingestive behavior and apparent digestibility of grazing cattle supplemented with or without propolis extract (LLOS®), during the rainy season. Thirty-two uncastrated crossbred steers (269±4.92 kg) with an average age of 20 months were used in a completely randomized design with a 2 × 2 factorial arrangement of treatments, with 8 repetitions. Two levels of supplementation were used (0.3 and 0.6% of body weight [BW], on a dry

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matter [DM] basis), with or without the addition of propolis extract (LLOS®). In treatments with propolis extract (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: Apparent digestibility and ingestive behavior. The digestibility coefficients, except for crude protein and non-fibrous carbohydrates, showed a positive correlation with the time the animals spent feeding at the trough. The digestibility of total dry matter, organic matter, total carbohydrates and crude protein showed a positive correlation with feed efficiency of crude protein (CPFE) ($P<0.05$). The feed efficiency of total carbohydrates showed a positive ($P<0.05$), weak correlation only with the digestibility coefficient of protein. The correlations found in this study allow us to understand, after ingesting the feed and during digestion, the behavioral alterations of animals, adapting to changes in the diets.

*Keywords: Feed efficiency; rumination efficiency; ethology; LIPE®; supplementation.*

## 1. INTRODUCTION

The more efficient management of beef cattle farming is related to technologies associated with nutrition, emphasizing supplementation, diets for grazing animals and the suitable management of the soil and pastures with the least damage to the environment [1]. Supplementing animals reared on pasture is a strategy that aims to improve animal performance and thus reducing the slaughter age, releasing the pastures for others categories and increasing the capital turnover of the system. However, at certain times, depending on the prices of inputs, one can make use of supplementation at low levels aiming only at meeting the maintenance requirements of the animals, thereby avoiding weight losses during dry spells, as occurs in a large portion of the Brazilian territory.

Understanding the ingestive behavior of grazing cattle will enable the prediction of gains based solely on the forage evaluation. Intake and digestibility are two of the main components that determine the quality of a feedstuff [2].

The animal-behavior study has been conducted with the purpose of evaluating their feeding habits, especially when in a grazing system [3].

The search for natural additives that can supply at least equivalent to the use of the ionophore without decreasing the productivity of the production system is a spread quality for products exempt from any toxicity [4].

Among the supplementation of alternatives, propolis has been studied as a promising showing positive results in studies with ruminants, as it is a resin with complex composition and numerous pharmacological properties including antimicrobial activity [5] but need information about your use.

Studies by [6] found that propolis is able to enhance the dry matter, protein, digestibility and reduce the number of methanogenic bacteria. [7] claim that the use of propolis improves feed conversion and consequently animal performance.

According to [8], there is a positive relationship between the forage digestibility and the level of intake caused by the physical limitation. The elevation in degradation rate and/or flow of rumen digesta increase intake. When ruminants are offered diets with high energy contents and these are digested fast, this physical limit is not reached and the animal controls its intake so as to meet its energy requirements. To meet the animal production requirements, it is necessary to supplement the nutrients that show to be scarce in the forage. However, the presence of concentrate in cattle diets usually depresses the intake of dry matter from forage. The objective of this study was to evaluate the existing correlations between the ingestive behavior and the apparent digestibility of uncastrated steers supplemented on pasture, with or without addition of propolis extract (LLOS®) to the diet.

## 2. 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. 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 (two supplementation levels and addition or absence of propolis extract -LLOS®) and eight replications. The factors were two supplementation levels (0.3 and 0.6% of the body weight [BW], on a dry matter basis), with or without addition of propolis extract (LLOS®) to the concentrate.

The diet was formulated according to the [9], considering a 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 experimental period was 126 days, of which the first 14 days were used for the animals to acclimate to the diet and management and the other 112 for collection of the experimental data (December 2010 to April 2011).

The animals received a dose (1 mL/50 kg BW) of vermifuge (Ivermectin 2.25% and Abamectin 1.25%) with "long-acting" power, which was longer than the experimental period.

