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Replacing corn with ground or pelleted citrus pulp in diets of Nellore heifers

Substituição do milho por polpa cítrica moída ou peletizada na dieta de novilhas Nelore

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SUMMARY

Citrus pulp can replace corn in feedlot diets in order to decrease metabolic problems by reducing formation of lactate ruminal. However, while eating, animals can easily select against pelleted *citrus* pulp due to the greater particle size of the pellet. Therefore, grinding *citrus* pulp pellet can be an alternative to decrease particle selectivity. This study was realized to evaluate the replacement of ground corn by pelleted *citrus* pulp and ground *citrus* pulp on animal performance, sorting index, and feeding behavior of Nellore heifers. Thirty-six Nellore heifers were randomly assigned to three treatments: control diet based on ground corn (GC), partial replacement of GC by ground *citrus* pulp (GCP), and partial replacement of GC by pelleted *citrus* pulp (PCP). . Heifers fed with the GC diet had higher final body weight (BW), average daily gain (ADG), and dry matter intake (DMI) compared with heifers fed with *citrus* pulp ($P < 0.05$). Ground *citrus* pulp increased DMI and fiber intake compared with the PCP group ($P < 0.05$). Heifers fed with PCP and GCP sorted for diet particles from 8 to 19 mm and selected particles with less than 1.18 mm ($P < 0.05$). Thus, the ground citrus pulp is better than pelleted *citrus* pulp due to higher feed intake and ADG, in consequence of lower selection index.

Keywords: confinement, consumption, particle size

RESUMO

A polpa cítrica pode substituir o milho nas dietas em confinamento, a fim de diminuir os problemas metabólicos, reduzindo a formação de lactato. No entanto, enquanto comem, os animais podem selecionar facilmente a polpa cítrica peletizada, devido ao maior tamanho de partícula do pélete. Portanto, a moagem do pélete da polpa cítrica pode ser uma alternativa para diminuir a seletividade de partículas. Este estudo teve como objetivo avaliar a substituição do milho moído por polpa cítrica peletizada e polpa cítrica moída

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sobre o desempenho animal, índice de seleção de partículas e comportamento alimentar de novilhas Nelore. Trinta e seis novilhas Nelore foram distribuídas aleatoriamente em três tratamentos: dieta controle à base de milho moído (MM), substituição parcial de MM por polpa cítrica moída (PCM) e substituição parcial de MM por polpa cítrica granulada (PCP). Novilhas alimentadas com dieta contendo MM apresentaram maior peso corporal final (PC), ganho médio diário (GMD) e consumo de matéria seca (CMS) em comparação com novilhas alimentadas com polpa cítrica (P <0,05). A polpa cítrica moída aumentou o CMS e o consumo de fibra em comparação ao grupo PCP (P <0,05). Novilhas alimentadas com PCP e PCM selecionaram a favor de partículas da dieta entre 8 e 19 mm e selecionaram partículas com menos de 1,18 mm (P <0,05). Assim, a polpa cítrica moída é melhor que a polpa cítrica peletizada, devido ao maior consumo de ração e ganho médio diário, em consequência do menor índice de seleção de partículas.

Palavras-chave: confinamento, consumo, tamanho de partícula

INTRODUCTION

Citrus pulp (CIP) is a high-pectin co-product available during the dry season. Its lower cost and similar energy content when compared to ground flint corn (PEREIRA et al., 2007) makes it an interesting co-product to include in cattle finishing diets in Brazil (PRADO et al., 2000; PINHEIRO et al., 2000; OLIVEIRA & MILLEN, 2014). *Citrus* pulp is typically used to replace ground corn in feedlot cattle diets, not only because of lower feeding costs, but also because CIP contains low starch and a high amount of pectin, which is a fast rumen degraded. Pectin, unlike starch, does not generate lactic acid in the rumen (KIM et al., 2007; GOUVÊA et al., 2016). Consequently, CIP addition in beef cattle diets avoids rumen acidosis and other metabolic disorders (ARTHINGTON et al., 2002).

