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Correlation between performance and ingestive behavior of steers post-weaned on pastures

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ABSTRACT. The objective of this study was to evaluate the correlations existing between nutrient intake and ingestive behavior of crossbred steers in the post-weaning phase on *Brachiaria brizantha* cv. Marandu, during the rainy period. Twenty-two steers were distributed into a completely randomized design, with two types of supplement and eleven replications, managed under rotational grazing, in a 6.5 ha area. Pearson's Linear Correlation analysis was performed between the behavior variables and the performance variables values. The correlation coefficients were tested by the t test. The average daily gain (ADG) showed positive correlation with the times spent ruminating and eating at the trough and total chewing time. Positive correlation was observed between the idle time and feed conversion (FC). The bite rate and the number of bites per day presented positive correlations with ADG. Positive correlations were found between the variables rumination efficiency of dry matter (DM) and of neutral detergent fiber (NDF) with ADG. The ingestive behavior has a direct influence on the productive performance of crossbred steers post-weaned on pasture during the rainy period. Rumination efficiency improved when the animals were fed protein supplementation, which led to better utilization the ingested feed.

Keywords: bite, cattle, gain, grazing.

Correlação entre o desempenho e o comportamento ingestivo de novilhos recriados em pastagens

RESUMO. O objetivo deste estudo foi avaliar as correlações existentes entre a ingestão de nutrientes e comportamento ingestivo de novilhos mestiços na fase pós-desmame em pastagem de Brachiaria brizantha cv. Marandu, durante o período chuvoso. Vinte e dois animais foram distribuídos em um delineamento experimental inteiramente casualizado, com dois tipos de suplemento e onze repetições, administrados sob pastejo rotacionado, em uma área de 6,5 ha. A análise de correlação linear de Pearson foi realizado entre as variáveis de comportamento e os valores das variáveis de desempenho. Os coeficientes de correlação foram testados pelo teste de t. O ganho de peso médio diário (GMD) apresentou correlação positiva com os tempos passados em ruminação, comendo no cocho e tempo de mastigação total. Foi observada uma correlação positiva entre o tempo ocioso e conversão alimentar (CA). A taxa de bocados e o número de bocados por dia apresentaram correlações positivas com GMD. Foram encontradas correlações positivas entre as variáveis eficiência ruminação da matéria seca (MS) e da fibra em detergente neutro (FDN) com GMD. O comportamento ingestivo tem uma influência direta sobre o desempenho produtivo de novilhos mestiços desmamados em pasto durante o período chuvoso. A eficiência de ruminação melhorou quando os animais foram alimentados com suplementação proteica, o que levou a uma melhor utilização do alimento ingerido.

Palavras-chave: bocado, gado, ganho, pastagem.

Introduction

On a production scale, animal performance is mainly a reflection of the nutritional management to which it is subjected, and it is extremely important to offer animals feeds with a high nutritional value, but at a low cost. Thus, one of the main factors affecting animal performance is voluntary feed intake, since most production animals in Brazil are fed in grazing systems. The search for the knowledge of animal-productivity aspects by studying the animal behavior has increasingly grown, given that it reflects the environment in which the animal is reared and the management to which it is subjected.

Voluntary intake, and consequently rearing cattle on pasture, depends on plant- and animal-related

factors. Therefore, the quantity and how forage and other feeds are available to the animals determines different responses and changes in their performance, which may imply behavioral changes due to the possible existence of several correlations between performance and behavioral variables. In this context, studying the ingestive behavior is a highly important tool in the evaluation of diets, because through it is possible to acquire knowledge of the possible relationships existing between the plant-supplements-animal interface, allowing us to adjust the feeding management of animals to obtain better productive performance (CAVALCANTI et al., 2008).

Given the above, investigating and seeking new feeding and nutritional management techniques, coupled to studies of ingestive behavior, are of fundamental importance as a way to provide subsidies to improve production in the national beef country industry.

Thus, the objective was to evaluate the correlations existing between performance and ingestive behavior of crossbred steers in the post-weaning phase on a *Brachiaria brizantha* cv. Marandu pasture in the rainy period.

