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CALCIUM OXIDE LEVELS IN SUGARCANE SILAGE, FRESH SUGARCANE OR CORN SILAGE FOR FEEDLOT NELLORE HEIFERS

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ABSTRACT

The objective of this study was to evaluate intake, total apparent digestibility and performance of beef cattle fed different roughages: sugarcane silage with 0.0, 0.75 and 1.5% levels of calcium oxide, fresh sugarcane or corn silage. The roughages were corrected with urea/ammonium sulfate to have 10,5% of crude protein. Thirty Nellore heifers with average body weight 273.6 kg ± 25.72 kg, and 18 months were distributed in a completely randomized design. The animals, five per treatment, were confined in five collective stalls with troughs covered with asbestos shingles. The animals fed diets with corn silage showed higher DM intake than those fed the diets containing sugarcane silages and fresh sugarcane. Higher intakes of nutrient, except crude protein, were obtained with the diet containing fresh sugarcane as compared with the sugarcane silages. The total apparent digestibility of the nutrients was higher for the diet containing corn silage. Inclusion of calcium oxide had a quadratic effect on DM digestibility, with maximum digestibility estimated at the calcium oxide level of 0.82%. Corn silage-based diets yield higher performance than those containing sugarcane. Animals that fed diets containing fresh sugarcane had better performance than the animals fed sugarcane silage-based diets. The energy intake and performance of heifers fed diets based on corn silage are better than those of heifers fed sugarcane. The use of sugarcane silage without additives results in lower energy intake and lower performance. The calcium oxide level that resulted in best energy intake is close to 0.82%.

Key words: intake, digestibility, performance

INTRODUCTION

The use of fresh sugarcane reduces the costs with the feeding of beef cattle, and this plant is remarkable due to its high productivity, the maintenance of its nutritional value until six months after maturation, and its harvesting period, which coincides with the period of forage scarcity in pastures. On the other hand, the major hindrance to its use in a large scale is the need for a daily harvest, which represents an operational constraint.

The ensilage of sugarcane is a strategy that can remedy this situation by eliminating the daily cut. However, it is important to note that because it has a large amount of soluble carbohydrates, sugarcane is highly susceptible to the activity of yeasts, which, in an anaerobic environment, cause significant losses due to the alcoholic fermentation. According to Woolford (1984), besides lactic acid, yeasts utilize soluble sugars and produce ethanol, which has no preservative value for the silage, and consequently there are losses of dry matter (DM) and energy. In fact, Pedroso *et al*. (2004) observed BW losses of 29.2% when sugarcane was ensiled without additives.

In view of this scenario, additives should be evaluated aiming to improve the fermentation pattern, the control of yeast development, and the preservation of sugarcane in the form of silage. Calcium oxide (CaO) has been indicated as an alternative additive, because in addition to its antimicrobial activity, which inhibits the development of the ethanol-producing yeasts, it can promote hydrolysis of the fiber of the ensiled material, thereby improving its digestibility.

According to Lima *et al*. (2007), addition of up to 1% CaO to the sugarcane at the moment of ensiling is characterized as a possible management strategy for reducing the cell-wall components and increasing intake and the digestibility coefficients, which is a desirable characteristic for the ensiling of this grass. In contrast, Cavali *et al*. (2010) found that addition of 1.5% CaO resulted in a higher recovery of DM from the ensiled mass, better *in vitro* DM digestibility, a higher population of lactic acid bacteria and a lower number of yeasts, indicating good fermentation. However, more information is necessary regarding the ideal level of CaO that maximizes the use of sugarcane silage and the performance of confined animals.

In this sense, the objective of this study was to evaluate the nutritional parameters and the performance of confined Nellore steers fed diets based on sugarcane silage treated with different levels of CaO, fresh sugarcane, and corn silage.

MATERIALS AND METHODS

Animals, experiment designed and diets. The experiment was conducted at the Animal Laboratory of Federal University of Viçosa, Brazil. Thirty Nellore heifers (five per treatment) with an average body weight of 273.6 kg (± 25.72 kg), at 18 months of age, on average, were confined in five collective stalls with troughs covered with asbestos shingles. The experimental protocol and procedures were approved by the Federal University of Viçosa Animal Care and Use Committee.

