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Performance of Holstein x Gyr dairy cows fed hydrolyzed sugarcane-based diets

Desempenho de vacas Holandês x Gir alimentadas com dietas baseadas em cana de açúcar hidrolisada

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Abstract

Twelve multiparous 7/8 Holstein x Gyr dairy cows were fed diets based on chopped sugarcane supplied *in natura* (control) or after being hydrolyzed (fresh matter basis) for 24 h with 0.5%, 1% or 2% calcium oxide (CaO). The voluntary consumption and digestibility of dietary nutrients, milk production and composition, and feeding behavior of cows were evaluated. A switchback design with three periods, four treatments and three blocks was used. The linear and quadratic effects of the treatments were analyzed using orthogonal contrasts, and the effects were considered significant when $P \leq 0.05$. Compared to the that in the control treatment, the Ca concentration increased by 297%, 570% and 1,083% in the diets including sugarcane hydrolyzed with 0.5%, 1% and 2% CaO, respectively, while the respective Ca:P ratios were 6.58:1, 10.70:1 and 19.77:1 (control Ca:P ratio: 1.55:1). The hydrolysis of sugarcane with increasing amounts of CaO promoted a linear reduction ($P < 0.01$) in the intake of dry matter (DM), nonfibrous carbohydrates, crude protein (CP), organic matter (OM), neutral detergent fiber corrected for ash and protein (NDFap) and ether extract. The intake of total digestible nutrients, acid detergent fiber (ADF), lignin, hemicelluloses and cellulose presented quadratic behavior ($P < 0.01$) in response to increasing CaO concentrations used for sugarcane hydrolysis. Increases in the amount of CaO used for sugarcane hydrolysis had no effect on the digestibility of NDFap ($P > 0.05$), but there were linear reductions ($P < 0.05$) in the digestibility of DM, OM and ADF; the production of milk corrected or not corrected to 4% fat; and the content of protein, lactose and total solids. Linear reductions ($P < 0.05$) were also observed in the production of all milk components. Only the milk fat content was not altered ($P > 0.05$) in response to the inclusion of hydrolyzed sugarcane in the diets. There was no effect ($P > 0.05$) of sugarcane hydrolysis with increasing amounts of CaO on the time the cows spent idle, ruminating and feeding, but there was a linear increase ($P < 0.05$) in the minutes spent ruminating 1 kg of DM and NDF. Chopped sugarcane hydrolyzed for 24 h with 0.5% to 2.0% CaO should not be used as exclusive roughage in diets for Holstein x Gyr dairy cows with an average milk production of 10 kg day^{-1}.

Key words: Alcali. Bovine. Calcium oxide. Digestibility. Feeding behavior. *Saccharum officinarum*.

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Resumo

Doze vacas multíparas 7/8 Holândês x Gir foram alimentadas com dietas à base de cana de açúcar picada fornecida *in natura* (controle) ou hidrolisada (base da matéria natural) por 24 h com 0,5%, 1% ou 2% de óxido de cálcio (CaO). O consumo voluntário e a digestibilidade dos nutrientes das dietas, a produção e composição do leite, e o comportamento alimentar das vacas foram avaliados. Um delineamento em *switchback* com três períodos, quatro tratamentos, e três blocos foi utilizado. Os efeitos linear e quadrático dos tratamentos foram analisados por contrastes ortogonais e diferenças foram consideradas significativas quando $P \leq 0,05$. Em comparação ao tratamento controle foram observados aumentos de 297%, 570% e 1.083%, respectivamente, nas concentrações de Ca nas dietas com cana de açúcar hidrolisada com 0,5%, 1% e 2% de CaO, enquanto que as respectivas proporções de Ca:P nas dietas foram de 6,58:1, 10,70:1 e 19,77:1 (controle = 1,55:1). A hidrólise da cana de açúcar com quantidades crescentes de CaO promoveu redução linear ($P < 0,01$) sobre os consumos de matéria seca (MS), carboidratos não fibrosos, proteína bruta (PB), matéria orgânica (MO), fibra em detergente neutro corrigida para cinzas e proteína (FDNcp) e extrato etéreo. Os consumos de nutrientes digestíveis totais, fibra em detergente ácido (FDA), lignina, hemiceluloses e celulose apresentaram comportamento quadrático ($P < 0,01$) em resposta ao aumento na inclusão de CaO na hidrólise da cana de açúcar. O incremento na quantidade de CaO na hidrólise da cana de açúcar não promoveu efeito sobre a digestibilidade da FDNcp ($P > 0,05$), mas houve reduções lineares ($P<0,05$) nas digestibilidades da MS, MO e FDA, bem como na produção de leite corrigida ou não para 4% de gordura, e nos teores de proteína, lactose e sólidos totais. Também houve reduções lineares ($P < 0,05$) nas produções de todos os componentes do leite, incluindo a gordura, cujo teor, no entanto, não foi alterado ($P > 0,05$) em resposta à inclusão de cana hidrolisada nas dietas. A hidrólise da cana de açúcar com quantidades crescentes de CaO não alterou ($P > 0,05$) os tempos despendidos pelas vacas em ócio, ruminação e alimentação, mas promoveu incremento linear ($P < 0,05$) sobre os tempos gastos com a ruminação de 1 kg de MS ou de FDN. A cana de açúcar picada e hidrolisada por 24 h com 0,5% a 2,0% de CaO não deve ser utilizada como volumoso exclusivo em dietas de vacas Holandês x Gir com produção de leite média de 10 kg dia^{-1}.