Material and methods

The experiment was conducted on Princesa do Mateiro farm, in the municipality of Ribeirão do Largo, located in the Southwest region of Bahia State, Brazil. Twenty-two uncastrated crossbred Holstein × Zebu steers with average age of seven months and average initial body weight of 164.09 ± 12.13 kg were used. The experimental period was from November 27, 2011 to March 4, 2012, totaling 98 days, 14 of which were used for the animals to adapt to the management and experimental diet.

All the animals were subjected to control of ecto- and endoparasites and to vaccinations, according to the calendar of the health authority of Bahia State. The animals were kept on a rotational-grazing system on *Brachiaria brizantha* cv. Marandu, total area 6.5 ha, which was divided into six paddocks of equivalent areas with average dry matter availability at entry and exit of the animals in and off the paddocks of 5,150 and 3,907 kg dry matter per hectare, respectively.

The steers remained 28 days in each paddock, alternating over two paddocks every two day to reduce the influence of biomass variation among the paddocks. After this period, they were transferred to another two distinct paddocks, in a randomly pre-established direction, doing this rotation for 28 days. Because each paddock was utilized in only one period, each paddock had a resting period of 56 days.

The animals were identified by their morphological characteristics and numbered plastic earrings, weighed and assigned to the type of supplementation through a completely randomized design. Each supplementation type had 11 replications, consisting of: protein/energy supplementation - 0.4% of the body weight in supplement per day, balanced so as to meet the nutrient requirements for gain of 1 kg day^{-1} (NRC, 2001); and mineral supplementation - mineral supplement *ad libitum* (Table 1).

Table 1. Proportion of ingredients of the supplements.

Ingredient (%)	Protein/energy supplement	Mineral supplement
Corn	45.4398	-
Soybean meal	45.4398	-
Urea + AS[1]	4.9928	-
Mineral mix[2]	4.6325	100

[1]Urea + Ammonium sulfate (9:1). [2]Composition: calcium 235 g; phosphorus 160 g; magnesium 16 g; sulfur 12 g; cobalt 150 mg; copper 1,600 mg; iodine 190 mg; manganese 1,400 mg; iron 1,000 mg; selenium 32 mg; zinc 6,000 mg; 1,120 mg; fluorine (maximum) 1,600 mg.

Supplementation was offered daily, at 10h00, in collective, uncovered plastic troughs with access from two sides, measuring 80 cm animal^{-1}.

The animals were weighed at the beginning and end of the experiment, after a feed-deprivation period of 12 hours, and at 28 days for evaluation of the average daily body weight gain to adjust the supplement supply. The total weight gain (WG) and the average daily gain (ADG) were determined as the difference between the final body weight (FBW) and the initial body weight (IBW) divided by the length of the experimental period, in days.

The supplement (concentrate) DM intake (SDMI) was estimated with the marker titanium dioxide, which was supplied at 10 g per animal, mixed in the concentrate, for eight days, following the same fecal collection scheme as described to estimate fecal excretion, through the equation:

$$\text{SDMI} = \frac{(\text{FE x } TiO_2 \text{ feces})}{TiO_2 \text{ supplement}}$$

in which TiO_2 feces and TiO_2 supplement refer to the concentration of titanium dioxide in the feces and supplement, respectively. The individual concentrate intake was estimated by dividing the total TiO_2 excretion by its respective concentration in the concentrate.

To estimate the voluntary intake of roughage, internal marker indigestible NDF (iNDF) was used;

it was obtained after ruminal incubation of 0.5 g of samples of feed, leftover and feces, in duplicate, for 240 hours (CASALI et al., 2008), utilizing non-woven textile (TNT) bags, grammage 100 (100 g m^{-2}), 5 × 5 cm. The remaining material from the incubation was subjected to extraction with neutral detergent, to determine the iNDF.

