SUGARCANE SILAGE TREATED WITH CALCIUM HYDROXIDE IN FEEDLOT CATTLE DIET: ANIMAL PERFORMANCE AND MEAT QUALITY[1]

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ABSTRACT - This study aimed to evaluate sugarcane (*Saccharum officinarum* L) silage treated with calcium hydroxide - $Ca(OH)_2$ - (slacked lime) as the only roughage source in a feedlot ration, regarding animal performance and meat quality. Forty five Canchim steers (22 months old, 345 kg body weight - BW) were assigned, in a complete randomized block design, to three treatments (total mixed rations - TMRs - with 35% roughage): T1- TMR with fresh sugarcane; T2 - TMR with sugarcane silage treated with calcium hydroxide (10 g $Ca(OH)_2$/kg of fresh forage); T3 - TMR with corn silage. Dry matter intake (DMI), digestible DM intake (DDMI), crude protein intake (CPI), feed efficiency (FE), average daily gain (ADG) and dressing percentage (DP) were evaluated. Meat was analyzed for quality parameters (pH, water holding capacity, cooking loss, color and shear force) and sensory attributes. Steers fed the silage treated with calcium hydroxide presented similar (P>0.05) DMI (10.8 kg DM/d), DDMI (8.5 kg/d) and DP (52.6%); higher CPI (1.8 vs. 1.4 kg/d) and lower (P<0.05) ADG (1.58 vs. 1.81 kg BW/d) and FE (0.15 vs. 0.17 kg BW/kg DMI) in comparison to those receiving corn silage. Compared to animals fed the fresh sugarcane, steers fed sugarcane silage treated with calcium hydroxide presented higher (P<0.05) DMI (10.9 vs. 9.4 kg DM/d), DDMI (8.7 vs. 7.4 kg/d), CPI (1.8 vs. 1.1 kg/d) and DP (52.7% vs. 51.2%) but similar (P>0.05) ADG and FE (1.5 kg BW/d and 0.15 kg BW/kg DMI, respectively). The different rations did not affect (P>0.05) meat quality parameters and sensory attributes, except for fat color and off flavor sensory attribute. It was concluded that calcium hydroxide can be indicated as an efficient additive for sugarcane ensilage. Feedlot cattle fed TMR containing sugarcane silage treated with Ca $(OH)_2$, as the only roughage source, presented adequate performance and meat quality.

Key words: dressing percentage, dry matter intake, feed efficiency, physicochemical analysis, sensory

DESEMPENHO E QUALIDADE DA CARNE DE NOVILHOS CONFINADOS ALIMENTADOS COM SILAGEM DE CANA-DE-AÇÚCAR TRATADA COM HIDRÓXIDO DE CÁLCIO

RESUMO: Este estudo teve como objetivo avaliar silagem de cana-de-açúcar (*Saccharum officinarum* L) tratada com hidróxido de cálcio - $Ca(OH)_2$ - (cal hidratada) como único volumoso em ração para confinamento de gado de corte, com respeito ao desempenho e qualidade da carne dos animais. Quarenta e cinco novilhos Canchim (22 meses de idade, 345 kg de peso vivo- PV) foram distribuídos, em um delineamento em blocos casualizados, em três tratamentos (rações totais - RTs - com 35% de volumoso): T1 - RT com cana-de-açúcar fresca; T2 - RT com silagem de cana-de-açúcar tratada com hidróxido de cálcio (10 g $Ca(OH)_2$/kg de forragem fresca); T3 - RT com silagem de milho. Foram avaliados o consumo de matéria seca (CMS), consumo de MS digestível (CMSD), consumo de proteína bruta (CPB), eficiência alimentar (EA), ganho médio diário (GMD) e rendimento de carcaça (RC). A carne foi avaliada quanto a parâmetros de qualidade (pH, capacidade de retenção de água, perdas no cozimento, cor e força de cisalhamento) e de análise sensorial descritiva. Os novilhos alimentados com a silagem de cana-de-açúcar tratada com hidróxido de cálcio apresentaram similares (P>0.05) CMS (10,8 kg/d), CMSD (8,5 kg/d) e RC (52,6%); mais alto (P<0.05) CPB (1,8 vs. 1,4 kg/d) e menor (P<0.05) GMD (1,58 vs. 1,81 kg PV/d) comparados aos que receberam silagem de milho. Comparados aos animais alimentados com cana-de-açúcar fresca, os novilhos alimentados com silagem de cana-de-açúcar tratada com hidróxido de cálcio apresentaram maior (P<0.05) CMS (10,9 vs. 9,4 kg MS/d), CMSD (8,70 vs. 7,4 kg/d), CPB (1,8 vs. 1,1 kg/d) e RC (52,7 vs. 51,2%), mas o GMD e EA foram similares (P>0.05) (1,5 kg PV/d e 0,15 kg PV/kg CMS, respectivamente). As diferentes rações não afetaram (P>0.05) os parâmetros de qualidade e os atributos sensoriais da carne, com exceção da cor da gordura e sabor estranho na carne. Concluiu-se que o hidróxido de cálcio pode ser indicado como um eficiente aditivo para a ensilagem da cana-de-açúcar. Animais alimentados com RT contendo silagem de cana-de-açúcar tratada com $Ca(OH)_2$, como única fonte de volumoso, apresentaram adequado desempenho e qualidade da carne.

Palavras chave: análises físico-químicas, consumo de matéria seca, eficiência alimentar, rendimento de carcaça, sensorial.

INTRODUCTION

The importance of sugarcane (*Saccharum officinarum* L) as cattle fodder in tropical countries is well established. Depending on herd size though, the daily harvesting becomes unpractical and ensilage of the forage is frequently used to facilitate management (Nussio et al., 2003). However, intense alcoholic fermentation in sugarcane silages causes extensive sugar loss and reduction in the silage's nutritive value, making it essential the use of additives in order to control yeasts and reduce losses during conservation (Alli et al., 1982).