Treatments consisted of different roughages: sugarcane silage with 0.0%, 0.75% and 1.5%, levels of CaO, fresh sugarcane (*in natura*), and corn silage. The roughages were corrected with urea/ammonium sulfate to have the same protein content (10.5% CP). All animals received the concentrate (Table 1) at the amount of 0.5% of their BW.

Table 1. Ingredient and chemical composition of the concentrate

Ingredient	(%)
Soybean meal	23.88
Corn meal	71.52
Sodium chloride	1.00
Mineral mix[1]	3.60
Chemical composition	
Dry matter (%)	93.98
Organic matter	92.81
Crude protein	17.98
Ether extract	3.17
Neutral detergent fiber	11.82
Acid detergent fiber	5.12
Non-fibrous carbohydrates	59.84
Calcium	0.96
Phosphorus	0.94

[1]Levels per kg: Ca - 240 g; I - 90 mg; P - 174 g; Mg - 2,000 mg; Zn - 5,270 mg; Se - 15 g; Co - 100 mg; F - 1,740 mg; Cu - 1,250 mg; Fe - 1,795 mg; excipient q.s. - 1,000 g).

The experiment lasted 99 days, which were divided into three 28-day periods, after 15 days of adaptations, when animals were weighed again after a solid-feed-deprivation period of 12 hours, which was repeated every 28 days. The weight of the animals was used to adjust the amount of concentrate supplied on the following day. The amount of diet to be supplied was calculated daily to allow for 10% in orts.

Experimental procedures and sampling: Samples of the feed supplied and leftovers from each animal were collected daily, conditioned in labeled plastic bags and stored in a freezer. Composite samples of the leftover feed from each treatment were formed weekly. Feces were collected for three consecutive days at different times (08.00 h, 12.00 h and 17.00 h) in the third week of each experimental period to estimate the total apparent digestibility of the nutrients. Fecal samples were pre-dried, ground in a knife mill (1.0 mm), and a composite sample was formed per animal, which was subsequently stored for analyses.

The fecal production was estimated using the purified and enriched lignin (LIPE®) marker according Rodriguez *et al*. (2007). Titanium dioxide was utilized as an external marker to estimate the individual concentrate intake. The individual roughage intake was estimated through indigestible neutral detergent fiber (iNDF).

External markers were administered daily in the morning, in a single dose. Titanium dioxide was mixed with the concentrate daily for eight consecutive days (five for adaptation and three for collection) at the dose of 0.7% of the concentrate (as is) daily. LIPE® was supplied in capsules, at the dose of 0.5 g/animal day^{-1} for a period of six days (three for adaptation and three for collection). Feces were collected directly from the rectum of the animals.

Chemical analysis: The laboratory analyses to determine the chemical composition of the roughages (Table 2) were performed according to the AOAC (1990). Samples of feed, feces and orts corresponding to the digestibility estimate were conditioned in Ankom® bags and incubated in situ for 240 hours in the rumen, and after each incubation they were subjected to digestion with neutral detergent to estimate the iNDF.

The titanium dioxide content was determined according to Myers *et al*. (2004). A 0.5 g sample of feces was digested for 2 hours at a temperature of 400 ° C in tubes for protein determination. After digestion, 10 ml of H_2O_2 (30%) were added slowly and the tube material, transferred to a beaker and supplemented with distilled water ad 100 g. Soon after this procedure the material the beaker was transferred to 100 mL flasks and added over 3 drops of H_2O_2 (30%). On digestion 15 ml of sulfuric acid and 5 g of the mixture digesting protein (KJELDAHL macro) were used. A standard curve was prepared with 0, 2, 4, 6, 8 and 10 mg of titanium dioxide and spectrophotometric readings made at a wavelength of 410 nm.

The determination of the content of LIPE® in the feces was performed by spectroscopy infrared, with KBr pellets and processed Fourier according (Saliba *et al*., 2003). The fecal output was calculated by logarithmic ratio of the intensities absorption spectral bands between wavelength λ1 (1050ηm) and λ2 (1650ηm).

Table 2. Chemical composition of the roughages evaluated.