The total DM intake was calculated as follows:

$$\text{total DMI}\left(\frac{\text{kg}}{\text{day}}\right) = \left[(\text{FE x CMF}) - \text{MS}\right] + \frac{\text{SDMI}}{\text{CMR}}$$

in which:

FE = fecal excretion (kg day^{-1}), obtained using titanium dioxide;

CMF = concentration of the marker in the feces (kg kg^{-1});

MS = concentration of the marker in the supplement;

CMR = concentration of the marker in the roughage (kg kg^{-1});

and SDMI = supplement DM intake. Feed conversion (FC) was determined according to the animal intake and performance, according to the equation below:

$$\text{FC} = \left(\frac{\text{DMI}}{\text{ADG}}\right)$$

in which DMI is the daily intake of dry matter, in kg, and ADG is the average daily live-weight gain, in kg.

The ingestive behavior was evaluated on the 34th and 41st days of the experiment, in January 2012, with observations performed at every 5 minutes, according to the methodology of Silva et al. (2006), for a period of 24 hours.

The animals were visually assessed by two trained observers for each type of supplement with the aid of binoculars; they were strategically positioned so as not to influence the animal behavior. Digital stopwatches were used to determine the time spent on each activity, and flashlights were used in the nocturnal observations to help collect the data.

The behavioral variables observed comprised the grazing time, rumination time, idle time and time eating at the trough; the activity of all animals was recorded. The collected data were tabulated and calculations were performed; the eating and rumination times were calculated according to the DM and NDF intakes (min. kg^{-1} DM or NDF).

The total eating (TET) and chewing (TCT) times were determined by the equations:

TET = grazing time + time eating at the trough;

TCT = grazing time + rumination time + time eating at the trough

A trained observer was specifically positioned to obtain the number of cud chews and the time spent ruminating each cud, for each animal, determined by the observations of three cuds in three different periods of the day (9:00-12:00 am, 3:00-6:00 pm and 7:00-9:00 pm), according to Burger et al. (2000). To determine the number of daily cuds, the total rumination time was divided by the average time spent ruminating each cud, as previously described.

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

The variables g of DM and NDF/meal were obtained by dividing the average individual intake of each fraction by the number of eating periods per day (in 24 hours). The feed and rumination efficiencies, expressed as g DM/hour and g NDF/hour, were obtained by dividing the average daily intake of DM and NDF by the total time spent eating and/or ruminating in 24 hours, respectively. The variables g of DM and NDF/cud were obtained by dividing the average individual intake of each fraction by the number of cuds per day (in 24 hours).

The bite rate (BITR) of the animals on each type of supplementation was estimated as the time spent by the animal to perform 20 bites (HODGSON, 1982). To calculate the bite mass (BITM), the daily intake was divided by the total daily bites (JAMIESON; HODGSON, 1979). The results of the observations of bites and cud-swallowing were recorded in six occasions during the day, according to Baggio et al. (2009); three in the morning, and three in the afternoon, and these were also used to determine the number of bites per day (BITDAY), which is the product between bite rate and grazing time.

The samples of concentrate, forage and feces, after being pre-dried, were ground in a Wiley mill with 1 mm screen sieve for the chemical analyses.

The dry matter (DM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF) and ash contents were obtained according to methodologies

described by the AOAC (1990). The concentration of NDF corrected for the residual ash and protein was analyzed according to the recommendations of Mertens (2002) (Table 2).

Table 2. Chemical composition of the *Brachiaria brizantha*, of the protein/energy supplement and total-digestible-nutrient concentrations of the diets.

Chemical composition	*Brachiaria brizantha*[1]	Protein/energy supplement
Dry matter	24.81	87.06
Mineral matter	7.89	10.24
Crude protein	12.20	48.21
Ether extract	2.16	2.72
ADF[2]	35.84	8.77
NDFap[3]	67.52	31.74
Non-fibrous carbohydrates	10.22	15.84
Total carbohydrates	77.74	38.82
TDN[4]	53.09	60.00

[1]Simulated grazing. [2]ADF - acid detergent fiber. [3]NDFap - neutral detergent fiber corrected for the residual ash and protein. [4]Total digestible nutrients.

The non-fibrous carbohydrates corrected for the residual ash and protein (NFCap) were obtained by the equation (HALL, 2003) NFCap = 100 – [(%CP – %CP from urea + % urea) + NDFap + %EE + %Ash].