Pelleting is the most common processing method for *citrus* pulp used in ruminant diets. However, because of its greater particle size, diet components can be easily sorted by the animals. Moreover, *citrus* pulp contains phenols and condensed tannins, which reduce diet palatability and affect dry matter intake (DMI) (MACÍAS-CRUZ et al., 2010). Therefore, we hypothezed that grounding the citrus pulp could minimize feed selection, improving animals' feed intake and performance. We aimed at evaluating the replacement of ground corn by *citrus* pulp, either pelleted (PCP) or ground, on animal performance, feed sorting, and feeding behavior of growing Nellore heifers.

MATERIAL AND METHODS

Animals procedures were previously approved by the FMVZ animal ethics committee (Protocol Number 7632051113), in accordance to the Institutional Animal Care and Use Committee Guidelines of the University of São Paulo. The feedlot study was conducted at the Beef Cattle Research Laboratory, University of São Paulo, located in the city of Pirassununga, in southeast Brazil (21°80′ 00″ S and 47°25′ 42″ W, 634 m altitude). The animals were kept in the feedlot for 56 days, with 14 days for diet and facilities adaptation followed by 42 days for data collection. Upon arrival, heifers were weighed, separated into 2 blocks according to initial BW, and randomly assigned to the pens (12 pens, 4 pens per treatment).

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Thirty-six Nellore heifers (14 months old, 257 ± 23 kg BW) were housed in collective pens (3 animals/pen, 3.0 m wide × 9.0 m deep, 3.0 m of linear bunk space) with *ad libitum* access to feed and water. Heifers were fed a sugarcane silage-based diet twice daily, at 0900 h and 1500 h (Table 1).

Table 1. Composition and analysed nutrient content of experimental diets

Item	Treatments[1]		
	GC	PCP	GPC
Ingredients (g/kg of DM[2])			
Sugarcane silage	334	334	334
Ground corn	579	157	157
Pelleted *citrus* pulp	-	426	-
Ground *citrus* pulp	-	-	426
Soybean Meal	32	32	32
Urea	23	27	27
Limestone	8	-	-
Commercial mineral salt	24	24	24
Analysed composition (g/kg of DM)			
Dry matter	500	506	506
Organic matter	933	923	922
Ash	66	78	78
Starch	405	112	113
Neutral detergent fibre	261	293	296
Acid detergent fibre	186	248	243
Crude protein	156	149	149
Acid detergent lignina	46	45	46
Ether extract	21	16	16
NEm[3] (Mcal/kg DM)	1.73	1.66	1.66
NEg[4] (Mcal/kg DM)	1.12	1.06	1.06
APS (mm)	70	101	70

[1]The treatments are diets containing ground corn (GC), pelleted *citrus* pulp (PCP) and ground *citrus* pulp (GCP).
[2]DM, dry matter;
[3]NEm, net energy for maintenance (NASEM, 2016);
[4]NEg, net energy for gain (NASEM, 2016);
[5]APS= average particle size of the diets;
*Commercial mineral salt guaranteed analysis per Kg of product: Ca min. 188 g, max. 231 g; Co min. 24 mg; Cu min. 720 mg; S min. 74 g; F max. 240 mg; P min. 24 g; I min. 40 mg; Mg min. 30 g; Mn 1500 mg; Se min. 8 mg; Na min. 60 g; Zn 2080 mg; Monensin min. 1830 mg.

The sugarcane used was the variety IAC-SP 93-3046, mechanically harvested and chopped to obtain mean particle length of 8 to 10 mm. During chopping, the sugarcane was inoculated with *Lactobacillus buchneri* (strain NCIMB 40788-LALSIL Cana, Lallemand Animal Nutrition, Aparecida de Goiânia, Goiás, Brazil) to prevent the alcoholic fermentation as suggested by Siqueira et al. (2007), and ensiled for 32 days before the beginning of the experiment.