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 hours 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 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, 12 samples (0.25 m$^2$ metallic square) were cut with gardening scissors, according to the methodology described by [10]. 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 intake of the experimental animals, according to [11].

After pre-drying in a forced-ventilation oven for 72 hours 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 analyses were performed at the 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 [12]: NFCap = 100 – [(%CP- %urea CP + %urea) + NDFap + %EE + %Ash]; the total carbohydrates (TCH), by the equation [13]: TCH = 100 – (%CP + %EE + %Ash) and the total digestible nutrients (TDN), by the equation of [14], but utilizing the NDF corrected for the residual ash and protein: TDN = %digestible CP + %digestible NDFap + %digestible NFC + (2.25 * %digestible EE).

The chemical composition of the forage (simulated grazing) and of the concentrate is shown in Table 1. The analyses of 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 [15]. Organic matter (OM) was estimated by subtracting the ash content from the dry matter content.

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.) [16]. Having the values of the cut samples visually estimated, using the equation proposed by [17], 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 kg DM. ha$^{-1}$ day.

The triple-pairing technique was employed to measure the biomass accumulation over time, considering the paddocks that remained ungrazed for 28 days as control [18].

**Table 1. Chemical composition of forage *Brachiaria brizanta* and concentrate used in diet**

| Ingredient (%) | Forage (simulated grazing) | Concentrate |
|---|---|---|
| Dry matter | 20.03 | 87.62 |
| Organicmatter | 98.84 | 98.73 |
| Crudeprotein | 11.46 | 21.78 |
| Etherextract | 1.99 | 0.20 |
| Total carbohydrates | 85.17 | 76.75 |
| Estimated total digestiblenutrientes | 76.96 | 76.19 |
| Non-fibercarbohydrates | 22.32 | 63.60 |
| Neutral detergent fiber corrected for the residual ash and protein | 58.09 | 1.75 |
| Estimated potentially degradable neutral detergent fiber | 42.63 | 1.54 |
| Aciddetergentfiber | 34.76 | 9.96 |
| Ash | 1.16 | 1.27 |
| Lignin | 6.45 | 1.77 |

The average dry matter accumulation rate (DAR) was 32.76 kg DM/ha day and its estimate was given by the equation proposed by [19]: DARj ($G_i - F_{i-1}$) / n

In which: DARj-daily dry matter accumulation rate in period j, in kg DM. $ha^{-1}$ 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 kg DM. $ha^{-1}$; 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. $ha^{-1}$/kg BW day.

The potentially digestible dry matter content (pdDM) of the pasture was estimated according to [20]: psDM = 0.98 * [(100-%NDF) + (%NDF-%iNDF)]

The pdDM availability (pdDMa) per hectare was estimated by the equation according to [20]: 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.

The data to estimate fecal production, intake and digestibility were collected between the 37$^{th}$ and 41$^{th}$ days of the experimental period.

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 the animal paddock, at five pre-established times (8h00, 10h00, 12h00, 14h00 and 16h00), thereby composing samples of feces per animal, were pre-dried in forced ventilation oven at 60°C then analyzed.

Fecal production was estimated by determining the amount of LIPE® in the feces, by infrared spectroscopy, at the Laboratory of Veterinary Medicine of UFMG, using the following formula adopted by [21]:

$$FP = \frac{\text{Amount of LIPE® supplied}_{(g)}}{(A_i / \text{totalDM}) * 100} \div DM_{(105°C)}$$

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 grams per animal, mixed to the concentrate, for eight days, according to the methodology described by [22], estimating fecal production by the equation: CDMI = (FP * $Cr_2O_3$feces)/($Cr_2O_3$ concentrate).