The total carbohydrates (TC) were determined by the equation (SNIFFEN et al., 1992): 100 – (%CP + %EE + %Ash).

The total digestible nutrients (TDN) were calculated by the equation of NRC (2001), but utilizing the NDF corrected for residual ash and protein: TDN = %digestible CP + %digestible NDFap + %digestible NFC + (2.25 * %digestible EE).

The performance and behavior data were correlated utilizing Pearson's Linear Correlation. The correlation coefficients were tested by the t test and processed on SAEG (2001), and were considered significant when $p < 0.05$. The following parameters were utilized: performance and ingestive behavior, Tables 3 and 4, respectively.

The correlation coefficients that were not significant were not included in the tables.

Results and discussion

Negative correlation ($p < 0.05$) was verified between the idle time (IDLE) and the average daily gain (ADG) (Table 5). This result contradicts the logic of the animal metabolism, since once the animal-metabolism requirements are more rapidly met, the idle time would be positive correlated with average daily gain, requiring less energy expenditure by the animal to search for food, which would then increase its average daily gain and idle time, which did not occur in this experiment.

Table 3. Mean values of average daily gain (ADG) and feed conversion of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

Performance	Supplementation	
	Protein/energy	Mineral
Average daily gain (kg day^{-1})	0.97	0.70
Feed conversion (FC)	7.53	8.74

Table 4. Mean values of the ingestive behavior, bite aspects, rumination aspects, discrete periods, and feed and rumination efficiencies of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

Item (%)	Supplementation	
	Protein/energy	Mineral
Grazing (min.)	457.04	442.95
Idle (min.)	490.00	558.86
Rumination (min.)	466.59	423.63
Eating at the trough (min.)	26.36	14.54
Total chewing (min.)	950.00	881.14
Total eating (min.)	483.41	457.50
BITR (n s^{-1})	0.81	0.64
BITM (g DM)	0.34	0.37
BITN (n/swallowed cud)	24.86	21.60
BITT (time/swallowed cud)	31.54	34.32
BITD (n day^{-1})	22216.96	16990.22
Cuds day^{-1}	627.69	572.72
Time cud^{-1} (s)	45.17	44.53
Chews cud^{-1}	53.25	52.04
Chews day^{-1}	33240.98	29699.84
NGP	13.09	12.09
NIP	30.45	23.45
NRP	21.91	16.54
NTP	3.00	1.82
TGP (min.)	32.79	36.95
TIP (min.)	14.94	17.35
TRP (min.)	26.46	37.79
TTP (min.)	8.20	7.00
DMIG (g DM meal^{-1})	455.51	534.73
NDFIG (g NDFap meal^{-1})	285.06	358.27
DMFE (kg DM hour^{-1})	100.80	105.86
NDFFE (kg NDFap hour^{-1})	122.45	149.92
DMRE (kg DM hour^{-1})	0.90	0.60
NDFRE (kg NDF hour^{-1})	0.50	0.40
RUGDM (g DM cud^{-1})	12.01	11.36
RUGNDF (g NDF cud^{-1})	7.52	7.60

Table 5. Linear correlation coefficients between performance and ingestive behavior of steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

Variable[1]	ADG	FC
	r^2	r^2
GRZ	—	—
IDLE	–0.5443	0.4509
RUM	0.4907	—
TRH	0.3853	—
TCT	0.5441	–0.4513
TET	—	—

[1]GRZ - grazing time; IDLE - idle time; RUM - rumination time; TRH - time eating at the trough; TCT - total chewing time; TET - total eating time; ADG - average daily gain; FC - feed conversion. [2]r - Pearson's correlation coefficient.

Positive correlation was verified ($p < 0.05$) between the rumination time (RUM) and the average daily gain (ADG) of the animals. Greater rumination leads to better use of the ingested feed, which consequently allows the animals to ingest

more, improving their performance. That being, the result obtained is in line with the existing literature on this subject (LIMA et al., 2012).