Experimental treatments were composed of two non-fiber carbohydrate sources with two different processing methods. The control diet was composed by finely-ground corn (GC), partially replaced by ground *citrus* pulp (GCP),

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and partial replacement of GC by pelleted *citrus* pulp (PCP). The particle size of the pelleted *citrus* pulp was an average of 30 mm, the finely-ground corn 1.2 mm, and the ground *citrus* pulp 1.3 mm. *Citrus* pulp replaced 73% of GC, and diets were formulated according to NASEM (2016) to fulfill the maintenance requirements and promote an average daily gain (ADG) of 0.7 kg/d. This level of growth is enough to ensure that heifers maintain body growth during the dry season to reach the recommended BW (300 kg) at the beginning of the mating season. The high level of *citrus* pulp inclusion was used to ensure the manifestation of possible negative effects on DM intake.

Heifers were fed at *ad libitum* intake, DMI was measured daily by accounting for the weights of offered feed and orts. The amount offered was adjusted daily allowing for a minimum of 5% of leavings during the experiment. Heifers were weighed after 16 h of feed restriction (shrunk BW), at the beginning of the experiment, and every 21 days to measure performance and gain:feed (G:F) ratio.

Diet ingredients were sampled weekly, pooled for chemical composition, and frozen for subsequent analysis of dry matter (method 967.03) and crude protein (method 981.10) according to AOAC (2010). Neutral detergent fiber was determined as described by VAN SOEST et al. (1991) using 8 M urea and heat stable α-amylase (Sigma Chemical Co., St. Louis, MO) in an ANKOM A200 fiber analyzer (ANKOM Technology Corp., Fairpoint, NY). Acid detergent lignin and acid detergent fiber (ADF) were analyzed according to VAN SOEST & ROBERTSON (1985). In addition, starch was determined by enzymatic degradation (Termamyl® 300L and Amyloglucosidase AMG 300L, Novozymes, Basal, Sweden) and glucose absorbance performed in a spectrophotometer as described by BACH KNUDSEN (1997).

Particle size distribution of the diets and orts was determined weekly. Samples of approximately 400 g were collected at 5 points in the feed bunk of each pen, to determine the selectivity of the animals according to the diets offered. After collection, the Penn State Particle Separator containing three sieves of 19 mm, 8 mm and 1.18 mm of aperture was used, following the methodology described by HEINRICHS & KONONOFF (2002). To evaluate the selection of particles, the sorting index (SI) of each sieve was calculated according to the methodology described by Silveira et al. (2007). The SI was calculated as the ratio between the actual and expected intake of particles retained in each screen. Actual intake for each fraction was calculated as the amount of feed offered × particle size distribution in the total mixed ration (TMR) - the weight of orts × particle size distribution in orts. The expected intake was determined as the particle size distribution of the TMR × actual feed intake. An SI of 1 indicates no sorting, SI <1 indicates sorting against and SI>1 indicates sorting for particles retained in each screen. The average particle size (APS) of the experimental diets was also calculated following the methodology described by HEINRICHS & KONONOFF (2002).

For the ingestive behavior analysis, heifers were observed on the 18th day of each experimental period. Individual visual monitoring was performed with observations every five minutes for 24 hours, beginning at 8 am and ending at 8 am on the following day. The observed variables were time spent with feeding, ruminating, and idleness, and other activities, which included urinating, defecating, or drinking water, according

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to methodology adapted from BÜRGER et al. (2000). The ingestive behavior parameters (ingestion, rumination times, and ruminating chews) were expressed as per day, per kg of DM, and per kg of NDF consumed.

Pens were considered the experimental unit for all reports and averages on animal within pen were obtained before the analysis. All statistical analyses were conducted using SAS version 9.1.2 for Windows (SAS Inst. Inc., Cary, NC) according to the following model:

$$Y_{ijk} = \mu + B_i + \tau_j + e_{ijk}$$

in which Y_{ijk} is the observation of the effect of treatments i on block j, at replication k, μ is the overall mean, B_i is the random effect of block, τ_j is the fixed effect of treatment, and e_{ijk} is the random error associated with each observation.