Palavras-chave: Álcali. Bovino. Comportamento alimentar. Digestibilidade. Óxido de cálcio. *Saccharum officinarum*.

Introduction

The high production of dry matter (DM) of forage and a high content of soluble carbohydrates (sucrose) during the seasonal period of growth in tropical pastures makes sugarcane (*Saccharum officinarum*, L.) an important roughage resource for feeding cattle in milk production systems in Brazil (CASTRO et al., 2009; RESENDE; LEITE, 2016; CAMPOS et al., 2017).

However, sugarcane presents nutritional limitations that restrict its use as an exclusive ingredient in the diet of high-producing ruminants, such as the low crude protein (CP) content in the DM of sugarcane forage (CAMPOS et al., 2017), which is on average 2.66% (VALADARES FILHO et al., 2010). The inclusion of nonprotein nitrogen sources, such as 1% urea (in fresh chopped sugarcane basis), in diets with 50% concentrates is a nutritional alternative for correcting the CP content of sugarcane, which, in addition to promoting a reduction in the costs of feeding cows, allows average milk yields of 22 kg day^{-1} to be reached (SOUZA et al., 2015).

The neutral detergent fiber (NDF) content of sugarcane, which is on average 54.5% DM (VALADARES FILHO et al., 2010), may be considered moderate when compared to the NDF content of forages of other tropical grasses (RIBEIRO et al., 2015; CAMPOS et al., 2017). However, sugarcane presents a comparatively high content of rumen-undegradable NDF that promotes a low ruminal digestion rate of the potentially degradable NDF (SANTOS et al., 2011). These fractions have a

strong effect on rumen fill, being responsible for the observed reduction in the voluntary consumption of sugarcane-based diets, with a negative impact on the productive performance of cows (CORRÊA et al., 2003; SANTOS et al., 2011).

Potentially, hydrolysis with alkalinizing agents such as sodium hydroxide (NaOH), calcium hydroxide ($Ca(OH)_2$) and calcium oxide (CaO) may promote an increase in the digestibility of the fibrous fraction of sugarcane and consequently in the voluntary consumption of sugarcane-based diets, resulting in greater availability of nutrients for maintenance and production. In theory, these alkalis promote the breakdown of the cell wall and the partial solubilization of hemicelluloses, lignin and silica through the hydrolysis of uronic esters and acetic acid and the swelling of cellulose (JACKSON, 1977).

Only five studies have compared the effects of chopped sugarcane supplied *in natura versus* hydrolyzed on the voluntary consumption of nutrients and on the production and composition of cow's milk (CARVALHO, 2008; SFORCINI, 2009; ALVES et al., 2010; SILVA JÚNIOR et al., 2015; TEIXEIRA JUNIOR et al., 2015). Irrespective of the dose and the alkalizing agent used (0.5% to 1% $Ca(OH)_2$ or 0.5% to 2.25% CaO), there was no effect of the chemical treatment of sugarcane on the DM intake of the diets. On the other hand, there was an increase in the milk yield of cows fed diets based on sugarcane hydrolyzed for 72 h with 0.5% CaO (SFORCINI, 2009) or for 24 h with 1% $Ca(OH)_2$ (ALVES et al., 2010). Only Sforcini (2009) reported a difference in milk composition with the use of hydrolyzed sugarcane; the protein content was lower in the milk of cows that received sugarcane hydrolyzed for 72 h with 0.5% CaO. Thus, in view of the divergence of results, further studies on the supply of diets based on hydrolyzed sugarcane to lactating cows are necessary.