The ensilage of sugarcane has frequently been unsuccessful due to the lack of efficient harvesting machinery and additives and the frequent use of poor-quality varieties. Nonetheless, significant improvements in equipment effectiveness and the availability of high quality and highly productive sugarcane varieties have led to an increase in the use of the technique, but more information on the efficiency of additives is still necessary.

Urea, sodium benzoate, bacterial inoculants and calcium hydroxide - $Ca(OH)_2$ (slaked lime) are among the most studied additives used in sugarcane ensilage (Siqueira et al., 2010; Siqueira et al., 2011).The use of calcium hydroxide or, sometimes, calcium oxide - CaO - has expanded based on the possibility of improving the forage's digestibility by fiber hydrolysis (Van Soest, 1994) and the positive effects obtained in some evaluations in which application of the additive reduced ethanol content and dry matter loss in the silage (Santos et al., 2008; Siqueira et al., 2011). Although the performance of beef cattle fed sugarcane silage treated with additives has been scarcely studied, adequate weight gains were observed by Roman et al. (2011) and Pedroso et al. (2011) when evaluating other additives. Nonetheless, animal performance was negatively affected when sugarcane silage treated with calcium oxide was used to feed European-Zebu (Girolando) crossbred male cattle in a study conducted by Magalhães et al (2012). Jacovaci et al (2017) carried out a data-analysis to evaluate the effects of calcium oxide on fermentation, aerobic stability and nutritive value of sugarcane silages, concluding that, although the additive improved the recovery of nutrients an aerobic stability, the resistance to pH drop was increased and the hygienic quality of the silages was worsened (increased enterobacteria and clostridia counts) what may have caused the lack of improvement in animal performance observed in the study. It must be considered though that those authors had a relatively small number of averages to be used in the data-analysis of animal performance in general (30 or less) and only nine averages for the analysis of daily live weight gain. Literature on the effects of feeding sugarcane silage, treated with calcium oxide/hydroxide on meat quality could not be found.

Considering the need to amplify the data base on the effectiveness of additives for sugarcane silage, calcium hydroxide was compared with urea + sodium benzoate (in three different combinations) and sodium propionate (in three dosages) in a preliminary trial (Pedroso et al., 2017). Fermentation parameters and losses were evaluated in a laboratory trial and the apparent digestibility of the treated silages was estimated with sheep. Considering the effectiveness in controlling alcoholic fermentation, reducing losses during ensilage and in preserving the forage's nutritional value, calcium hydroxide and urea combined with sodium benzoate were considered efficient additives, superior to sodium propionate.

The lack of data on the performance of beef cattle fed sugarcane silages treated with calcium hydroxide indicated the necessity of further studies. Consequently, this study was carried out to test the hypothesis that the beneficial effects of treating sugarcane silage with calcium hydroxide, such as the improvement in the forage's digestibility and reduction of yeast fermentation and losses during ensilage, overcome the negative aspects inherent to the ensiling process, making it a viable substitute for fresh sugarcane as the only roughage in feedlot rations. Silage treated with calcium hydroxide was compared with fresh sugarcane and corn silage, as a positive control, as components of TMRs (total mixed rations) for feedlot cattle, regarding animal performance and meat quality.

MATERIAL AND METHODS

This research was done in agreement with ethical principles of animal experimentation in accordance with the Institutional Animal Care and Use Committee Guidelines of EMBRAPA - Brazilian Agricultural Research Corporation - (Protocol 06/2009).

The feedlot trial was carried out at Embrapa Southeast Livestock's experimental feedlot, São Carlos, SP, Brazil (22º1′ S and e 47°53′ W, 853 m above sea level). The sugarcane used to produce the silage and to be given fresh to the animals was from the variety RB85-5536 (UFSCAR, Araras, SP), approximately 12 months old, second cut, 20.5 °Bx. The forage was mechanically harvested, with the harvester adjusted for a cut length between 5 and 10 mm, and ensiled in a pile (approximately 22 t). Calcium hydroxide - $Ca(OH)_2$ - (slacked lime) - was applied to the forage at ensiling in aqueous solution, using a sprayer (Hidrocana®, SP, Brazil) adapted to the harvester, aiming at a concentration of 10 g $Ca(OH)_2$/kg of fresh forage (FF) or 10 kg $Ca(OH)_2$/t FF. Calcium hydroxide was dissolved in water at the ratio of 20kg of calcium hydroxide per 60 L of water. The volume of this suspension amounted to 68 L which was applied at the rate of 34 L/t of forage. Corn at the half milk line stage (milk line positioned half-way between the tip and the base of the kernel) was mechanically harvested (at approximately 25 cm chop height), with a harvester adjusted for a cut length between 5 and 10 mm, and ensiled in a bunker. Both silages were stored for approximately nine months.