The data were submitted to analysis of normality of the residues and homogeneity of the variances. When these assumptions were satisfied, the data were submitted to analysis of variance. Treatment effects were decomposed into two orthogonal contrasts: 1) NCF: effect of non-fiber carbohydrate source (GC vs. PCP+GCP); 2) PROC: effect of citrus pulp processing (PCP vs. GPC). Significance was declared at $P \leq 0.05$, and trends were considered at $P > 0.05$ and $P \leq 0.10$ for all analyses.

RESULTS AND DISCUSSION

Initial BW was similar (P > 0.05) for the treatments, demonstrating homogeneity at the initial allocation (Table 2). Replacing GC by CIP, either pelleted or ground, reduced final BW (P = 0.03, Table 2), ADG by 28% (P < 0.01), DMI by 11.9% (P = 0.04), and tended to reduce G:F ratio (P = 0.07), compared to heifers receiving the GC diet. Grinding the CIP increased DMI (P = 0.02) by 20% compared to the PCP group. In addition, feeding GCP tended to increase the final BW (P = 0.09) in comparison to the PCP group.

Table 2. Initial and final body weight, average daily gain, and nutrient intake of heifers fed with different non-fiber carbohydrates and *citrus* pulp processing methods

Item	Treatments[1]			*SEM*[2]	*P*-values[3]	
	GC	PCP	GCP		NFC	PROC
Initial body weight (kg)	261	254	258	4.00	0.38	0.69
Final body weight (kg)	296	276	286	5.00	0.03	0.09
Average daily gain (kg/d)	0.85	0.56	0.66	0.04	<0.01	0.30
Dry matter intake (kg/d)	6.25	4.99	6.02	0.25	0.04	0.02
Neutral detergent fiber intake (kg/d)	1.73	1.47	1.78	0.09	0.33	0.01
Crude protein intake (kg/d)	0.98	0.76	0.88	0.04	<0.01	0.08
Gain to feed ratio	0.14	0.11	0.11	0.01	0.07	0.81

[1]The treatments are diets containing ground corn (GC), pelleted *citrus* pulp (PCP) and ground *citrus* pulp (GCP).
[2]Standard error of the mean.
[3]Ground corn vs. *citrus* pulp contrast (NFC) and pelleted *citrus* pulp vs. ground *citrus* pulp contrast (PROC).

The estimated energy of *citrus* pulp in the present study is 1.99 Mcal NEm/kg, which is very close to the reference value (NASEM, 2016) of 2.0 Mcal NEm/kg. Nevertheless, the expected-to-observed dietary NE decreased 8% (from 1.01 to 0.93 Mcal NEm/kg) and the expected-to-observed DMI increased 9% (from 0.98

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to 1.08) when grinding the *citrus* pulp compared to the pelleted form. In fact, compared to pelleted *citrus* pulp, grinding the *citrus* pulp decreased 11% its NE content (2.11 vs 1.87 Mcal/kg). The greater observed-to-expected DMI and lower dietary NE in grinded *citrus* pulp suggest that this presentation negatively affected its energy value. But, weight gain of animals fed GCP was not decreased because of the greater DMI compared to the PCP diets.

Heifers fed with the GC diet selected against the smaller particles <1.18 mm (SI = 0.92, Table 3), and partial replacement of PCP by GCP reduced the intensity of selection against particles <1.18 mm (*P* = 0.04). Moreover, when analysing numerically, it can be demonstrated that partial replacement of PCP by GCP increased the sorting to >19 (SI = 1.07 *vs.* 1.04, *P* = 0.11) and 1.18-8 mm particles (SI = 1.04 *vs.* 1.02, *P* = 0.11) compared to GC, as the *P*-values were very close to tendency.