The aim of this study was to evaluate the voluntary consumption and digestibility of nutrients, the feeding behavior, and the milk production and composition of Holstein x Gyr dairy cows fed diets based on chopped sugarcane supplied *in natura* or hydrolyzed with 0.5%, 1% or 2% CaO.

Material and Methods

The study was carried out at Embrapa Dairy Cattle in Valença (RJ), Brazil. All experimental procedures with animals were carried out according to Embrapa Dairy Cattle guidelines for animal care and use in research.

A switchback design with three periods, four treatments, three blocks and twelve multiparous 7/8 Holstein x Gyr dairy cows past the peak of lactation was used. At the beginning of the experiment, the cows were producing an average of 12.1±3.0 kg day^{-1} of milk and weighed 484±50 kg. Each period comprised 21 days, with 14 and seven days, respectively, for adaptation to the diets and data collection. The cows were homogeneously allocated to the treatments and blocks based on milk production, days in milk and body weight as measured in the pre-experimental period. The animals were kept in tie stalls, each equipped with an individual trough and automatic drinking water fountain.

Four diets based on chopped sugarcane were evaluated as the only roughage (Table 1). The sugarcane was supplied *in natura* (control) or was first hydrolyzed (fresh matter basis) for 24 h with 0.5%, 1% or 2% CaO. The CaO was supplied by Ical (Indústria de Calcinação Ltda., Felixlândia, MG, Brazil) in microprocessed form with low levels of dioxins, furans and magnesium.

A concentrated supplement of 1 kg for every 10 kg of sugarcane (fresh matter basis) was provided in a total mixed ration (TMR). The diet was provided to the animals twice a day, at 08h00 and 15h00, and it was adjusted to allow for 15% orts on an as-fed basis, based on the intake of the previous day. The concentrate supplied had the following ingredient

composition (as fed): 50% soybean meal, 42% corn meal, 5% urea:ammonium sulfate mixture (9:1), and 3% mineral supplement. The macro- and micromineral concentrations of the mineral supplement and of CaO are shown in Table 2. The RB-73-9735 variety of sugarcane was used, which has an average productivity of forage (fresh matter) of over 150 t ha^{-1} $year^{-1}$, medium/late maturation, medium tillering and rare flowering (RESENDE; LEITE, 2016). The sugarcane presented a mean Brix value of 22°. The formulation of the experimental diets was based on the nutritional requirements of the cows, determined according to the NRC (2001).

Table 1. Chemical composition of the diets expressed in percentage of dry matter (% DM).

Nutrient (% DM)	% CaO added to sugarcane (fresh matter basis)			
	0.0	0.5	1.0	2.0
Dry matter (%, fresh basis)	33.18	33.38	34.52	35.34
Organic matter	88.63	85.30	83.29	80.10
Ether extract (EE)	1.40	1.33	1.13	0.98
Nonfibrous carbohydrates (NFC)[1]	46.13	43.33	42.91	41.22
NDFap[2]	31.75	32.02	30.95	29.92
Acid detergent fiber	23.27	19.53	20.77	19.84
Lignin	4.71	3.39	4.03	3.62
Cellulose	18.57	16.14	16.74	16.22
Hemicelluloses	9.72	14.37	12.07	12.67
Crude protein (CP)	9.35	8.63	8.30	7.99
Mineral matter (MM)	11.37	14.70	16.71	19.90
Calcium (Ca)	0.30	1.19	2.01	3.55
Phosphorus (P)	0.19	0.18	0.20	0.20
Ratio Ca:P	1.55	6.58	10.70	19.77

[1]NFC = 100 - (%NDFap + %CP + %EE + %MM), according with Weiss (1999).
[2]NDFap = Neutral detergent fiber corrected for ash and protein.