Forty five Canchim (3/8 Nelore + 5/8 Charolais) steers, 22 months old and 345 ± 7 kg of body weight - BW, in average, were assigned, in a completely randomized design, to three treatments (TMRs with different roughages): T1- TMR with fresh sugarcane; T2 -TMR with sugarcane silage treated with calcium hydroxide; T3 -TMR with corn silage. The TMRs (Table 1) were formulated according to NRC (1996) to be isoenergetic, providing the same average daily weight gain (ADG) between treatments, despite the small differences predicted for neutral detergent fiber (NDF) and crude protein (CP) contents in the diets (Table 2). The average values for the TMRs components were obtained in the literature. Animals were housed, individually, in 30 m² open dirt-floor pens and fed once a day (at 08:00 h, approximately). Refusals were quantified daily for adjustment of the next day feeding, allowing *ad libitum* consumption of the TMRs (10% refusals). The TMRs and silages were sampled every 14 days for chemical analysis. Samples of the different forages and TMRs were dried in an air forced dry oven (65°C, 72 h) for DM determination and posterior chemical analyses. Dried samples were grounded in a Wiley mill through a 1 mm screen and analyzed as follows: acid detergent fiber (ADF), neutral detergent fiber (NDF) and lignin according to Van Soest and Robertson (1985); DM, ash and crude protein (CP) according to AOAC (1997), methods number 934.01; 942.05 and 984.13, respectively. Calcium and P were analyzed according to Nogueira and Souza (2005). *In vitro* DM disappearance (IVDMD) was determined using the method proposed by Tilley and Terry (1963). The rumen fluid used in the IVDMD analysis was collected from rumen-fistulated Holstein dry cows receiving a daily ration of corn silage *ad libitum* and 2.0 kg of an 18% CP concentrate.

Table 1 - Composition of the experimental total mixed rations - TMRs

Components (% DM)	TMR T1	TMR T2	TMR T3
Forage	35	35	35
Ground corn	45	51	37.5
Soybean meal	-	12	-
Wheat bran	17	-	25
Urea	1.2	1.0	0.7
Limestone	0.8	-	0.8
Minerals	1.0	1.0	1.0
Total	100	100	100

T1= TMR with fresh sugarcane; T2 = TMR with sugarcane silage treated with calcium hydroxide (10 kg/t fresh forage); T3 = TMR with corn silage; DM - dry matter

Steers in the performance trial were dewormed and injected with an ADE vitamin supplement before the 10-d period of adaptation to the diets. Animals were weighed at the beginning and at the end of the 68-d experimental period, after 16 h of solid food fastening for the calculus of average daily

Table 2 - Expected composition of the experimental total mixed rations (TMRs) and respective ADG

TMR	NDF (% DM)	NEg (Mcal/kg DM)	TDN (% DM)	CP (% DM)	ADG (kg/d)
T1	27	1.11	72	12.1	1.75
T2	27	1.11	73	13.9	1.75
T3	30	1.11	72	13.0	1.75

T1 = TMR with fresh sugarcane; T2 = TMR with sugarcane silage treated with calcium hydroxide (10 kg/t fresh forage); T3 = TMR with corn silage; DM - dry matter; NDF - neutral detergent fiber; NEg - net energy for gain; TDN - total digestible nutrients; CP - crude protein; ADG - average daily weight gain.

weight gain (ADG). Daily dry matter intake (DMI) was calculated by difference between the DM weight in the amount of TMR fed and the DM weight in the refusals in each feed bunk. The IVDMD and CP contents of the TMRs and refusals were used to calculate the amount of digestible DM and CP offered to each animal daily and the amount not consumed (refusals) and, by difference, the digestible DM intake (DDMI) and CP intake (CPI). Feed efficiency (FE) was represented by the ratio of live-weight gain to dry matter intake of each animal during the 68-d experimental period.

Animals were shipped the day before slaughter to a commercial slaughterhouse and held overnight with access to water. Animals were slaughtered following the procedures of the Regulation of Industrial Inspection and Safety of Animal Products – RIISPOA (BRASIL, 1997). Carcasses were chilled overnight at 2°C. The dressing percentage (DP) was calculated by dividing the carcass weight (sum of the two half carcasses resulting from slaughter) by the BW of the animal and multiplying the result of this division by 100. At 24 hours *post mortem*, the left half-carcasses were cut between the 12 and 13th rib. The loin eye area (LEA) was evaluated in the *longissimus* muscle. The outer perimeter of the muscle was directly traced on tracing paper, and the loin eye area was measured using a plastic grid. Back fat thickness (BFT) was measured in the *longissimus* muscle using a ruler. Steaks 2.5 cm-thick were removed for quality (pH, water holding capacity, cooking loss, objective color and shear force) and sensory analyses at EMBRAPA's Meat Analysis Laboratory. Steaks for quality analysis (pH, objective color, cooking loss, water holding capacity and shear force) were immediately analyzed whereas steaks for sensory analyses were labeled, vacuum-packed and frozen at -18°C.

For color analysis, steaks were exposed to atmospheric oxygen for thirty minutes prior to the analyses and CIE L* (luminosity), a* (redness) and b* (yellowness) parameters were measured at three locations across the steak's surface using a Hunter Lab colorimeter model Mini Scan XE with Universal Software v. 4.10 (Hunter Associates Laboratory, Inc., Reston, VA, USA), illuminant D65 and observer 10°. The pH was then measured also at three locations across the steak's surface using a Testo pH measuring instrument, model 230 (Testo AG, Lenzkirch, Germany). Water holding capacity was obtained by the difference between the weights of a meat sample of approximately 2.0 g, before and after it was submitted to a pressure of 10 kgf for 5 minutes as described by Hamm (1986). For cooking loss and shear force measurements, the same steak of 2.5 cm thickness was weighed and cooked in a Tedesco combined oven, model TC 06 (Tedesco, Caxias do Sul, RS, Brazil), at 170°C until the temperature at the center of the sample reached 70°C, controlled by thermocouples linked to the FE-MUX software (Flyever, São Carlos, SP, Brazil). Samples were then cooled at room temperature and weighed again. Cooking loss was calculated by the difference between the weights before and after cooking, expressed as percentage. These steaks were transferred to a cooler and held for 24 hours, after which, eight cores, 1.27 cm in diameter, were removed per steak, parallel to the fiber grain. Peak shear force was determined on each core perpendicular to the fiber grain using a 1.016 mm Warner Bratzler probe in a TA.XT Plus Texture Analyzer (crosshead speed 200 mm/min and a 50 kg load cell, 40 mm distance, calibration weight 10 kg - Stable Micro Systems Ltd., Surrey, UK). Full peak shear force was recorded and maximum shear force was calculated as the average of the eight cores. For sensory evaluation, frozen steaks were placed in a refrigerator at 5°C overnight. The following day the steaks were cooked in a Tedesco combined oven, model TC 06 (Tedesco, Caxias do Sul, RS, Brazil), at 170°C, until reaching an internal temperature of 75°C. Each steak was cut into 1.5 cm cubes and each sample was randomly assigned to a ten-member trained taste panel. Samples were presented for each panelist in a balanced design assigned by Fizz Software version 2.41 (Biosystemes, Couternon, France). Samples were evaluated in a total of three sessions with eight samples per panelist in each of them. Attribute ratings were electronically collected using nine point descriptive scales for beef characteristic aroma/flavor (1 = extremely bland; 9 = extremely intense), strange aroma/flavor (1 = extremely intense; 9 = none), tenderness (1 = extremely tough; 9 = extremely tender) and juiciness (1 = extremely dry; 9 = extremely juicy).