The time eating at the trough (TRH) and the average daily gain (ADG) were positively correlated ($p < 0.05$). Providing protein/energy supplementation to grazing animals generates an additional uptake of nutrients to the ruminal microorganisms, which propitiates ideal conditions of growth, and use of the fiber, which consequently elevates the average daily gain.

The total chewing time (TCT) was positively correlated ($p < 0.05$) with the average daily gain. As the animal spends more time eating and ruminating on a pasture with good forage allowance, as in the present study (6,117.97 kg DM ha^{-1}), it is inferred that it will ingest more nutrients, and the particles ingested will also be better processed due to the rumination process, which will consequently result in better performance, as the correlation in question demonstrates. By contrast, negative correlation ($p < 0.05$) was found between the total chewing time (TCT) and feed conversion (FC). In this aspect, we can infer that as the animal ingests more nutrients, and the quality of the feed is improved by inclusion of supplementation, the animal performance is improved at the expense of FC, which will reduce.

Positive correlation was observed ($p < 0.05$) between the idle time (IDLE) and the feed conversion (FC). This correlation demonstrated that the reduction of the idle time and consequent increase in the grazing and rumination time also reduces the feed conversion, because the animal will consume more nutrients and improve its performance.

Positive correlation was found ($p < 0.05$) between NIP, NRP and NTP and the average daily gain (ADG) of the animals (Table 6). Given that the supply of protein/energy supplement to animals kept in a grazing system leads to more rapidly meeting the metabolic requirements and improvement in the ruminal environment through the supply of the same readily digestible protein source (urea), it can be inferred that the consequence of the abovementioned events is improvement in animal performance. This would contradict the assertion of Santana Junior et al. (2013), that the discrete periods are not associated with the productive parameters.

Negative correlations were observed ($p < 0.05$) between NIP and NTP and feed conversion (FC), because elevation in the number of periods on any of the activities reduces their duration per period. The increase in NTP implies greater nutrient intake, which improves the animal performance and consequently reduces feed conversion.

Table 6. Linear correlation coefficients between performance and discrete periods of the activities and ingestive behavior of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

Variable[1]	ADF	FC
	r^2	r^2
NGP	—	—
NIP	0.5522	–0.4062
NRP	0.5090	—
NTP	0.4838	–0.4099
TGP	—	—
TIP	—	—
TRP	—	—
TTP	—	—

[1]NGP - number of grazing periods; NIP - number of idle periods; NRP - number of rumination periods; NTP - number of periods eating at the trough; TGP - time per grazing period; TIO - time per idle period; TRP - time per rumination period; TTP - time per period eating at the trough; ADG - average daily gain; FC - feed conversion. [2]r – Pearson's correlation coefficient.

The bite rate (BITR) and the number of bites per day (BITD) presented positive correlations ($p < 0.05$) with average daily gain (ADG) (Table 7). The bite rate is influenced by the pasture structural characteristics such as height, leaf:stem ratio and density. Thus, the bite rate and the number of bites per day influence forage intake. Since greater intake of good-quality forage directly affects animal performance, the correlations reported are coherent with the results presented herein.

Table 7 displays the absence of correlations between variables bite mass (BITM) number of bites per cud swallowed (BITN), and time per bite (BITT) and the average daily gain (ADG), as well as absence of correlations between all variables under study with feed conversion (FC).

Table 7. Linear correlation coefficients between performance and bite aspects of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

	Bite aspects	
Variable[1]	ADG	FC
	r^2	r^2
BITR	0.4515	—
BITM	—	—
BITN	—	—
BITT	—	—
BITD	0.4783	—

[1]BITR - bite rate; BITM - bite mass; BITN - number of bites per cud swallowed; BITT - time per bite; BITD - number of bites per day; ADG - average daily gain; FC - feed conversion. [2]r - Pearson's correlation coefficient.

The number of ruminated cuds per day (CUD day^{-1}) showed positive correlation ($p < 0.05$) with the average daily gain (ADG). Given the very high correlation ($r > 0.90$) between rumination efficiency and average daily gain (Table 8), it can be inferred that the additional protein intake by the animals improved the rumen environmental conditions, increasing the digestibility of the NDF from the forage, which made its rumination efficiency increase, providing greater dry matter intake and consequently greater performances.