Table 2. Mineral composition of the mineral supplement and calcium oxide (CaO).

Item	Macromineral (% DM)				Micromineral (ppm)			
	Ca	Mg	P	K	Cu	Zn	Fe	Mn
Mineral supplement	9.6	1.0	8.7	0.08	1,254	4,228	5,258	427
CaO	44.5	0.3	2.9	0.05	41	73	1,388	128

Ca = Calcium; Mg = Magnesium; P = Phosphorus; K = Potassium; Cu = Copper; Mn = Manganese; Fe = Iron and Zn = Zinc.

From the 15th to the 20th day of each switchback period, the voluntary intakes of each cow were measured as the difference between the daily quantities supplied and their individual orts. Samples of the TMR from each treatment were collected twice a day (before the morning and afternoon feedings) and stored (−10°C) until chemical analysis. In addition, samples of the individual orts were collected daily in the morning and stored (−10°C). After thawing, the feed and orts samples were dried in a forced-ventilation oven (55°C) for 72 h and ground through a 1 mm screen (Wiley Mill;

A. H. Thomas, Philadelphia, PA, USA). Feces and orts were pooled per animal by daily weight based on the 55°C DM.

Individual fecal DM production was estimated using chromic oxide - Cr_2O_3 (Óxido de Cromo III Puríssimo - Código 841, Vetec Química Fina Ltda., Duque de Caxias, RJ, Brazil) as an external marker at a rate of 12 g cow^{-1} day^{-1}, administered orally and wrapped in paper for 11 days in two doses of 6 g each immediately after the milking. During the last five days of Cr_2O_3 administration, fecal samples were individually collected by rectal grabbing twice a day after the milking and stored (−10°C) until chemical analysis. At the end of the experiment, the fecal samples were thawed, predried (55°C, 72 h), milled (5 mm), and then pooled by cow x switchback period based on predried DM. Afterwards, the composite fecal samples were ground again to pass through a 1 mm screen and stored for later analysis of Cr content using atomic absorption spectrophotometry according to the INCT-CA M-005/1 method (DETMANN et al., 2012). Fecal DM production was determined by the ratio between the amount of the marker administered to the cow (g day^{-1}) and its concentration in fecal DM, expressed as g kg^{-1} (LOPES, 2007).

The samples of TMRs, orts and feces were analyzed in the Laboratory of Food Analysis of Embrapa Dairy Cattle (Juiz de Fora, MG, Brazil) for the contents of DM (at 105°C), crude protein (CP), ether extract (EE), mineral matter (MM), neutral detergent insoluble nitrogen (NIDN), NDF, acid detergent fiber (ADF) and lignin, and NDF corrected for ash and protein (NDFap), according to the methods described by Detmann et al. (2012). To analyze the calcium (Ca) and phosphorus (P) contents, a mineral solution was prepared according to the methodology described by Silva and Queiroz (2002). The Ca and P contents in these samples were determined in an atomic absorption spectrophotometer.

The *in vivo* digestibility coefficients of DM, organic matter (OM), NDFap and ADF were calculated, as described by Berchielli et al. (2011).

Cows were mechanically milked twice a day (07h00 and 14h00), and milk production was recorded for five consecutive days from the 15th to the 19th day of each switchback period. On the 15th and 16th day of each switchback period, aliquots of milk from each milking (2/3 at morning milking + 1/3 at afternoon milking) were collected to compose individual samples (30 mL) that were stored in flasks with bronopol preservative for subsequent analysis of protein, fat, lactose and total solids content via medium infrared spectrometry (Bentley 2300; Bentley Instruments Inc., Chaska, MN, USA) in the Milk Quality Laboratory of Embrapa Dairy Cattle (Juiz de Fora, MG, Brazil).

On the 17th day of each switchback period, the feeding behavior of the cows was examined. The time spent feeding, ruminating and idle was assessed by visual observation for 24 h in 10-minute intervals (OLIVEIRA et al., 2007), and mean values were obtained for each activity. During the night, the feeding behavior of the cows was observed while keeping the environment under artificial lighting.