Data related to animal performance and the meat quality trials were analyzed as completely randomized designs. Data were subjected to ANOVA by the GLM procedure of SAS (SAS Inst., Inc., Cary, NC), considering in the model the effect of treatments (sugarcane; sugarcane silage and corn silage) and the initial BW as a covariate ($Yij=\mu+ti+Xj+eij$). Differences among averages were tested using LSMEANS and the Tukey's test. Differences were declared significant if $P<0.05$.

RESULTS AND DISCUSSION

The ensilage process resulted in higher concentration of ADF, FDN and ash in the sugarcane silage's DM in comparison to the fresh sugarcane (Table 3). The increase in fiber components and ash in the silage was expected considering that the fermentation process of sugars by yeasts results in proximately 49% loss of the substratum as CO_2 and H_2O (McDonald et al., 1991). Yeast fermentation may consume up to 70% of the sugars originally present in sugarcane silages, increasing cell wall components and mineral concentrations, normally reducing the nutritional value of the silages (Pedroso et al., 2005). In this trial, the ensiling process of the sugarcane treated with calcium hydroxide caused only a 0.5% reduction in the forage's IVDMD compared with the fresh sugarcane, indicating that the application of the strong alkali was efficient in controlling alcoholic fermentation, avoiding the excessive loss of nutrients during ensilage, as observed by Cavali et al., 2010 and Siqueira et al., 2011. An increase in the IVDMD, from approximately 600 g/kg DM in the fresh sugarcane to 700 g/kg DM in the silage treated with 10 g CaO/kg FF was obtained by Santos et al. (2008), in this case showing the complementary effects of yeast control and fiber hydrolysis promoted by the additive, indicated, respectively, by the low ethanol concentration in the silage (3.8 g/kg DM) and the reductions in the forage's NDF and hemicellulose contents during the storage period. The higher calcium content obtained in the silage treated with calcium hydroxide, compared with the two other forages, was a direct consequence of the amount of additive applied to the forage at ensiling (10 kg $Ca(OH)_2$/t FF). As expected, the corn silage overall nutritional quality was superior in comparison to the other two forages.

Diet formulation was efficient in obtaining TMRs with small differences in IVDMD despite the differences in CP, ADF and lignin contents observed (Table 3). It is possible that the higher level of CP in the TMR produced with sugarcane silage compensated for its higher ADF content, resulting in IVDMD 1.8% higher compared with the other two TMRs. No reason could be identified though for the higher CP content in the TMR produced with sugarcane silage, considering that the CP content obtained for the forage (31.1g/kg DM) was within the expected range. The Ca content in the ration produced with silage treated with calcium hydroxide was approximately 36% higher ($P<0.05$) than in the TMRs produced with fresh sugarcane and corn silage. The Ca level in T2 (approximately 15g/kg DM) was at the limit considered as safe for growing and finishing cattle (NRC, 1996). Adequate utilization of calcium is affected not only by the amount of the mineral fed, but also by the Ca:P ratio in the diet, with a ratio of 1.5:1.0 being considered ideal and a range between 1:1 to 4:1 being acceptable (NRC, 2005). The Ca:P ratio obtained in the TMRs formulated with fresh sugarcane, sugarcane silage treated with calcium hydroxide and corn silage were 2:1, 3:1 and 1.6:1.0, respectively, therefore within the recommended limits.

Steers fed the TMR formulated with

Table 3. Chemical composition of the experimental forages and total mixed rations (TMRs)

Forages	DM	CP	ADF	NDF	Ash	Lig	Ca	P	IVDMD
	(g/kg FF)	(g/kg DM)							
Fresh sugarcane	312.0	30.4	321.3	523.3	24.1	64.9	1.8	0.41	588.2
Sugarcane silage[1]	319.5	31.1	399.6	609.1	59.0	65.2	21.7	0.48	585.3
Corn silage	358.8	76.4	269.0	451.3	32.1	32.1	1.7	2.34	725.9
T1	523.7	121.0	170.8	360.3	48.2	32.9	11.5	5.8	778.6
T2	543.6	162.1	192.1	375.9	53.7	27.4	15.1	5.2	793.7
T3	568.3	132.1	161.3	355.6	53.0	14.3	10.7	6.8	780.4

[1]Silage treated with calcium hydroxide (10 kg/t FF). T1: TMR with fresh sugarcane; T2: TMR with sugarcane silage treated with calcium hydroxide (10 kg/t FF); T3: TMR with corn silage; DM - dry matter; CP - crude protein; ADF - acid detergent fiber; NDF - neutral detergent fiber; Lig - lignin; IVDMD - *in vitro* dry matter disappearance; Ca - calcium; P - phosphorus; FF - fresh forage

sugarcane silage treated with calcium hydroxide and those receiving the ration with corn silage presented similar (P>0.05) DMI, DDMI, but the formulation with corn silage resulted in higher (P<0.05) final BW, 14.5% increase in ADG and 13.3% increase in FE (Table 4) compared with the sugarcane silage treatment, despite the higher CPI presented by the animals fed the sugarcane silage. Dressing percentages (DP) were similar in both treatments. Compared with the animals fed the fresh sugarcane, animals in the sugarcane silage treatment presented higher (P<0.05) DMI, DDMI and DP but similar (P>0.05) ADG and FE. The DDMI and CPI values obtained for the three treatments corresponded to what would be expected considering the IVDMD and CP content in the TMRs and the amount of ration DM consumed, indicating there was no sorting (selective consumption of individual feed components) of the TMRs.