Item	Sugarcane silage (% CaO)			Sugarcane	Corn silage
	0.0	0.75	1.5		
Dry matter	24.9	29.4	27.4	27.8	31.1
Organic matter	93.8	93.2	91.2	87.0	93.9
Crude protein	3.0	3.9	3.4	2.8	7.0
Ether extract	1.2	1.3	1.5	1.4	3.0
Neutral detergent fiber (NDF)	61.4	55.7	45.1	42.1	55.6
Indigestible NDF	28.35	23.60	26.79	26.07	17.63
Non-fibrous carbohydrates	28.2	32.2	41.2	40.7	28.3
Acid detergent fiber	41.2	325	25.5	26.3	32.0
Lignin	7.98	6.1	7.2	6.4	4.2
Calcium	0.28	0.22	1.03	2.13	0.30
Phosphorus	0.03	0.07	0.03	0.03	0.19

Statistical analysis: The study was conducted under a completely randomized design. The treatments were compared using orthogonal contrasts: the diet containing corn silage × sugarcane-based diets; diet with fresh sugarcane × sugarcane silages; linear and quadratic effects of inclusion of CaO in the sugarcane silage. The significance level of 5% was adopted for all procedures.

RESULTS AND DISCUSSION

Intake: The heifers that received corn silage showed higher intake ($P<0.05$) than the animals fed the diets containing sugarcane silages and fresh sugarcane, which provided a higher intake ($P<0.05$) of all nutrients except EE than the diets containing sugarcane silages (Table 3). In contrast, the intake of nutrients displayed a quadratic behavior with inclusion of CaO in the sugarcane silage, with maximum values (kg/day) of total DM (TDM), roughage DM (RDM), crude protein (CP), neutral detergent fiber (NDF) and total digestible nutrients (TDN) being estimated at the CaO levels of 0.85, 0.84, 0.86, 0.73 and 0.82%, respectively. When the maximum levels of CaO inclusion for DM and NDF (g/kg BW) were estimated, however, the values obtained were 0.87, 0.81 and 0.79% of CaO, respectively.

Table 3. Intake of total dry matter (TDM), roughage DM (RDM), concentrate DM (CDM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), non-fibrous carbohydrates (NFC) and total digestible nutrients (TDN) of Nellore heifers according to the roughage.

Item	Roughage					Contrasts				CV (%)
	Sugarcane silage (% CaO)			Sugarcane	Corn silage					
	0.0	0.75	1.50			A[1]	B[2]	C[3]	D[4]	
			kg/day							
TDM[5]	4.06	5.12	4.72	5.69	7.86	<.0001	<.0001	0.0043	<.0001	6.5
RDM[6]	2.59	3.57	3.24	4.09	6.09	<.0001	<.0001	0.0069	<.0001	8.9
CDM[7]	1.47	1.55	1.48	1.60	1.77	<.0001	<.0001	0.0243	<.0001	9.8
OM[8]	3.93	4.78	4.11	5.28	7.35	<.0001	<.0001	0.3601	<.0001	6.4
CP[9]	0.48	0.61	0.54	0.67	0.92	<.0001	<.0001	0.0007	<.0001	6.5
EE[10]	0.08	0.11	0.09	0.10	0.25	<.0001	0.1571	0.2448	0.0004	7.7
NDF[11]	1.57	2.16	1.66	2.72	3.80	<.0001	<.0001	0.4085	<.0001	7.4
NFC[12]	2.10	2.52	2.06	2.07	2.63	<.0001	0.0142	0.5816	<.0001	5.7
TDN[13]	2.26	4.06	2.80	4.38	5.94	<.0001	<.0001	0.0173	<.0001	9.3
			g/kg BW							
TDM[14]	14.4	19.5	17.0	19.3	25.3	<.0001	0.0641	0.0895	0.0056	13.3
OM[15]	13.9	17.6	14.8	17.9	23.7	<.0001	0.0313	0.5267	0.0094	13.0
NDF[16]	5.6	7.4	6.0	9.2	12.3	<.0001	<.0001	0.5154	0.0065	13.5