The results were analyzed according to a switchback design with four treatments and 12 cows in three blocks using the general linear model procedure of SAS v. 9.0. The model included effects for block, cow within block, period (linear) by cow within block, period (class variable) within block, and treatment, according to the model proposed by Sanders and Gaynor (1987). The linear and quadratic effects of the treatments were analyzed using orthogonal contrasts. As the levels of the treatments (% CaO added to sugarcane) were not equally spaced, the ORPOL function in the CONTRAST statement in the Interactive Matrix Language (IML) procedure of SAS was used to create the orthogonal polynomial trend contrast coefficients. Results are reported as least squares means and effects were considered significant when $P \leq 0.05$.

Results and Discussion

Compared to that in the control treatment, the Ca concentration increased by 297%, 570% and 1,083% in the diets based on sugarcane hydrolyzed with 0.5%, 1% and 2% CaO, respectively, while the respective Ca:P ratios were 6.58:1, 10.70:1 and 19.77:1 (control Ca:P ratio: 1.55:1) (Table 1). These increases were a consequence of the high Ca content in CaO (Table 2), which was also the main factor responsible for the increases in the MM and DM content of the diets with hydrolyzed sugarcane as well as the reductions in OM compared with those of the control treatment (Table 1). The results of the present study corroborate those presented by Daniel et al. (2013), who performed a meta-analysis study of 20 published articles and observed a reduction in OM content and an increase in the concentrations of DM, MM and Ca in sugarcane hydrolyzed with 0.5% to 3% CaO.

On the other hand, since there was no change in the P content of the four diets evaluated (Table 1) and since both sugarcane and CaO present low concentrations of this mineral, the Ca:P ratio, which in the control treatment was 1.55:1, increased to 19.77:1 in the diet including sugarcane hydrolyzed with 2% CaO (Table 1), an increase of 1,176%. Significant increases in the Ca:P ratio due to sugarcane hydrolysis with CaO were also observed by Domingues et al. (2014) and Chizzotti et al. (2015), who reported Ca:P ratios of 1.85:1 to 1.95:1 for chopped fresh sugarcane and ratios of 4.29:1 to 36.46:1 for sugarcane hydrolyzed with 0.5% to 2% CaO. Wise et al. (1963) evaluated the effect of Ca:P ratios ranging from 0.4:1 to 14.3:1 on voluntary intake and weight gain in growing cattle (114 kg). These authors concluded that diets with Ca:P ratios ranging from 1:1 to 7.1:1 did not impair the growth of the animals, presenting similar performance results. In the present study (Table 1), diets including sugarcane hydrolyzed with 1% and 2% CaO presented Ca:P ratios well above the upper limit of this range, which was considered optimal by Wise et al. (1963) and by the NRC (2001).

There was a linear increase ($P<0.01$) in the intake of MM and Ca in response to the amount of CaO used for hydrolysis of sugarcane. In comparison with the Ca intake in the control group cows, an increase in Ca intake of more than 460% was observed for the cows that received the diet based on sugarcane hydrolyzed with 2% CaO (Table 3). Considering the Ca absorption coefficient of 0.38 recommended by the NRC (2001) and the Ca absorption requirements for maintenance (0.0031 g kg body weight^{-1}) and production (1.37 g kg milk^{-1}), the cows receiving diets including sugarcane hydrolyzed with 0%, 0.5%, 1% and 2% CaO presented absorbed Ca intake that was 25%, 170%, 359% and 719% greater than their requirements, respectively. According to the NRC (2001), excessive intake of Ca can interfere with trace mineral absorption (especially zinc absorption) and can replaces energy or protein that could be used by the animal to increase production.

The hydrolysis of sugarcane with increasing amounts of CaO promoted a linear reduction ($P<0.01$) in DM intake and, consequently, a linear reduction in the consumption of nonfibrous carbohydrates (NFC), CP, OM, NDFap and EE (Table 3). In addition to the reductions in DM intake, reductions were generally observed in the contents of these nutrients as sugarcane hydrolyzed with higher amounts of CaO was included in the experimental diets (Table 1), which also contributed to a decrease in the consumption of these fractions. The reduction observed in the OM content in hydrolyzed sugarcane-based diets was directly associated with the increase in the MM content due to the use of CaO in sugarcane hydrolysis, which also caused a dilution effect, reducing the concentrations of other nutrients such as NFC, EE and CP (Table 1). In this sense, in relation to that of the control diet, there were substantial increases in MM content of 29%, 47% and 75%, respectively, when 0.5%, 1% and 2% CaO was used in the sugarcane hydrolysis (Table 1). Moreover, the heat resulting from the CaO hydration reaction in the forage submitted to hydrolysis can accelerate

the sugarcane fermentation process, reducing the soluble carbohydrate content and, consequently, the NFC content (DANIEL et al., 2013).