The levels of ADG obtained with the fresh sugarcane and the sugarcane silage treated with calcium hydroxide (Table 5) were below the expected gain (1.75 kg/d), what may be credited to differences between the expected composition of the rations and the real composition obtained in the field. The predicted NDF content was 280 g/kg DM but the average NDF content obtained for those rations was 368 g/kg DM. Feeding the fresh sugarcane resulted in the lowest DMI, DDMI and CPI among treatments. The lower intake in this case may be credited to the normally low digestibility of NDF of fresh sugarcane. The higher intake observed for the ration prepared with sugarcane silage, in comparison to the ration prepared with the fresh sugarcane, indicates that calcium hydroxide must have exerted a positive effect over the forage's NDF during ensilage, improving its digestibility, as observed by Oliveira et al. (2007).

Feed efficiency is considered the best parameter in the evaluation of animal performance in feedlots. The similarity (P>0.05) in FE obtained for the animals fed the fresh sugarcane and those fed the sugarcane silage indicates that sugarcane silages treated with calcium hydroxide may be used as efficiently as fresh sugarcane in diets for feedlot cattle but both forages are expected to result in lower animal performance compared with corn silage (Table 4).

Considering the effects of sugarcane silages treated with other additives, some previous results were encouraging. Differently from the present study, Roman et al. (2011) observed similar ADG (1.3 kg/d) and FE (0.12 kg ADG/kg DM) for steers fed rations formulated with sugarcane silage treated with a bacterial inoculant (*L. buchneri*) or corn silage, despite the lower DMI (10.1 vs. 10.5 kg DM/d) and DP (52.7 vs. 54.0%) presented by the animals fed the sugarcane silage. The ADG of the animals in that study was lower than observed in this trial probably due to the lower TDN in the diets (654 to 683 kg/kg DM). Those researchers considered it feasible the use of sugarcane silage treated with additives in diets for finishing beef cattle. The viability of using sugarcane silages in feedlots was also indicated by Pedroso et al. (2011) who reported high ADG (average of

1.7 kg/d, approximately) for Canchim steers fed TMRs containing approximately 350 g/kg DM of sugarcane silages treated with urea + benzoate or *L. buchneri*.

Previous results of experiments with sugarcane silages treated with calcium oxide/ hydroxide were variable. Feeding sugarcane silage treated with calcium oxide had a negative impact on animal performance in a study by Magalhães et al (2012). When comparing diets formulated to have 120 g CP/ kg DM and using silage produced with 20ºBx sugarcane, conditions similar to the present study, those researchers obtained lower DMI (7.5 vs. 9.8 kg DM/d) and ADG (0.89 vs. 1.48 kg/d) for the diet containing sugarcane silage compared to the diet prepared with corn silage. It is possible to speculate that the dose of the additive in that experiment (5 g/kg FF) was ineffective in preserving the forage's nutrients during ensilage, considering that the chemical composition of the treated silage was not different from the silage without additive.

Table 4. Performance of Canchim steers fed total mixed rations (TMRs) containing different forages

Item	TMR			*SE*
	T1	T2	T3	
DMI (kg/d)	9.40[b]	10.88[a]	10.70[a]	1.27
DDMI (kg/d)	7.36[b]	8.74[a]	8.32[a]	0.98
CPI (kg/d)	1.12[c]	1.79[a]	1.42[b]	0.18
Initial BW (kg)	345.1	347.7	342.7	7.4
Final BW (kg)	445.6[b]	454.3[b]	470.0[a]	16.8
ADG (kg BW/d)	1.45[b]	1.58[b]	1.81[a]	0.25
FE (kg BW/kg DMI)	0.15[b]	0.15[b]	0.17[a]	0.02
DP (%)	51.24[b]	52.71[a]	52.45[a]	0.21

[a b c] Averages in the same row with different superscript differ by the Tukey's test (P<0.05). SE = standard error.
T1= TMR with fresh sugarcane; T2 = TMR with sugarcane silage treated with calcium hydroxide (10 kg/t FF); T3 = TMR with corn silage; DM - dry matter; DMI - dry matter intake; DDMI - digestible DM intake; CPI - crude protein intake; BW -body weight; ADG - average daily gain; FE - feed efficiency; DP -dressing percentage.

Chizzoti et al. (2015) evaluated diets (50:50 forage/concentrate ratio) containing silages treated with four levels of CaO (0, 5, 10 and 15 g/kg FF), in a performance trial involving 35 crossbred steers (Holstein x Nelore). Those authors observed a positive liner effect of CaO level on DM and NDF digestibility and a quadratic effect of CaO level on DM intake of the diets, with better results for the diet containing silage treated with 5 g CaO/kg FF. Dry matter intake (8.5 kg/d), ADG (0.89 kg BW/d) and FE (0.106 kg ADG/kg DMI) were reduced in that study, for the diet containing sugarcane silage treated with 10 g CaO/kg FF, in comparison to the present trial, most probably due to the lower level of crude protein in that diet (120 vs. 162g/kg DM),but it is also possible that the high Ca:P ratio in the diet(7.65:1), which was out of the range considered acceptable (1:1 to 4:1; NRC, 2005), negatively affected the results. Those researchers concluded that application of CaO in doses above 5 g/kg FF was not recommended. In the present experiment, the lower level of forage in the diet (35% in DM) allowed the use of a higher dose of the additive (10 g/kg FF) without exceeding the recommended Ca:P ratio in the diet.