However, when heifers were fed with the PCP diet, the heifers selected against the 8-19 mm particles (SI = 0.95, *P* < 0.01). However, grinding the *citrus* pulp changes the selectivity of diet. Heifers fed with the GCP selected the 8-19 mm particles (*P* < 0.01), avoided low particles (*P* < 0.01), and tended to select for the particles >19 mm (*P* = 0.07) compared to the animals receiving the PCP. There was no effect of non-fibrous carbohydrate or processing method on the sorting index of 1.18-8 mm particle sizes (*P* > 0.05).

Table 3. Orts composition and sorting index of heifers fed different non-fiber carbohydrates and *citrus* pulp processing methods

Item	Treatments[1]			*SEM*[2]	*P*-values[3]	
	GC	PCP	GCP		NFC	PROC
Orts (% of offer)	6	7	5	0.80	0.73	0.07
Orts NDF[4] (g/kg of DM)	227	257	212	6.00	0.21	<0.01
Orts CP[5] (g/kg of DM)	156	116	180	1.20	0.01	<0.01
Sorting index						
>19 mm	1.04	1.05	1.09	0.01	0.11	0.07
8-19 mm	1.04	0.95	1.09	0.01	0.12	<0.01
1.18-8 mm	1.02	1.04	1.03	0.01	0.11	0.32
<1.18 mm	0.92	1.02	0.91	0.12	0.04	<0.01

[1]The treatments are diets containing ground corn (GC), pelleted *citrus* pulp (PCP) and ground *citrus* pulp (GCP).
[2]Standard error of the mean.
[3]Ground corn vs. *citrus* pulp contrast (NFC) and pelleted *citrus* pulp vs. ground *citrus* pulp contrast (PROC).
[4]NDF, neutral detergent fiber;
[5]CP, crude protein.

Changes in the ability of the animals of selecting feedstuffs can also be observed in the different chemical composition of the orts. Diets with PCP had orts with higher NDF content (*P* < 0.01) and lower CP content (*P* < 0.01), reflecting the greater *citrus* pulp refusal in this diet.

The partial replacement of GC by CIP decreased rumination time (*P* < 0.05, expressed as h/d, min/kg DM and min/kg NDF, Table 4), increased intake time (*P* < 0.01, also expressed as h/d, min/kg DM and min/kg NDF), decreased chewing activity (*P* < 0.05, expressed as

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1,000 units/d, 1,000 units/kg DM and 1,000 units/kg NDF) and decreased ruminal boluses (expressed as units/d, units/kg DM and units/kg NDF). There was no effect of NFC source on total chewing time, idle time and time spent on other activities. Regarding *citrus* pulp processing, the GCP treatment decreased (*P* = 0.03) rumination time expressed as min/kg DM and min/kg NDF, with no changes (*P* = 0.44) when rumination was expressed as h/d. The GCP increased (*P* = 0.05) ingestion expressed as h/d, but there were no other differences between PCP and GCP (*P* > 0.05). In addition, grinding the *citrus* pulp also tended to decrease idle time (*P* = 0.08) and the number of ruminal boluses/day (*P* = 0.08) compared with pelleted *citrus* pulp.

Table 4. Ingestive behavior activities of heifers fed with different non-fiber carbohydrates and *citrus* pulp processing methods

Item	Treatments[1]			*SEM*[2]	*P*-value[3]	
	GC	PCP	GCP		NFC	PROC
Rumination (h/d)	7	6	6	0.20	<0.01	0.44
Rumination (min/kg of DM)	70	67	58	1.75	0.03	0.03
Rumination (min/kg of NDF)	252	227	197	6.80	<0.01	0.03
Ingestion (h/d)	4.00	4.60	5.34	0.20	<0.01	0.05
Ingestion (min/kg of DM)	36	55	53	2.40	<0.01	0.63
Ingestion (min/kg of NDF)	130	188	180	8.00	<0.01	0.60
TCT[4] (h/d)	11	10	11	0.14	0.51	0.10
Idle (h/d)	13	13	12	0.24	0.53	0.08
Other (h/d)	0.3	0.4	0.4	0.10	0.80	0.56
RC[5] (1,000 units/d)	26	19	20	0.91	<0.01	0.45
RC (1,000 units/kg of DM)	4	4	3	0.13	0.04	0.16
RC (1,000 units/kg of NDF)	15	13	11	0.50	<0.01	0.16
RB[6] (units/d)	446	298	353	17	<0.01	0.08
RB (units/kg of DM)	71	65	59	2.60	0.04	0.34
RB (units/kg of NDF)	258	219	198	9.50	0.01	0.33