Table 3. Nutrient intake in lactating Holstein x Gyr cows fed sugarcane-based diets hydrolyzed with calcium oxide (CaO).

Item	% CaO added to sugarcane (fresh matter basis)				Standard error of the mean	P-value	
	0.0	0.5	1.0	2.0		Linear	Quadratic
kg cow^{-1} day^{-1}							
Dry matter (DM)	11.44	10.41	9.51	8.40	0.2981	0.0004	0.3114
Organic matter	10.14	8.91	7.94	6.72	0.2309	<0.0001	0.1229
Crude protein (CP)	1.04	0.86	0.82	0.70	0.0557	0.0069	0.3344
Nonfibrous carbohydrates (NFC)[1]	5.25	4.51	4.08	3.45	0.1393	0.0001	0.1227
Total digestible nutrients	8.06	6.70	5.94	5.02	0.2170	<0.0001	0.0457
NDFap[2]	3.40	3.14	2.73	2.36	0.0826	0.0001	0.3042
Ether extract (EE)	0.18	0.14	0.12	0.09	0.0087	0.0005	0.2103
Acid detergent fiber	2.68	1.91	1.91	1.62	0.0688	<0.0001	0.0015
Lignin	0.53	0.30	0.38	0.30	0.0108	<0.0001	0.0005
Hemicelluloses	0.85	1.42	0.98	0.94	0.0437	0.1920	0.0023
Cellulose	2.14	1.61	1.54	1.33	0.0584	0.0001	0.0087
Mineral matter (MM)	1.34	1.53	1.58	1.71	0.0329	0.0003	0.0882
Phosphorus (P)	0.0223	0.0198	0.0179	0.0167	0.0018	0.0760	0.4956
Calcium (Ca)	0.0544	0.1182	0.1901	0.3051	0.0087	<0.0001	0.4771
kg 100 kg body weight^{-1}							
DM	2.33	2.11	1.96	1.78	0.0503	0.0003	0.1513
NDFap[2]	0.69	0.64	0.56	0.50	0.0140	<0.0001	0.1619

[1]NFC = 100 - (%NDFap + %CP + %EE + %MM), according with Weiss (1999).
[2]NDFap = Neutral detergent fiber corrected for ash and protein.

The intake of total digestible nutrients (TDN), ADF, lignin, hemicelluloses and cellulose presented quadratic behavior (P<0.01) in response to the increase in CaO inclusion (Table 3). This result may be a consequence of the increase in the fibrous fraction concentrations in response to the loss of NFC caused by the possible fermentation of the sugarcane forage treated with CaO. In this sense, in relation to that of the control treatment, the NFC content was reduced by 11% in the diet including sugarcane hydrolyzed with 2% CaO (Table 1). Carvalho (2008) also observed quadratic behavior for TDN intake in diets supplied to lactating cows that were based on chopped sugarcane supplied *in natura* or hydrolyzed with up to 2.25% CaO. In the present study, the minimum TDN intake value of 5.48 kg cow^{-1} day^{-1} was estimated when 2.0% CaO was used in sugarcane hydrolysis.

The absence of an effect on NDFap digestibility (P>0.05) and the linear reductions (P<0.05) observed in DM, OM and ADF digestibility in response to the increase in the amount of CaO used in sugarcane hydrolysis (Table 4) indicate that treatment with this alkaline agent did not reach the objective of altering the chemical composition of the sugarcane fibrous fractions to increase its digestibility and, consequently, the voluntary intake of diets based on this roughage. Thus, consistent with the findings

of Carvalho (2008), it can be said that CaO does not constitute a promising alkaline agent for the treatment of sugarcane for lactating cows, since there was no positive effect of sugarcane hydrolysis on digestibility (Table 4) and, consequently, on the intake of the diets (Table 3). In general, this is the result that has been systematically observed in the few studies performed on lactating cows fed diets based on sugarcane hydrolyzed with CaO. Illustrating this, Carvalho (2008) and Silva Júnior et al. (2015) did not observe a positive effect (P>0.05) of sugarcane hydrolysis for 24 h with 0.75% to 2.25% CaO on the digestibility of DM, OM, CP, NDF and TDN. Similarly, there was no effect (P>0.05) on DM, CP, NDF, NDFap, ADF and TDN intake in diets based on sugarcane hydrolyzed for up to 48 h with 0.5% to 2% CaO (CARVALHO, 2008; SFORCINI, 2009; SILVA JÚNIOR et al., 2015; TEIXEIRA JUNIOR et al., 2015).