Jacovaci et al (2017) carried out a data-analysis of results of twenty seven experiments (124 treatments) in which the effects of calcium oxide on fermentation, aerobic stability and nutritive value of sugarcane silage were evaluated. The analysis indicated that the additive improved the recovery of nutrients an aerobic stability but the resistance to pH drop was increased by the alkaline effect of CaO and the hygienic quality of the silages was worsened (increased enterobacteria and clostridia counts). It was observed that adding 10 g/kg of CaO (the most frequent dose in the data set) led to silages with 6.71 g/kg DM of butyric acid, what may have caused the lack of improvement in animal performance observed in the study. It is known that intake by livestock is reduced when fed silages with evidence of substantial clostridial activity (i.e., butyric acid at > 5 g/kg DM) (Muck, 1010). It must be considered though, that clostridia growth is restricted by a combination of a low pH (< 4.2) and a high DM level in the silage (> 300 g/kg FF) (McDonald et al., 1991) and, the lower the DM content in the ensiled forage, the lower the pH necessary to avoid clostridia activity (Muck, 2010). Thus, the high butyric acid content in the silages related in the referred

Table 5. Meat quality of Canchim steers fed total mixed rations (TMRs) containing different forages

Parameters	Diet			*SE*	*P*
	T1	T2	T3		
Rib-eye area (cm^{2})	68.56	70.95	69.94	9.49	0.753
Fat thickness (mm)	2.55	2.90	3.52	1.28	0.156
pH	5.55	5.59	5.60	0.08	0.235
Cooking loss (%)	24.77	23.86	26.60	4.41	0.257
Water holding capacity (%)	79.28	80.28	79.24	2.47	0.421
Initial meat color, 24h					
L*	40.50	41,61	40.76	1.74	0.350
a*	14.68	14.13	14.36	0.89	0.419
b*	13.29	13.27	13.07	1.04	0.842
Fat color					
L*	75.14	75.05	73.70	2.51	0.230
a*	7.11^{b}	7.58^{ab}	9.22^{a}	2.28	0.047
b*	17.40^{b}	17.78^{b}	20.21^{a}	2.33	0.005
Shear force (kgf/cm^{2})	6.82	7.24	6.85	1.96	0.846

$^{a\,b}$ Averages in the same row with different superscript differ by the Tukey's test (P<0.05). SE = standard error.
T1 = TMR with fresh sugarcane; T2 = TMR with sugarcane silage treated with calcium hydroxide (10 kg/t fresh forage); T3 = TMR with corn silage.

data-analysis study was most probably caused by a combination of delayed pH drop and low average DM content in the silages (237 g/kg FF). It contributes to this argument the fact that, in a previous evaluation, the application of calcium hydroxide (10 g/kg FF) during the ensilage of a mature sugarcane, which had high DM content (321 g/kg FF), did not result in a high level of butyric acid in the silage (0.07 g/kg DM) (Pedroso et al, 2017).

Diets had no effect (P>0.05) on meat quality characteristics except on fat color a* and b* parameters (P<0.05) (Table 5). Appearance of beef fat is determined mainly by the effect of carotene and hemoglobin concentration on yellowness (b*) and redness (a*), respectively. The chemical state of hemoglobin and the translucency of fat and connective tissue also affect fat color (Irie, 2001). Fat from the animals fed corn silage had higher red (a*) and yellow (b*) values. An increase in the concentration of carotenoids increases yellowness (Daley et al., 2010). In this study, yellowness (b*) was higher in meat fat from the animals fed corn silage. Corn silage has been found to have a higher concentration of carotenoids than ground corn (Pickworth et al., 2012), what explain this result even with a higher concentration of ground corn in the other TMRs.

There was an effect (P<0.05) of diet on the "strange flavor" sensory attribute (Table 6). Meat from the animals fed fresh sugarcane received a lower value (8.0) for this attribute, which corresponds to "very bland", in comparison to the meat from the animals fed sugarcane silage, which received a 8.6 value, next to "none" (no strange flavor). Meat from animals fed corn silage was not different (P>0.05) from the meat of the two other treatments in this aspect. Diet had no effect on "characteristic beef aroma/ flavor", "strange aroma", "tenderness" and "juiciness" sensory attributes. In previous studies comparing diets containing corn silage or fresh sugarcane fed to Canchim or Hereford animals, no difference was found in sensory and other meat characteristics, such as rib-eye area, fat thickness, pH, water holding capacity, shear force and cooking loss (Fernandes et al., 2008; Vaz and Restle, 2005). In those studies, sensory characteristics were described only as "flavor" and different scales and trained panels were used, making it difficult the comparison with the results obtained in this study. The fatty acid composition of meats is significantly correlated with meat flavor (Melton et al., 1982; Larick and Turner, 1990) and differences

Table 6. Sensory analysis of meat from Canchim steers fed total mixed rations (TMRs) containing different forages

Attributes	Diet			*SE*	*P*
	T1	T2	T3		
Characteristic beef aroma	5.5	5.3	5.5	0.65	0.46
Strange aroma intensity	8.5	8.3	8.5	0.23	0.27
Characteristic beef flavor	5.1	4.9	5.0	0.58	0.53
Strange flavor intensity (off-flavor)	8.0^{b}	8.6^{a}	8.5^{ab}	0.38	0.02
Tenderness	4.7	5.5	5.7	1.23	0.17
Juiciness	5.3	5.3	5.5	0.54	0.61

$^{a\,b}$ Averages in the same row with different superscript differ by the Tukey's test (P<0.05); SE = standard error.
Characteristic beef aroma/flavor (1 = extremely bland; 9 = extremely intense); Strange aroma/flavor (1 = extremely intense, 9 = none); Tenderness (1 = extremely tough; 9 = extremely tender) and Juiciness (1 = extremely dry; 9 = extremely juicy). T1 = TMR with fresh sugarcane; T2 = TMR with sugarcane silage treated with calcium hydroxide (10 kg/t fresh forage); T3 = TMR with corn silage.

in diet composition, mainly between the diets based on sugarcane silage and fresh sugarcane, might have led to the differences observed in the beef "off-flavor" attribute.