In which: 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 (RDMI), used a fistulas animal, we used the internal marker present in the forage, indigestible NDF (iNDF), obtained according to [23] after ruminal incubation of 0.5 g of feed (forage and supplement) and feces, for 240 hours, using bags manufactured with non-woven textile (TNT) grammage 100 (100 g.m2), 5×5 cm. To determine the iNDF, the remaining material from incubation was subjected to extraction with neutral detergent.

The total dry matter intake (total DMI) was calculated by the equation:

Total DMI = [{(FP * CMF) – MC} + CDMI]/CMR.

In which: 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 digestibility coefficient (DC) of the components was estimated by the formula: DC (%)={(kgDMingested–kgDMfeces)/kg DMingested}* 100; mean values can be viewed in Table 3.

The ingestive behavior of the animals was evaluated by previously trained assessors. The data were collected in two distinct periods lasting 24 hours and with intervals of five minutes between observations, according to the methodology described by [24]. The studied variables were: Time eating at the trough, idle time, grazing time and rumination time.

To obtain the number of rumination chews and the time spent ruminating each ruminal bolus of, animal, three observations were made in three different periods of the day (09h00-12h00, 15h00-18h00 and 19h00-21h00), according to [25]. To determine the number of daily boli, the total rumination time was divided by the average time spent ruminating each bolus.

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 period 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 [26].

The feed and rumination efficiencies were obtained according to the methodology of [25], as follows:DMFE = DMI/ET; NDFFE = NDFI/ET; DMRU = DMI/RUT; NDFRE = NDFI/RUT and TCT = ET + RUT.

In which: DMFE-dry matter feeding efficiency; DMI-dry matter intake; ET-eating time; NDFFE-neutral detergent fiber feeding efficiency; NDFI-neutral detergent fiber intake; DMRU-dry matter rumination efficiency; RUT-rumination time; NDFRE-neutral detergent fiber rumination efficiency; NDFI-neutral detergent fiber intake and TCT-total chewing time.

The mean values for feed and rumination efficiencies can be viewed in Table 2.

The correlation coefficient was tested by the "t" test at 5% of significance, utilizing statistical software [27]. The evaluated parameters were: apparent digestibility coefficient and ingestive behavior.

To evaluate the correlation between the apparent digestibility coefficient and the ingestive behavior of supplemented grazing cattle, Pearson's linear coefficient correlation (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 weak, weak, moderate, strong and very strong (Table 4).

## 3. RESULTS AND DISCUSSION

The correlations between the apparent digestibility coefficients and the ingestive behavior of the animals can be observed in Table 5. The digestibility coefficients of the nutrients, except for CP and NFC, showed positive correlation with the time the animals remained eating at the trough. The digestibility coefficients of CP and NFC did not present correlation with any behavioral variable evaluated in this study and the time the animals remained idle did not show correlation with any digestibility coefficient either (Table 5).

**Table 2. Ingestive behavior of supplemented grazing cattle diets with different levels of propolis**

| Variables | Propolis (P) | | Levels (L) | | | Significance | | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | 0.3% BW | 0.6% BW | CV (%) | P | L | PxL |
| 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 | 157.61 | 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 |

*CV (%) = coefficient of variation; *significant (P<0.05), NS= not significant (F test). GRAZING, RUMINATION, IDLE and TROUGH (min.day-1) TCT 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 375 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*

**Table 3. Apparent digestibility coefficients of dry matter, organic matter, crude protein, neutral detergent fiber, total digestible nutrients, total carbohydrates and non-fibrous carbohydrates**