Table 4. Nutrient digestibility in lactating Holstein x Gyr cows fed sugarcane-based diets hydrolyzed with calcium oxide (CaO).

Digestitility (%)	% CaO added to sugarcane (fresh matter basis)				Standard error of the mean	P-value	
	0.0	0.5	1.0	2.0		Linear	Quadratic
Dry matter	76.89	72.16	70.25	66.15	1.2236	0.0011	0.2956
Organic matter	78.76	74.78	73.74	70.62	1.4745	0.0114	0.4565
NDFap[1]	51.54	44.40	40.73	41.01	3.9019	0.1345	0.2678
Acid detergent fiber	52.50	31.85	38.55	29.63	4.2070	0.0239	0.1973

[1]NDFap = Neutral detergent fiber corrected for ash and protein.

As a direct reflection of the reduction in nutrient intake and digestibility of the diets in response to sugarcane hydrolysis with increasing amounts of CaO (Tables 3 and 4), there were linear reductions (P<0.05) in milk production corrected or not corrected to 4% fat and in protein, lactose and total solids content (Table 5). Because of this, linear reductions (P<0.05) were also observed in the production of all milk components. Only the milk fat content was not altered (P>0.05) in response to the inclusion of hydrolyzed sugarcane in the diets (Table 5). In studies on lactating cows evaluating diets based on sugarcane hydrolyzed up to 48 h with 0.5% to 2.25% CaO, there were no differences (P>0.05) in milk yield or in the content of protein, fat, lactose and total solids in relation to those obtained with the control diets based on chopped fresh sugarcane. However, in a study carried out with 1% $Ca(OH)_2$ as an alkaline agent, Alves et al. (2010) reported a positive effect of sugarcane hydrolysis on milk production, while Sforcini (2009) used sugarcane hydrolyzed for 72 h with 0.5% CaO and observed an increase in milk yield and a reduction in milk protein content. These were the only studies on lactating cows in which there was any change in milk production or composition due to the inclusion of hydrolyzed sugarcane. The milk yields and compositions observed in the present study are within the ranges reported in previous studies in which sugarcane hydrolyzed with CaO was supplied to lactating cows: 7.29-19.98 kg milk cow^{-1} day^{-1} with 2.96%-3.41% protein, 3.23%-4.32% fat, 4.09%-5.63% lactose, and 11.22%-13.00% total solids (CARVALHO, 2008; SFORCINI, 2009; SILVA JÚNIOR et al., 2015; TEIXEIRA JUNIOR et al., 2015).

There was a quadratic effect (P=0.0233) of sugarcane hydrolysis with CaO on feed efficiency expressed in kg of milk per kg of DM consumed (Table 5). The maximum value of 1.09 for feed

efficiency was estimated when 1.3% CaO was used for sugarcane hydrolysis. The observed values for kg of milk per kg of DM consumed are situated in the range of 0.68 to 1.25 reported by Carvalho (2008) and Silva Júnior et al. (2015). In these studies, Carvalho (2008) did not observe an effect (P>0.05) of sugarcane hydrolysis with 0.5% to 2.25% CaO on feed efficiency, whereas Silva Júnior et al. (2015) evaluated diets with added urea and reported higher feed efficiency (P<0.05) in the diet with hydrolyzed sugarcane than in that with chopped fresh sugarcane.

Table 5. Performance and milk composition in Holstein x Gyr cows fed sugarcane-based diets hydrolyzed with calcium oxide (CaO).