[1] Diet with corn silage × sugarcane-based diets, [2] Sugarcane-based diet × diet containing sugarcane silages, [3] Linear effect of inclusion of CaO in the sugarcane silage, [4] Quadratic effect of inclusion of CaO in the sugarcane silage, [5] $\hat{Y} = 4.06 + 3.89\ CaO - 2.30\ CaO^2$, [6] $\hat{Y} = 2.49 + 2.09\ CaO - 1.24\ CaO^2$, [7] $\hat{Y} = 1.15 + 1.03\ CaO - 0.59\ CaO^2$, [8] $\hat{Y} = 3.93 + 3.03\ CaO - 1.94\ CaO^2$, [9] $\hat{Y} = 0.36 + 0.36\ CaO - 0.21\ CaO^2$, [10] $\hat{Y} = 0.08 + 0.06\ CaO - 0.04\ CaO^2$, [11] $\hat{Y} = 1.57 + 1.51\ CaO - 0.98\ CaO^2$, [12] $\hat{Y} = 2.10 + 1.14\ CaO - 0.78\ CaO^2$, [13] $\hat{Y} = 2.26 + 4.45\ CaO - 2.73\ CaO^2$, [14] $\hat{Y} = 1.43 + 1.20\ CaO - 0.69\ CaO^2$, [15] $\hat{Y} = 1.39 + 0.92\ CaO - 0.57\ CaO^2$, [16] $\hat{Y} = 0.56 + 0.46\ CaO - 0.29\ CaO^2$

The animals fed corn silage provided had increase in total DM intake ($P<0.05$) of 38.14% compared with the heifers that received the diet based on fresh sugarcane; of 93% as compared with those fed the diet with sugarcane silage with 0.0% CaO; 38% than those fed the sugarcane silage-based diet with 0.75% CaO; and 67% than those which received the diet containing sugarcane silage with 1.5% CaO. All the animals fed sugarcane silages had less intake than the animals fed diets containing fresh sugarcane ($P<0.05$).

This behavior is possibly due to the very chemical composition of the corn silage, which is a roughage with lower lignin and iNDF contents (Table 2) than all other roughages studied. In the sugarcane ensiling process there was a increase concentration of lignin and iNDF in the silage, which also explains the higher intake of non-ensiled sugarcane, because lignin is part of the fraction indigestible by ruminants; thus, as its concentration in a given feed is increased, its degradation becomes slower, and so does the emptying of the rumen, which will increase the sensation of physical filling by the animal, causing it to reduce its ingestion of matter and all nutrients. Roman *et al*. (2011) observed that diets containing corn silage resulted in a higher DM intake than diets containing sugarcane silages. According to Resende *et al*. (2005), this observation might have been due to the presence of acetic acid and ethanol, which is characteristic of the sugarcane silage-fermentation process, having a direct influence on the chemical processes related to satiety. The dry matter intake is affected when cattle consume forages of different quality, irrespectively of the feeding strategy (Magalhães *et al*., 2006). To explain the lower DM intake in diets with sugarcane, Oliveira *et al*. (2011) compared the rumen degradation kinetics of corn silage with that of sugarcane. Potentially digestible NDF values of 72% and NDF degradation rates of 2.8%/h were obtained for corn silage, whereas the respective values for sugarcane were 48.2% and 3.2%/h. When the NDF retention times were calculated, sugarcane showed 34.9 h and corn silage, 29 h. These data suggest that the longer time of retention of the NDF from sugarcane in the rumen is a result of its higher indigestible-NDF content, rather than due to the digestion rate of the potentially digestible NDF. The longer rumen-retention time of the NDF from sugarcane explains the lower intake observed in diets containing higher levels of sugarcane.

Menezes *et al*. (2011) evaluated the intakes and passage and digestion rates of DM and NDF in cattle fed diets composed of corn silage, ground sugarcane supplied fresh, ground sugarcane supplied after three days of storage, and sugarcane ensiled with 1% CaO, and a same concentrate fixed at 1% of the BW. According to the authors, the use of CaO in the ensiling of sugarcane was not able to change the rates of intake, passage and digestion of DM and NDF in relation to the sugarcane silage without the additive, which justified the similar intakes of the animals that consumed the sugarcane silages.

The higher digestion and passage rates of the DM and NDF obtained by the animals fed the diets containing corn silage explain their higher intake. The higher passage rate in the animals that received the diets containing sugarcane supplied fresh compared with its ensiled version explain the higher intakes of these diets.