| Variables | Propolis (P) | | Levels (L) | | | Significance | | |
|---|---|---|---|---|---|---|---|---|
| | With | Without | 0.3% BW | 0.6% BW | CV (%) | P | L | PxL |
| $_{DC}$ TDM | 63.28 | 63.37 | 61.45 | 65.19 | 2.96 | NS | * | NS |
| $_{DC}$OM | 64.37 | 64.81 | 62.76 | 66.42 | 2.80 | NS | * | NS |
| $_{DC}$TCH | 65.49 | 65.51 | 63.34 | 67.67 | 2.66 | NS | * | NS |
| $_{DC}$CP | 61.39 | 60.15 | 59.82 | 61.71 | 3.33 | NS | * | NS |
| $_{DC}$NFC | 96.41 | 94.47 | 96.40 | 96.48 | 0.14 | NS | NS | * |
| $_{DC}$EE | 60.60 | 57.26 | 49.34 | 68.53 | 3.53 | * | * | * |
| $_{DC}$NDF | 71.57 | 76.53 | 72.12 | 75.97 | 1.80 | * | * | * |
| $_{DC}$TDN | 72.83 | 75.43 | 72.47 | 75.79 | 1.49 | * | * | NS |

*CV (%) = coefficient of variation; * significant (P<0.05); NS= not significant (F test). digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

The time the animals remained ruminating showed weak, negative correlation with the digestibility coefficients of total dry matter ($_{DC}$TDM), organic matter ($_{DC}$OM) and total digestible nutrients ($_{DC}$TDN) and moderate, negative correlation with the digestibility coefficient of ether extract ($_{DC}$EE) (Table 5). These results demonstrate that as the digestibility of these nutrients increased, there was a decrease in their rumination times. According to [28], when the supplementation level is increased, ruminal digestion is reduced and consequently the intestinal digestion of the dry matter is increased. Therefore, this behavior may have a direct relationship with the supplement intake by the animals, minimizing the rumination time, since the latter has a higher passage rate in relation to the forage material.

**Table 4. Values of the interactions (r)**

| r negative | Correlation | r positive |
|---|---|---|
| –0.19 to 0.00 | Veryweak | 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 | Verystrong | 0.90 to 1.00 |

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

The correlations according to the time the animals spent eating at the trough are considered moderate for $_{DC}$TDM, $_{DC}$TCH and $_{DC}$EE and strong for $_{DC}$OM, $_{DC}$NDF and $_{DC}$TDN (Table 5). Evaluating supplemented grazing cattle, [29] observed that the digestibility coefficients of DM, OM, CP and NDF increased as the supplementation level increased, on the basis of the body weight. Hence, digestibility increases as it remains eating at the trough, due to the higher uptake of nutrients resulting from the greater concentrate intake.

When the total chewing time (TCT) was correlated with the digestibility of nutrients, observe that only the digestibility of total carbohydrates showed negative, moderate correlation (Table 6). According to [30], this is due to the greater selectivity of the animals and the amount of concentrate in the diet. The same behavior was observed when correlating the number of ruminated boli per day with the digestibility coefficient of ether extract (Table 6).

For the bite rate (BITR), positive, moderate correlations were observed (Table 6) for the apparent digestibility coefficient of TDM, OM, TCH, CP and EE, i.e. the nutrient digestibility by the animals increases as the bite rate is increased. This behavior is probably due to the greater preference (selectivity) of the animals for the forage parts that present better nutritional value at the moment of grazing, second [31], the bite rate usually tends to increase, but this increment is not sufficient to prevent the intake rate from dropping; the animal responds to this situation by extending the grazing time.

The same behavior reported above occurs when we correlate the number of bites per day (BITDAY) with the digestibility coefficients of TDM, OM, CP and EE. However, the only positive, moderate correlation for this parameters occurs for the digestibility coefficient of ether extract; the other evaluated parameters had positive, weak correlations (Table 6).

The number of grazing periods (NGP) did not present correlation (P>0.05) with any of the digestibility coefficients evaluated herein and the number of idle periods (NIP) showed negative, weak correlation only with the digestibility coefficient of neutral detergent fiber (Table 7). Lower NDF digestibility results in longer idle periods.

In the evaluation of the number of rumination periods (NRP), negative, moderated correlations can be observed (Table 7) for the digestibility of DM, OM, TCH, EE and TDN; in other words, the rumination periods reduced as the digestibility of nutrients improved. When the supply of concentrate is increased, the digestibility of nutrients increases as well and the rumination periods decrease.