CONCLUSIONS

Sugarcane silage treated with calcium hydroxide is a viable substitute for fresh sugarcane, when formulating diets for feedlot cattle, resulting in comparable animal performance, without negative effects on quality parameters and sensory attributes of the meat. Both ensiled and fresh sugarcane result in inferior animal performance in comparison to corn silage, when used as the sole forage source in feed lot cattle rations.

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REFERENCES

ALLI, I.; BAKER, B.E.; GARCIA, G. Studies on the fermentation of chopped sugarcane. **Animal Feed Science and Techonogy**, v.7, p.411-417, 1982. https://doi.org/10.1016/0377-8401(82)90010-4

AOAC - ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. **Official methods of analysis of AOAC International**. 16thed. Gaithersburg, MD: AOAC, 1997.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal: Decreto nº 30.691, de 29 de março de 1952, alterado pelo Decreto 1255 de 25 de junho de 1962. Alterado pelo Decreto 2244 de 04/06/1997. **Diário Oficial da União**, Brasília-DF, junho de 1997.

CAVALI, J.; PEREIRA, O.G.; VALADARES FILHO, S.C.; SANTOS, E.M.; CARVALHO, G.G. P; SANTOS, M.V.; PORTO, M.O.; RODRIGUES, J.F.H. Bromatological and microbiological characteristics of sugarcane silages treated with calcium oxide. **Revista Brasileira de Zootecnia**, v, 39, p.1398-1408, 2010. https://doi.org/10.1590/s1516-35982010000700002

CHIZZOTTI, F.H.M.; PEREIRA, O.G.; VALADARES FILHO, S.C.; CHIZZOTTI, M.L.; RODRIGUES, R.T.S.; TEDESCHIC, L.O.; SILVA, T.C. Does sugar cane ensiled with calcium oxide affect intake, digestibility, performance, and microbial efficiency in beef cattle? **Animal Feed Science and Technology**, v.203, p.23-32, 2015. https://doi.org/10.1016/j.anifeedsci.2014.12.014

DALEY, C.; ABBOTT, A; DOYLE, P; NADER, G.; LARSON, S. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. **Nutrition Journal**, v.9, 2010. https://doi.org/10.1186/1475-2891-9-10

FERNANDES, A.R.M.; SAMPAIO, A.A.M.; HENRIQUE, W.; OLIVEIRA, E.A.; TULLIO, R.R.; PERECIN, D. Características da carcaça e da carne de bovinos sob diferentes dietas, em confinamento. **Arquivo Brasileiro de**

Medicina Veterinária e Zootecnia, v.60, p.139-147, 2008. https://doi.org/10.1590/s0102-09352008000100020

HAMM, R. Functional properties of the myofibrillar system and their measurement. In: BECHTEL, P.J. **Muscle as food.** Orlando: Academic Press, 1986. p.135-199. https://doi.org/10.1016/b978-0-12-084190-5.50009-6

IRIE, M. Optical evaluation of factors affecting appearance of bovine fat. **Meat Science**, v.57, p.19-22, 2001. https://doi.org/10.1016/s0309-1740(00)00069-3

JACOVACI, F.A.; JOBIM, C.C.; SCHMIDT, P.; NUSSIO, L.G.; DANIEL, J.L.P. A data-analysis on the conservation and nutritive value of sugarcane silage treated with calcium oxide. **Animal Feed Science and Technology**, v.225, p.1-7, 2017. https://doi.org/10.1016/j.anifeedsci.2017.01.005

LARICK, D.K.; TURNER, B.E. Flavor characteristics of forage and grain-fed beef as influenced by phospholipid and fatty acid compositional differences. **Journal of Food Science**, v.55, p.312-317, 1990. https://doi.org/10.1111/j.1365-2621.1990.tb06751.x

MAGALHÃES, F.A.; VALADARES FILHO, S.C.; MENEZES, G.CC.; GIONBELLI, M.P.; ZANETTI, D.; MACHADO, M.G.; PINA, D.S.; KOMURA, K. Intake and performance of feedlot cattle fed diets based on high and low Brix sugar cane with or without calcium oxide and corn silage. **Revista Brasileira de Zootecnia**, v.41, p.1499-1508, 2012. https://doi.org/10.1590/s1516-35982012000600026

MCDONALD, P.; HENDERSON, A.R.; HERON, S.J.E. **The biochemistry of silage**. 2.ed. Marlow, [UK]: Chalcomb Publ., 1991. 340 p.

MELTON, S.L.; AMIRI, M.; DAVIS, G.W.; BACKUS, W.R. Flavor and chemical characteristics of ground beef from grass, forage-grain and grain-finished steers. **Journal of Animal Science**, v.55, p.77-87, 1982. https://doi.org/10.2527/jas1982.55177x

MUCK, R.E. Silage microbiology and its control through additives. **Revista Brasileira de Zootecnia**, v.39 (Suppl. spe), p.183-191, 2010. https://doi.org/10.1590/s1516-35982010001300021

NOGUEIRA, A.R.A.; SOUZA, G.B. **Manual de Laboratório:** Solo, água, nutrição vegetal, nutrição animal e alimentos. São Carlos: Embrapa Pecuária Sudeste, 2005. 313p.