On the other hand, CaO levels close to 0.75% provided nutrient intakes close to those observed in the animals that consumed fresh sugarcane. According to Alcântara *et al*. (1989), alkalizing substances are capable of modifying the fermentation process and present a better chemical composition, reduction of the ethanol production, higher lactic acid content and higher digestibility, thereby resulting in elevations in the DM intake and in the weight gain by the animals. According to Lima *et al*. (2007), adding up to 1.0% CaO to sugarcane at the moment of ensiling is a possible strategy because it reduces the cell-wall components and elevates intake and the digestibility coefficients, which means a desirable feature for the ensiling of this grass.

Digestibility: The heifers fed diets containing corn silage showed higher total apparent digestibility ($P<0.05$) of DM, CP and NDF as compared with those fed diets based on fresh sugarcane and sugarcane silage with or without addition of CaO (Table 5).

Except for EE, the diet containing fresh sugarcane provided higher digestibility ($P<0.05$) in relation to those containing sugarcane silages. Inclusion of CaO at the moment of ensiling sugarcane had a quadratic effect on the digestibility of DM, OM, CP and NFC, respectively, with maximum values estimated with the CaO levels of 0.82, 0.77, 0.67 and 0.89% in the silages, respectively.

Concerning the better digestibilities observed for the diet containing corn silage, the lower digestibility of NDF from sugarcane in relation to that of diets with corn silage is a noteworthy fact (Corrêa *et al*., 2003). In fact, according to Oba and Allen (1999), the NDF digestibility is an important forage-quality parameter due to the large variability of the rumen degradation and its influence on the animal performance.

Alkaline additives are used aiming to increase the sugarcane digestibility, given that they promote expansion of cellulose with reduction in the intermolecular hydrogen bonds, which bind the molecule of cellulose and hemicellulose with consequent solubilization and increased digestibility of these fractions (Van Soest, 1987). In fact, the inclusion of CaO at levels close to 0.75% resulted in an increase in the DM digestibility. In contrast, higher levels did not yield improvements in the digestibility of the nutrients (Table 5). Cavali *et al*. (2010) also observed a quadratic response from the *in vitro* DM digestibility, although the maximum value was estimated with a CaO level of 1.8%, differently from that observed in the current study.

Table 5. Total apparent digestibility (%) of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and neutral detergent fiber (NDF) in Nellore heifers according to the roughage

Item	Roughage					Contrasts				CV (%)
	Corn silage (% CaO)			Sugarcane	Corn silage					
	0.0	0.75	1.50			A[1]	B[2]	C[3]	D[4]	
DM[5]	47.92	64.25	52.87	61.58	74.78	<.0001	0.0011	0.0311	<.0001	6.2
OM[6]	58.93	70.61	60.09	68.15	79.78	<.0001	0.0022	0.5207	<.0001	4.5
CP[7]	68.64	74.70	65.15	74.49	84.75	<.0001	0.0076	0.1099	0.0002	4.9
EE	82.51	87.24	84.27	85.04	94.99	0.0002	0.8811	0.5550	0.1438	5.9
NDF	52.82	57.53	53.97	64.46	69.50	0.0002	0.0024	0.7459	0.1859	10.2
NFC[8]	59.21	84.84	72.83	88.11	81.68	0.0037	<.0001	<.0001	<.0001	4.8

[1] Diet with corn silage × sugarcane-based diets,[2] Sugarcane-based diet × diet containing sugarcane silages
[3] Linear effect of inclusion of CaO in the sugarcane silage,[4] Quadratic effect of inclusion of CaO in the sugarcane silage,[5] $\hat{Y} = 47.92 + 40.25\ CaO - 24.63\ CaO^2$,[6] $\hat{Y} = 58.94 + 30.37\ CaO - 19.71\ CaO^2$,[7] $\hat{Y} = 68.64 + 18.48\ CaO - 13.86\ CaO^2$,[8] $\hat{Y} = 59.21 + 59.25\ CaO - 33.45\ CaO^2$

However, Magalhães *et al*. (2013) affirmed that addition of CaO was not efficient in improving the digestibility of DM and NDF of the sugarcane silage. According to those authors, although there was improvement in the cell-wall components, digestibility did not improve, which was possibly because the passage rate was slower, which extended the digestive retention and caused intake to reduce. Lima *et al*. (2007), on the other hand, observed an increasing linear effect of the CaO levels on the apparent digestibility of DM. According to those authors, elevations in the digestibility of the DM from roughages treated with alkaline products are usually related to increase in DM intake, reduction in NDF intake and increase in the digestibility of these components. Thus, it can be inferred that the improvement in the DM digestibility with inclusion of 0.75% CaO was due to the partial solubilization of the cell-wall components demonstrated by the lower cellulose and hemicellulose values in these silages.