Item	% CaO added to sugarcane (fresh matter basis)				Standard error of the mean	P-value	
	0.0	0.5	1.0	2.0		Linear	Quadratic
Yield							
Milk (kg day^{-1})	10.92	11.02	10.38	9.26	0.3196	0.0075	0.3304
FCM[1] (kg day^{-1})	10.50	10.26	9.64	8.45	0.4223	0.0124	0.6766
Protein (g day^{-1})	340.0	333.6	312.9	277.1	9.4368	0.0028	0.5828
Fat (g day^{-1})	409.0	390.2	366.2	316.4	20.5083	0.0186	0.8724
Lactose (g day^{-1})	477.6	479.2	443.6	393.5	13.4547	0.0032	0.4122
Solids-not-fat (g day^{-1})	932.9	926.9	862.6	763.8	25.9549	0.0028	0.4744
Total solids (g day^{-1})	1,341.9	1,317.1	1,228.8	1,080.2	44.9282	0.0053	0.6235
Milk composition (%)							
Protein	3.12	3.04	3.02	3.00	0.0243	0.0181	0.1606
Fat	3.77	3.55	3.51	3.44	0.1065	0.1071	0.3852
Lactose	4.38	4.37	4.27	4.23	0.0332	0.0125	0.6482
Solids-not-fat	8.56	8.45	8.32	8.24	0.0411	0.0016	0.1675
Total solids	12.33	11.99	11.82	11.68	0.1163	0.0103	0.2085
Feed efficiency							
kg of milk/kg of dry matter intake	0.95	1.08	1.11	1.10	0.0264	0.0132	0.0233
kg of FCM/kg of dry matter intake	0.92	1.00	1.03	1.01	0.0312	0.1250	0.1123

[1]FCM = 4% fat-corrected milk (NRC, 2001) = 0.4*MilkProduction + 15*(%MilkFat/100)*MilkProduction.

There was no effect (P>0.05) of sugarcane hydrolysis with increasing amounts of CaO on the time spent (minutes day^{-1}) by cows idle, ruminating or feeding, nor was there an effect in the time spent feeding 1 kg of DM and NDF (Table 6). The absence of an effect of sugarcane hydrolysis on rumination activity (Table 6), combined with the lower DM and NDF intakes observed in cows fed hydrolyzed sugarcane-based diets (Table 3) promoted a linear increase (P<0.05) in the time spent ruminating 1 kg of DM and NDF (Table 6). Compared to the cows in the control treatment, those fed sugarcane hydrolyzed with 2% CaO took 38% and 46% longer to ruminate 1 kg of DM and NDF, respectively. These results indicate that hydrolysis with CaO did not reach the objective of reducing the fibrous fractions of sugarcane. To reinforce this hypothesis, in a companion study performed concomitantly with the present study, Campos et al. (2011) did not observe any effects of the inclusion of 1% or 2% CaO on *in situ* ruminal degradability of the fibrous fractions (NDF and ADF) of hydrolyzed sugarcane.

Table 6. Feeding behavior in lactating Holstein x Gyr cows fed sugarcane-based diets hydrolyzed with calcium oxide (CaO).

Item	% CaO added to sugarcane (fresh matter basis)				Standard error of the mean	P-value	
	0.0	0.5	1.0	2.0		Linear	Quadratic
Activity (minutes day^{-1})							
Idle	465.8	453.9	488.9	527.0	27.1972	0.1226	0.6524
Rumination	526.3	570.1	558.2	533.2	26.7899	0.9144	0.3025
Feeding	331.9	301.9	278.8	277.5	20.2777	0.1241	0.3433
Time spent ruminating 1 kg of dry matter (DM) and neutral detergent fiber (NDF)							
Minutes kg^{-1} of DM	45.9	54.7	58.4	63.4	3.1873	0.0110	0.2959
Minutes kg^{-1} of NDF	154.2	180.7	203.5	225.8	11.3313	0.0049	0.3758
Time spent feeding 1 kg of dry matter (DM) and neutral detergent fiber (NDF)							
Minutes kg^{-1} of DM	29.7	28.9	29.2	33.4	2.1011	0.2270	0.3869
Minutes kg^{-1} of NDF	100.3	95.5	101.5	119.3	7.3333	0.0866	0.3199

Conclusion

Chopped sugarcane hydrolyzed for 24 h with 0.5% to 2.0% CaO should not be used as exclusive roughage in diets for Holstein x Gyr dairy cows with an average milk production of 10 kg day^{-1}.

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