[1]The treatments are diets containing ground corn (GC), pelleted *citrus* pulp (PCP) and ground *citrus* pulp (GCP).
[2]Standard error of the mean.
[3]Ground corn vs. *citrus* pulp contrast (NFC) and pelleted *citrus* pulp vs. ground *citrus* pulp contrast (PROC).
[4]TCT, total chewing time (Rumination + ingestion);
[5]RC, ruminating chews;
[6]RB, ruminal bolus.

Our hypothesis was that partial replacement of GC by PCP would decrease daily weight gain of heifers because of lower intake, and that grinding of *citrus* pulp would prevent the decrease in intake and performance. Corroborating our hypothesis, partial replacement of GC by CIP negatively affected the DMI and BW gain of the heifers, although the grinding of *citrus* pulp did not influence G: F, or the ADG. However, it increased feed intake and also tended to increase final BW, compared to pelleted *citrus* pulp. Differences among *citrus* pulp and corn diet compositions are due to the lower CP and EE contents of pelleted and ground *citrus* pulp compared to corn. Moreover, dietary protein also includes non-protein nitrogen source, with more

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urea included in *citrus* pulp diets to reduce variations in crude protein levels. However, this small variation may also have contributed to differences in crude protein intake and final body weight (FBW).

The expansion of *citrus* pulp after hydration by saliva and subsequently in the rumen, lowers the density of PCP and could result in higher rumen fill compared to GC possibly explaining the lower DMI for diets containing CIP (BAMPIDIS & ROBINSON, 2006). Similar results have been reported by Gouvêa et al. (2016), when replacing ground corn by CIP in different levels of inclusion in finishing diets containing 40% of corn. The authors reported that the inclusion of PCP above 50% of replacement of the corn decreased DMI and performance of Nellore bulls, while with lower levels of replacement, PCP substitution for corn increased DMI.

Although the grinding of *citrus* pulp did not influence neither the G:F ratio, nor the ADG, it increased the feed intake and also tended to increase final BW, compared to pelleted *citrus* pulp. The increase in intake with GCP happened because of changes in the ability of the animal to select diet ingredients. Whereas the PCP was easy to select in the bunk, the efficiency of particle selection decreases as the particle size is decreased by grinding. Another possible explanation for the selection against PCP could be lower diet palatability compared with GC. This may be because palatability has a major influence on dry matter intake in ruminants and the sense of taste is highly developed in cattle (HARPER et al., 2016). In the present study, however, grinding the *citrus* pulp seems to have alleviated the selection against CIP and, therefore, the effects of lower palatability on DMI.

The present study demonstrated that the selectivity indexes of the animals fed with GC and GCP (APS of the diet = 7.01 and 6.95 mm, respectively) were similar, and both were different from PCP (APS of the diet = 10.13 mm). Heifers selected against finer particles (<1.18 mm) when fed diets with ground ingredients, SI of 0.92, while heifers fed PCP were nearly neutral in sorting particle sizes, SI of 1.02. However, heifers selected against long particles (8-19 mm) when fed PCP, SI of 0.95, compared to those fed with the other two diets containing either ground corn or *citrus* pulp, SI of 1.07. This modification in diet selection was also apparent when analyzing the differences in chemical composition of the orts.