Performance: Higher final BW, higher performance and better feed conversion (P<0.05) were observed in the animals fed the corn silage-based diet (Table 6). Likewise, the heifers that consumed diets containing sugarcane had higher final BW, performance and better feed conversion (P<0.05) than the animals which consumed diets based on sugarcane silage.

No effect (P>0.05) of inclusion of CaO was observed in the sugarcane silages in performance. However, the diet containing silage with 0.75% of CaO caused performance to increase by approximately 46% in relation to the sugarcane silage without the additive.

Comparing diets containing corn silage and sugarcane-based diets for heifers, Gallo *et al*. (2000) observed a lower DM intake in the animals that consumed diets containing sugarcane as compared with those which received corn silage. In contrast, Fernandes *et al*. (2007), in a study involving Canchim animals fed 40% sugarcane or corn silage, did not find differences in performance (average 1.42 and 1.43 kg/day, respectively), confirming the potential of use of this forage in diets with elevated participation of concentrates. It is noteworthy that the animals fed the diet containing sugarcane silage without CaO had a lower DM intake than those fed sugarcane silage containing 0.75% CaO.

The performance of animals fed the diet containing sugarcane silage with 1.5% CaO was 13.24% lower than that of animals fed the sugarcane silage-based diet with 0.75% CaO. This reduction in weight gain rate can be partly explained by the excess calcium in the diet of these animals.

According to AFRC (1991), cattle have a great tolerance to Ca intakes above their requirements, provided that the P requirements are met; however Ca:P ratios above 8:1 may compromise their performance. Domingues *et al*. (2014) evaluated the concentration of macrominerals in sugarcane treated with increasing doses of quicklime (CaO) with a large variation in the Ca:P ratio, in which the Ca:P ratio for the sugarcane without CaO (0.00%) was 1.85:1, which is very close to the ideal (2:1). When increasing levels of CaO were added to the sugarcane, the authors found an increase in the Ca:P ratios, which were 10.70:1; 18.07:1; 30.65:1, and 36.46:1 for the CaO doses of 0.5, 1.0, 1.5, and 2.0%, respectively. According to those authors it should be stressed that the gross rates of each mineral in the hydrolyzed sugarcane - i.e., without their bioavailability - were used for the calculations presented for the Ca:P ratio, which might have slightly altered this ratio.

Based on this study, it can be observed that application of CaO promotes an elevation in the Ca contents and a large variation in the Ca:P ratio. Thus, a lack of care regarding the mineral content of diets containing sugarcane with CaO as roughage may result in elevation of the concentration of Ca and the Ca:P ratio.

According to Challa and Braithwaite (1988), the absorption of ingested phosphorus is reduced when diets have a Ca:P ratio higher than 5:1, because it results in the precipitation of phosphorus in the digestive tract. This may culminate in lower performance and reproductive problems in the animals.

Table 6. Final weight (FW, kg), feed conversion (FC) and average daily gain (ADG, kg/day) of Nellore heifers according to the roughage

Item	Roughage					Contrasts				CV (%)
	Sugarcane silage (% CaO)			Sugarcane	Corn Silage					
	0.0	0.75	1.50			A[1]	B[2]	C[3]	D[4]	
FW	294.67	310.17	296.67	320.25	353.58	<.0001	<.0001	0.5065	0.0565	16.5
FC	17.89	12.10	12.86	10.80	8.34	<.0001	0.0033	0.5154	0.0665	17.0
ADG	0.227	0.423	0.367	0.527	0.94	<.0001	0.0048	0.0709	0.0599	25.9

[1] Diet with corn silage × sugarcane-based diets, [2] Sugarcane-based diet × diet containing sugarcane silages. [3] Linear effect of inclusion of CaO in the sugarcane silage,[4] Quadratic effect of inclusion of CaO in the sugarcane silage

Indeed, the calcium intake affects phosphorus absorption. Field (1983) investigated the effect of different proportions of calcium and phosphorus in the absorption of phosphorus in sheep. The studied levels were 1.5, 3.1 and 6.2 g phosphorus and 3.4 or 5.4 g calcium, and the Ca:P ratios varied from 0.6 to 3.6. With the highest calcium levels, phosphorus absorption was reduced by 18%, which can be explained in part by the formation of low-solubility salts.