The number of periods eating at the trough (NTP) had moderate, positive correlation with the digestibility coefficients of TDM, OM, TCH, EE, NDF and TDN (Table 7). Because it improves the diet, the use supplementation on pasture promotes an increase in the digestibility coefficient of TDM, OM, TCH, EE, NDF and TDN, so the supplement intake improved the digestibility of the evaluated nutrients.

With regard to the time spent per periods grazing (TGP), idle (TIP), rumination (TRP) and eating at the trough (TTP), only the digestibility coefficient of the non-fibrous carbohydrates ($_{DC}$NFC) showed negative, weak correlation with TGP (Table 8). This is because when the time intended for forage intake is increased, there is greater presence of cellulolytic bacteria at the expense of the amylolytic bacteria, which, if present at a higher proportion, would favor the digestion of NFC.

The digestibility coefficients of TDM, OM, TCH and CP presented positive, moderate correlation with the feed efficiency of protein (CPFE) (Table 9). This was due to the quality of the feed supplied to the animals. For the evaluation of the feed efficiency of total carbohydrates (TCHFE), however, there was positive, weak correlation only with the digestibility coefficient of the protein.

**Table 5. Correlation between ingestive behavior and apparent digestibility coefficient of the nutrients in supplemented grazing cattle**

| Variables | Trough | | Grazing | | Rumination | | Idle | |
|---|---|---|---|---|---|---|---|---|
| | R | P | R | P | R | P | r | P |
| $_{DC}$TDM | 0.6777 | 0.0001 | - | - | –0.3978 | 0.0271 | - | - |
| $_{DC}$OM | 0.7142 | 0.0000 | - | - | –0.3981 | 0.0270 | - | - |
| $_{DC}$TCH | 0.6891 | 0.0001 | - | - | - | - | - | - |
| $_{DC}$CP | - | - | - | - | - | - | - | - |
| $_{DC}$NFC | - | - | - | - | - | - | - | - |
| $_{DC}$EE | 0.6266 | 0.0005 | 0.3448 | 0.0495 | –0.5858 | 0.0013 | - | - |
| $_{DC}$NDF | 0.8560 | 0.0000 | - | - | - | - | - | - |
| $_{DC}$TDN | 0.8882 | 0.0000 | - | - | –0.3946 | 0.0282 | - | - |

*Times spent: TROUGH eating at the trough, GRAZING grazing, RUMINATION ruminating, IDLE idle. apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

**Table 6. Correlations between bites and swallowing and the digestibility of the nutrients of supplemented grazing cattle**

| Variables | TCT | | BOLDAY | | BITR | | BITDAY | |
|---|---|---|---|---|---|---|---|---|
| | R | P | R | P | R | P | r | P |
| $_{DC}$TDM | - | - | - | - | 0.4899 | 0.0076 | 0.3775 | 0.0345 |
| $_{DC}$OM | - | - | - | - | 0.4792 | 0.0089 | 0.3740 | 0.0359 |
| $_{DC}$TCH | –0.4038 | 0.0252 | - | - | 0.4206 | 0.0203 | - | - |
| $_{DC}$CP | - | - | - | - | 0.4862 | 0.0080 | 0.3611 | 0.0415 |
| $_{DC}$NFC | - | - | - | - | - | - | - | - |
| $_{DC}$EE | - | - | –0.5700 | 0.0018 | 0.6706 | 0.0002 | 0.5893 | 0.0012 |
| $_{DC}$NDF | - | - | - | - | - | - | - | - |
| $_{DC}$TDN | - | - | - | - | - | - | - | - |

*TCT total chewing time, BOLDAY ruminatedboli per day, BITR bite rate, BITDAY number of bites per day apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