NRC - NATIONAL RESEARCH COUNCIL. **Mineral Tolerance of Animals**. 2.ed. rev. Washington, DC.: National Academy Press, 2005.

NRC - NATIONAL RESEARCH COUNCIL. **Nutrient requirements of beef cattle**. 7.ed. Washington, D.C.: National Academy Press, 1996.

NUSSIO, L.G.; SCHMIDT, P.; PEDROSO, A.F. Silagem de cana-de-açúcar. In: SIMPÓSIO DE PASTAGENS, 20., 2003, Piracicaba. **Anais...** FEALQ: USP/ESALQ, 2003. p. 100-150. Disponivel em: < https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/46603/1/PROCI2003.00077.pdf >

OLIVEIRA, M.D.S.; ANDRADE, A.T.; BARBOSA, J.C.; SILVA, T.M.; FERNANDES, A.R.M.; CALDEIRÃO, E.; CARABOLANTE, A. Digestibilidade da cana-de-açúcar hidrolisada, in natura e ensilada para bovinos**. Ciência Animal Brasileira**, v.8, n.1, p.41-50, 2007.

PEDROSO, A.F.; ESTEVES, S.N.; BARIONI JUNIOR,W.;Souza,G.B.Chemicalcomposition, fermentation profile and apparent digestibility of sugarcane silage treated with chemical additives. **Boletim de Indústria Animal**, v.74, p.182-194, 2017. https://doi.org/10.17523/bia.v74n3p182

PEDROSO, A.F.; NUSSIO, L.G.; PAZIANI, S.F.; LOURES, D.R.S.; IGARASI, M.S.; COELHO, R.M.; PACKER, I.H.; HORII, J.; GOMES. L.H. Fermentation and epiphytic microflora dynamics in sugar cane silage. **Scientia Agricola**, v.62, n.5, p.427-432, 2005. https://doi.org/10.1590/s0103-90162005000500003

PEDROSO, A.F.; RODRIGUES, A.A.; BARIONI JUNIOR, W.; BARBOSA, P.F.; SANTOS, F.A.P.;

NUSSIO, L.G. Aditivos químicos e inoculante bacteriano na ensilagem de cana-de-açúcar: efeitos sobre a fermentação das silagens e o desempenho de garrotes. **Revista Brasileira de Zootecnia**, v.40, p.1181-1187. 2011. https://doi.org/10.1590/s1516-35982011000600004

PICKWORTH, C. L., LOERCH, S. C., KOPEC, R. E., SCHWARTZ, S. J., FLUHARTY, F. L. Concentration of pro-vitamin A carotenoids in common beef cattle feedstuffs. **Journal of Animal Science**, v.90, p. 1553-1561. 2012. https://doi.org/10.2527/jas.2011-4217

ROMAN, J.; JOBIM, C.C.; RESENDE, F.D.; SIQUEIRA, G.R.; FARIA, M.H.; OLIVEIRA NETO, R.A. Performance of finishing beef cattle fed different diets containing whole-crop maize silage or sugarcane silage. **Revista Brasileira de Zootecnia**, v.40, p.682-689, 2011. https://doi.org/10.1590/s1516-35982011000300029

SANTOS, M.C.; NUSSIO, L.G.; MOURÃO, G.B.; SCHMIDT, P.; MARI, L.J.; RIBEIRO, J.L. Influência da utilização de aditivos químicos no perfil da fermentação, no valor nutritivo e nas perdas de silagens de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.37, p.1555-1563, 2008. https://doi.org/10.1590/s1516-35982008000900006

SAS INSTITUTE INC. **System for Microsoft Windows**. Release 9.3. Cary, NC, USA: SAS Institute, 2010. CD-ROM.

SIQUEIRA, G.R.; REIS, R.A.; SCHOCKEN-ITURRINO, R.P.; PIRES, A.J.V.; BERNARDES, T.F.; ROTH, M.T.P. Queima e aditivos químicos e bacterianos na ensilagem de cana-de-açúcar. **Revista Brasileira de Zootecnia**, v.39, n.1, p.103-112, 2010. https://doi.org/10.1590/s1516-35982010000100014

SIQUEIRA, G.R.; SCHOCKEN-ITURRINO, R.P.; ROTH, A.P.T.P.; DOMINGUES, F.N.; FERRAUDO, A.S.; REIS, R.A. Óxido de cálcio e *Lactobacillus buchneri* NCIMB 40788 na ensilagem de cana-de-açúcar *in natura* ou queimada. **Revista Brasileira de Zootecnia**, v.40, p.2347-2358, 2011. https://doi.org/10.1590/s1516-35982011001100010

TILLEY, J.M.A.; TERRY, R.A. A two-stage Technique for the in vitro Digestion of Forage Crops. **Journal of the British Grassland Society**, v.18, n.2, p.104-111, 1963. https://doi.org/10.1111/j.1365-2494.1963.tb00335.x

VAN SOEST, P.J. **Nutritional Ecology of the Ruminant**. 2.ed. Ithaca, NY, USA: Cornell University Press, 1994.

VAN SOEST, P.J.; ROBERTSON, J.B. **Analysis of forages and fibrous foods**. Ithaca, NY, USA: Cornell University Press, 1985.

VAZ, F.N.; RESTLE, J. Características de carcaça e da carne de novilhos Hereford terminados em confinamento com diferentes fontes de volumoso. **Revista Brasileira de Zootecnia**, v.34, p.230-238, 2005. https://doi.org/10.1590/s1516-35982005000100027