The injection of calcium in the animals resulted in an increase in calcium retention by the skeleton, leading to a higher need for phosphorus. As a consequence, there is higher absorption of phosphorus and lower endogenous fecal loss (Braithwaite, 1984). It is not clear if this reduction in the endogenous fecal loss of phosphorus results from the lower secretion of phosphorus in the tract, via saliva, or if it results from an increase in the phosphorus absorptive efficiency which would affect both the dietary and salivary phosphorus.

According to Rajaratne *et al*. (1994), the increase in the absorption and retention of phosphorus as a consequence of the higher calcium retention is caused by higher efficiency absorption rather than by reduction in the secretion of endogenous phosphorus in the digestive tract. There is a strong relationship between the metabolisms of Ca and P, because these minerals are regulated by identical biological and physiochemical mechanisms. They are present in the bones in the form of hydroxylapatite, at the proportion of 2:1 (Ca:P), and due to the statistical relationship of these minerals in the bones, the effect of the calcium metabolism relative to the bone absorption or resorption may alter the concentrations of P in the blood (Valk, *et al*., 2000).

The regulation of these minerals is influenced by two important hormones: the parathyroid hormone (PTH) and 1,25 dihydroxyvitamin D [1,25$(OH)_2$D], which is the metabolic hormone of vitamin D produced in the kidneys (Horst, 1986). Dua and Care (1999) observed that the infusion of phosphate in the rumen of cattle increased the absorption of Ca through the rumen wall and suggested that the change in the proportion between P and Ca in the blood probably interferes with the secretion of circulating PTH, which increases in response to the phosphate infusion.

1,25$(OH)_2$D is considered the hormonal form of vitamin D, because that it meets the criteria employed for hormones, i.e., it is produced in one location (in the kidney) and will act in another one (intestine, bones and teeth, as destination tissues), and its production is regulated by a feedback mechanism (Zeola & Geron, 2006).

Under hypercalcemia there is suppression of PTH and consequent reduction of the synthesis of 1,25 dihydroxyvitamin D, which results in a decrease in the renal absorption of calcium, mobilization of bone calcium, and absorption of calcium by the intestine. Hypercalcemia also stimulates the secretion of calcitonin by thyroid C-cells through a positive-feedback mechanism. Calcitocin has a minor hypocalcemic effect under normal circumstances, as compared with the effects of PTH and 1,25 dihydroxyvitamin D.

Thus, these three calciotropic hormones act in their effector organs, especially bones, intestine and kidneys, by altering the transport of the calcium ions to the interior or exterior of the extracellular fluid, thereby modulating the maintenance of homeostasis of this ion (Brown, 1999; Hauache, 2001). As previously mentioned, unlike monogastrics, ruminants tolerate higher differences in the Ca:P ratio of the diet, which can vary from 1:1 to 5:1, provided that the right level of P is supplied in the diet. In the present study, the Ca:P ratio of the diets containing sugarcane silage were 1.5:1; 3.3:1

and 5.6:1, respectively, for the CaO levels of 0.0, 0.75 and 1.5%.

Thus, considering the abovementioned observations, the drop observed in the performance of the animals that received the diet with sugarcane silage plus 1.5% CaO may also be due to the problem of excessive calcium intake and its imbalance with the phosphorus-intake level. The growth speed is also a consequence of the higher amount of energy ingested and the higher digestibility of nutrients by the animals fed diets containing higher levels of concentrate (Bond *et al*., 1972). In this context, it can be observed that the diets which provided higher energy intake (Table 3) also provided better performance and feed conversion.

Conclusions: The energy intake and consequently the performance of Nellore growing heifers fed corn silage-based diets are better than those of heifers fed sugarcane. The use of sugarcane silages without additives results in a lower energy intake and worse performance. The CaO level in sugarcane silage that resulted in the best energy intake is 0.82%.

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