**Table 7. Correlations between the discrete periods of ingestive behavior and apparent digestibility coefficient of supplemented grazing cattle**

| Variables | NGP | | NIP | | NRP | | NTP | |
|---|---|---|---|---|---|---|---|---|
| | R | P | R | P | R | P | r | P |
| $_{DC}$ TDM | - | - | - | - | –0.4321 | 0.0175 | 0.5334 | 0.0036 |
| $_{DC}$OM | - | - | - | - | –0.4326 | 0.0174 | 0.5593 | 0.0022 |
| $_{DC}$TCH | - | - | - | - | –0.4012 | 0.0260 | 0.5270 | 0.0041 |
| $_{DC}$CP | - | - | - | - | - | - | - | - |
| $_{DC}$NFC | - | - | - | - | - | - | - | - |
| $_{DC}$EE | - | - | - | - | –0.6428 | 0.0004 | 0.6579 | 0.0002 |
| $_{DC}$NDF | - | - | –0.3603 | 0.0419 | - | - | 0.6319 | 0.0005 |
| $_{DC}$TDN | - | - | - | - | –0.4042 | 0.0251 | 0.6942 | 0.0001 |

*Number of: NGP grazing periods, NIP idle periods, NRP rumination periods, NTP periods eating at the trough. - apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

According to [32], the digestibility is the product of the rumen-retention time by the degradation properties of the feed. The larger particles of the feed remain longer in the rumen, making it digestible to its most extent, i.e. its digestibility potential.

The correlations of the rumination efficiency of dry matter (DMRE) were positive, moderate with almost all the digestibility coefficients assessed, except for the digestibility coefficient of NDF ($_{DC}$NDF), which showed positive, weak correlation and with the digestibility correlation of the NFC ($_{DC}$NFC), which did not present correlation with any of the evaluated parameters (Table 10).

In view of the above, it is believed that the availability of nutrients to be degraded by the ruminal microorganisms increases as the rumination efficiency of the dry matter increases. The protein rumination efficiency showed strong correlation with the ether extract digestibility.

The rumination efficiency of neutral detergent fiber (NDFRE) did not present correlation with the digestibility coefficients evaluated in the present study (Table 10).

The rumination efficiency of the CP (CPRE) showed positive, moderate correlation with the digestibility coefficients of total dry matter, organic matter, total carbohydrates and crude protein and TDN; positive, strong correlation with the digestibility coefficient of ether extract and positive, weak correlation with the digestibility coefficient of NDF (Table 10).

The rumination efficiency of the NFC (NFCRE) had positive, moderate correlation with the digestibility coefficients of total dry matter, organic matter, total carbohydrates, crude protein and ether extract, TDN and positive, weak correlation with the digestibility coefficient of the NDF (Table 10).

**Table 8. Correlations between the times per periods of behavioral activities and digestibility coefficients of the nutrients in supplemented grazing cattle**

| Variables | TGP | | TIP | | TRP | | TTP | |
|---|---|---|---|---|---|---|---|---|
| | R | P | r | P | R | P | R | P |
| $_{DC}$ TDM | - | - | - | - | - | - | - | - |
| $_{DC}$OM | - | - | - | - | - | - | - | - |
| $_{DC}$TCH | - | - | - | - | - | - | - | - |
| $_{DC}$CP | - | - | - | - | - | - | - | - |
| $_{DC}$NFC | –0.3579 | 0.0430 | - | - | - | - | - | - |
| $_{DC}$EE | - | - | - | - | - | - | - | - |
| $_{DC}$NDF | - | - | - | - | - | - | - | - |
| $_{DC}$TDN | - | - | - | - | - | - | - | - |

*Times spent per: TGP grazing period, TIP idle period, TRP rumination period, TTP period eating at the trough. - apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