Berchielli et al. (2011) affirmed that dry matter intake is positively related to NDF digestibility, in which the increase in digestibility causes the dry matter intakes to increase. According to Allen (2000), the increase of a single unit in forage-NDF digestibility is associated with an increase of 170 g in dry matter intake.

Table 8. Linear correlation coefficients between performance and rumination aspects of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

	Rumination aspects	
Variable[1]	ADG	FC
	r^2	r^2
CUD day^{-1}	0.5500	—
T cud^{-1}	—	—
C cud^{-1}	—	—
C day^{-1}	0.4887	–0.4024

[1]CUD day^{-1} - number of ruminated cuds per day; T cud^{-1} - time per ruminated cud; C cud^{-1} - chews per cud; C day^{-1} - number of cud chews per day; ADG - average daily gain; FC - feed conversion. [2]r – Pearson's correlation coefficient.

Positive correlation was verified ($p < 0.05$) between the variable number of cud chews per day (C day^{-1}) and average daily gain (ADG) and negative correlation ($p < 0.05$) with feed conversion (FC). Because the animals were kept under a grazing system, they consequently showed higher NDF intakes, so it took a higher number of chews during the day for the ingested material to be properly fractionated, which promoted better utilization, thereby increasing performance.

The ingestion of NDF per meal in grams (NDFIG) was negatively correlated ($p < 0.05$) with average daily gain (ADG) (Table 9). Because the NDF content of the feeds is directly related to intake, and the latter with performance, as the NDF intake is elevated, the intake by the animals might be limited by the filling effect, which may impair performance.

Table 9. Linear correlation coefficients between performance and feed and rumination efficiencies of crossbred steers fed protein/energy supplementation or mineral supplementation on *Brachiaria brizantha* cv. Marandu in the rainy period.

Variable[1]	ADG	FC
	r^2	r^2
DMIG	—	0.4030
NDFIG	–0.3820	0.4318
DMFE	—	—
NDFFE	—	—
DMRE	0.7326	–0.5200
NDFRE	0.6987	–0.5036
RGDM	—	—
RGNDF	—	—

[1]DMIG - dry matter intake, in grams; NDFIG - neutral detergent fiber intake, in grams; DMFE - dry matter feed efficiency; NDFFE - neutral detergent fiber feed efficiency; DMRE - dry matter rumination efficiency NDFRE - neutral detergent fiber rumination efficiency; RGDM - rumination in grams of dry matter; RGNDF - rumination in grams of neutral detergent fiber; ADG - average daily gain; FC - feed conversion. [2]r – Pearson's correlation coefficient.

Positive correlations were verified ($p < 0.05$) between variables dry matter rumination efficiency (DMRE) and neutral detergent fiber rumination efficiency (NDFRE) and average daily gain (ADG), which is explained by the better utilization of the ingested material through improvement in the rumination process provided by the supply of protein/energy supplementation to the animals, which resulted in better performance. According to Welch (1982), the rumination efficiency is important in the control of the use of low-digestibility feeds, because the animal can ruminate greater amounts of feed of this type and thus have greater feed intake and better productive performance. In this context, the rumination efficiencies of dry matter (DMRE) and neutral detergent fiber (NDFRE) are negatively correlated ($p < 0.05$) with feed conversion due to their positive correlation with ADG.

Intake in grams of DM (DMIG) and NDF (NDFIG) per meal showed positive correlation with feed conversion. Because the ingestion of the two abovementioned nutrients is obtained by the sum of grazing and eating at the trough, the animals needed to ingest the same quantity of DM and NDF to gain one kilo of body weight.

Conclusion

The productive performance has a direct influence on the ingestive behavior of steers post-weaned on pasture during the rainy periods. Numerous positive and negative correlations were verified, demonstrating this influence. Although this is one of the first studies evaluating grazing animals kept on tropical pastures, these correlations can support both the development of further research and the understanding of the productive variables through studies of the animal behavior in previously conducted works.

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