Several factors, such as density, texture, physical size of the pellet, and taste differences, affect the palatability of PCP (CRIBBS et al., 2015). However, particle size alone can explain variations in selectivity and intake. In a trial that tested diets with no *citrus* pulp, Zebeli et al. (2009) demonstrated that only decreasing the particle length of the corn silage was sufficient to modulate the selective consumption against longer particles and to improve dry matter intake of dairy cows. Similarly, a study conducted by Maulfair et al. (2010) evaluated diets with four particle sizes fed to lactating cows and, as the particle size of the diet increased, the animals refused the longer particles with greater intensity. In the same study, cows fed diets with the smallest geometric mean particle length (4 mm) exerted no sorting behavior. These results demonstrate that decreasing the particle size of the diet can be an effective method to reduce selectivity. Furthermore, less selection of the diet has positive effects on circadian energy intake by reducing the variation in the nutritive value of the ingested diet (HART et al., 2014).

Studies with dairy cows have shown that *citrus* pulp can replace part of the corn in

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the diet, reducing the risk of acidosis and stimulating rumination (BAMPIDIS & ROBINSON, 2006). In contrast, in beef cattle finishing diets with low-forage levels, Gouvêa et al. (2016) reported no effect on rumen pH when increasing the replacement of ground corn by *citrus* pulp. Minervino et al. (2014) fed adult sheep with concentrate containing *citrus* pulp, either ground or pelleted, and observed that the animals spent more time ruminating and less time resting when compared to ground corn diets, and there was no effect of grinding the *citrus* pulp on the feeding behavior. However, in that study, neither the inclusion of the ingredients in the concentrate nor feed intake were reported.

Time spent eating can be considered the main activity responsible for the amount of feed consumed (MISSIO et al., 2012). However, in the present study, heifers that received CIP spent more time eating per day but had lower DMI compared with the GC diets. Thus, this increased time spent eating can be explained by the selective behavior. When dry feeds are mixed, it generally separates into fine, high-density particles at the bottom of the feed bunk and long, lower density particles on top (LEONARDI & ARMENTANO, 2003). Large ruminants have little ability to nibble, therefore, they utilize their tongues to eat the fine particles and noses to push away the longer particles and sort the feed (BEAUCHEMIN, 1991a). In the present study, however, the time heifers spent eating per kg of dry matter or NDF was increased when fed CIP compared to GC.

In the present study, even though heifers were fed *ad libitum*, the CIP diets increased the time spent eating and, consequently, decreased time ruminating compared with GC diets. The length of time spent ruminating is reported to be directly correlated to the concentration of fiber in forage-based diets (KLEEFISCH et al., 2017). However, in the present study, the diets had 33.42% of forage on a DM basis and the treatments that contained CIP, with greater fiber content, decreased the time spent ruminating, compared with GC diets.

Chewing reduces the particle size of feed, which is a prerequisite for the passage of feeds from the fore stomach, but the extent of particle breakdown during chewing depends on the feed (BEAUCHEMIN, 1991b). With roughages, reduction of particle size usually reduces the number of the chews per kg of feed (FORBES, 2007). However, in the present study, there were no effects of particle size of the CIP on the number of chews per day or per kg of feed consumed. This parameter was reduced only when CIP replaced the GC, regardless of the processing method.

On the other hand, grain mastication and formation of ruminating boluses are related to the potential of the feed to be sufficiently covered with saliva, and the ease of deglutition. Non-processed grain, such as shelled corn, will be rapidly swallowed, as the reduction in the size of particles is not a factor of major importance in the mastication of this material. Grinding of corn and exposure of the starchy endosperm can increase the number of mastication chews because of the difficulty of insalivation necessary before deglutition (BEAUCHEMIN et al., 1994). Therefore, in the present study, the reduction in particle size of the CIP was not a factor of major importance on the number chews and ruminating boluses needed per day and per unit of feed consumed, but the difficulty to prepare the ground starchy corn for deglutition.

In conclusion, the negative effect on ground *citrus* pulp energy utilization was masked by the increase on feed intake

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that permitted greater average daily weight gain, in consequence of lower selection index.

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