**Table 9. Correlation between feeding efficiencies and digestibility coefficients of supplemented grazing cattle**

| | DMFE | | NDFFE | | CPFE | | NFCFE | | TCHFE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | P | r | P | r | P | r | P | r | P |
| $_{DC}$TDM | - | - | - | - | 0.5252 | 0.0042 | - | - | - | - |
| $_{DC}$OM | - | - | - | - | 0.5123 | 0.0052 | - | - | - | - |
| $_{DC}$TCH | - | - | - | - | 0.5254 | 0.0042 | - | - | - | - |
| $_{DC}$CP | - | - | - | - | 0.5407 | 0.0032 | - | - | 0.3791 | 0.0339 |
| $_{DC}$NFC | - | - | - | - | - | - | - | - | - | - |
| $_{DC}$EE | - | - | - | - | - | - | - | - | - | - |
| $_{DC}$NDF | - | - | - | - | - | - | - | - | - | - |
| $_{DC}$TDN | - | - | - | - | - | - | - | - | - | - |

*Feeding efficiency of: DMFE dry matter, NDFFE neutral detergent fiber, CPFE crude protein, NFCFE non-fibrous carbohydrates, TCHFE total carbohydrates. apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

**Table 10. Correlations between rumination efficiencies and digestibility coefficients of supplemented grazing cattle**

| | DMRE | | NDFRE | | CPRE | | NFCRE | | TCHRE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | P | r | P | r | P | R | P | r | P |
| $_{DC}$TDM | 0.6097 | 0.0008 | - | - | 0.639 | 0.0004 | 0.6662 | 0.0002 | 0.5565 | 0.0024 |
| $_{DC}$OM | 0.6033 | 0.0009 | - | - | 0.6326 | 0.0005 | 0.6575 | 0.0002 | 0.5515 | 0.0026 |
| $_{DC}$TCH | 0.6288 | 0.0005 | - | - | 0.6564 | 0.0002 | 0.6875 | 0.0001 | 0.5745 | 0.0017 |
| $_{DC}$CP | 0.4453 | 0.0146 | - | - | 0.4745 | 0.0096 | 0.5129 | 0.0052 | 0.391 | 0.0294 |
| $_{DC}$NFC | - | - | - | - | - | - | - | - | - | - |
| $_{DC}$EE | 0.6886 | 0.0001 | - | - | 0.7037 | 0.0001 | 0.6902 | 0.0001 | 0.6648 | 0.0002 |
| $_{DC}$NDF | 0.3795 | 0.0337 | - | - | 0.3992 | 0.0267 | 0.3978 | 0.0271 | 0.3545 | 0.0446 |
| $_{DC}$TDN | 0.5046 | 0.0060 | - | - | 0.5276 | 0.004 | 0.5289 | 0.0039 | 0.4722 | 0.0099 |

*Rumination efficiency of: DMRE dry matter, NDFRE neutral detergent fiber, CPRE crude protein, NFCRE non-fibrous carbohydrates, TCHRE total carbohydrates. apparent digestibility coefficients of: $_{DC}$TDM total dry matter, $_{DC}$OM organic matter, $_{DC}$TCH total carbohydrates; $_{DC}$CP crude protein, $_{DC}$NFC non-fibrous carbohydrates, $_{DC}$EE ether extract, $_{DC}$NDF neutral detergent fiber, $_{DC}$TDN total digestible nutrients*

Lastly, the rumination efficiency of TCH (TCHRE) showed positive, moderate correlation with the digestibility coefficients of total dry matter, organic matter, total carbohydrates, ether extract and TDN and positive, weak correlation with the coefficients of crude protein and NDF (Table 10). According to [33], rumination efficiency is increased when increasing the level of diet supplementation, this is due to the physical characteristics and density of foods.

## 4. CONCLUSIONS

The correlations found in this study allow us to understand how, after ingesting feeds and during the process to its digestion, animals demonstrate behavioral alterations, adapting to the changes that occur in the diet. As obvious as it might seem to be, quantifying the correlation between certain variables has never, or only recently, been reported. These results may serve to break the paradigm that the study of cattle eating behavior does not have any contribution to nutritional trials.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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