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Fatty acid profile, meat quality, and carcass traits of Nellore young bulls fed different sources of forage in high-concentrate diets with crude glycerin

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ABSTRACT - The objectives of this study were to evaluate the effect of forages with different nutritional values — specifically, corn silage (CS), sugar cane (SC), and sugar cane bagasse (SB) — in diets with crude glycerin, on carcass traits, meat quality, and fatty acid profile, using young Nellore bulls finished in the feedlot. Thirty young Nellore bulls with an initial average body weight of 416.70±24.74 kg were randomly assigned to three treatments containing different sources of forage. The carcass traits and variables related to meat quality of the Nellore young bulls were not significantly influenced by different sources of forage in diets with crude glycerin. The yellow color index was significantly greater in the fat of animals fed corn silage. Heptadecenoic fatty acid was significantly lower in the meat of animals fed sugar cane bagasse. The sources of forage in diets with crude glycerin did not influence the profile of saturated, monounsaturated, or polyunsaturated fatty acids in the *longissimus* muscle. Overall, our results indicate that none of the treatments changed the carcass and meat quality traits of Nellore young bulls finished in the feedlot. Thus, sugar cane and sugar cane bagasse could be used in feedlot as a viable forage alternative to corn silage.

Key Words: beef cattle, feedlot, forage NDF

Introduction

Beef is considered a highly nutritious and valued food (Scollan et al., 2006). The polyunsaturated fatty acids (PUFA), such as linoleic and α-linoleic, present in beef are considered essential for humans because they are not synthesized in the body, and they are the main precursors of conjugated linoleic acid (CLA; Oliveira et al., 2011). Therefore, strategies to enrich such properties in beef are highly sought.

Several studies have shown that the fatty acid profile of meats can be influenced by the feedstuff used in animal diets (Pereira and Vicente, 2013). By feeding animals diets with a high percentage of concentrate, such as feedlot diets, it may be possible to modify meat fatty acid profile by decreasing biohydrogenation (the process responsible for the saturation of dietary fatty acids in ruminants) via the inhibition of lipolysis (Harfoot and Hazlewood, 1988; Doreau and Ferlay, 1994). However, the unstable prices of grains have encouraged research towards alternative feedstuff for animals. Crude glycerin, a byproduct from biodiesel agroindustry, has been used to replace corn in ruminant diets by up to 10% of diet dry matter (DM) (Mach et al., 2009).

A factor that may influence meat fatty acid deposition is the forage source used in diets. High-concentrate diets are associated with a high indigestible fraction (iNDF), and exhibit higher passage rates in animals (Pereira et al., 2000; Mertens, 2001). These diets subsequently affect ruminal biohydrogenation that could be an influence on fatty acid flow to the duodenum, and thus interfere with fatty acid muscle deposition (Scollan et al., 2014). Among the options for ruminant feed in Brazil, sugar cane and sugar cane bagasse have higher availability, and lower cost per unit of DM (Santos et al., 2011) compared with corn silage; however, they have nutritional limitations, such as a higher level of iNDF (Ezequiel et al., 2006; Queiroz et al., 2012).

The objectives of this study were to evaluate the effect of forages with different nutritional values — specifically, corn silage, sugar cane, and sugar cane bagasse — in diets with crude glycerin, on carcass traits, meat quality, and fatty acid profile of young Nellore bulls finished in the feedlot.

Material and Methods

The trial was carried out following humane animal care and handling procedures, according to the UNESP

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guidelines. All experimental procedures were approved by the Commission on Ethics and Animal Welfare (CEBEA) of Colégio de Ciências Agrárias e Veterinárias (case no. 021118/11).

Animals were weighed, identified, and housed in individual pens with feeders and drinkers. The animals spent 21 days adapting to the diets, facilities, and management. The 30 remaining animals, with average initial body weights of 416.70±24.74 kg, were randomly assigned to one of the following experimental diets. Three sources of forage were used: corn silage (CS), sugar cane (SC), and sugar cane bagasse (SB). The neutral detergent fiber from forage (NDFf) was fixed at 15% of DM to ensure ruminal fiber requirements for avoiding ruminal disturbances. Crude glycerin was included as 10% of DM, replacing corn in the concentrate.

The corn silage used in the present study was obtained from a UNESP farm. A corn hybrid (whole plant; hybrid 2B688Hx - Dow AgroSciences) was harvested at about 31% DM and chopped to 5 cm. The chopped corn material was placed in a trench-type silo, covered with black plastic, and ensiled for two months minimum. Sugar cane was obtained from a local farm, chopped to particles of 2-3 cm. Sugar cane bagasse, in particles of 3-4 cm, was obtained from a private biofuel plant. The forage particle sizes were different due to their precedence. Crude glycerin was acquired from the soybean-oil based biodiesel production company ADM (Rondonópolis, Brazil) (80.34% glycerol, 1.59% ether extract, 5.03% ash, and 12.02% water).

The concentrates were composed of ground corn, soybean meal, crude glycerin, and mineral supplement (Table 1). Concentrate ingredients were ground in a hammer mill fitted with strainers and 2-mm sieves. Continuous homogenization of the diets was performed in a horizontal mixer for 15 min. The diets were calculated using the Agriculture and Food Research Council system (AFRC, 1993) for 1.5 kg of average daily gain.

At the beginning of the experiment, animals were weighed after 16 h solid fast to obtain the values of shrunk body weight (SBW), and assigned randomly to the three treatments, at 10 animals per treatment. Animals were fed twice daily, at 08.00 h and 16.00 h, and feed refusals were recorded daily for each pen. The amount of feed offered to animals was adjusted to allow a surplus of approximately 10% in relation to the total amount consumed on the previous day.

After 85 days of feeding, all animals were slaughtered at a commercial beef plant; a shrunk body weight of 554.51±38.51 kg was recorded. Pre-harvest handling was in accordance with good animal welfare practices, and slaughtering procedures followed the Sanitary and Industrial Inspection Regulation for Animal Origin Products (Brasil, 1997).

After slaughter, carcasses were identified, washed, and then divided into halves, which were individually weighed. All carcasses were refrigerated at 0 °C for approximately 24 h, then taken from the cooling chambers and weighed again to determine cold carcass weight (CCW). The difference between the CCW and hot carcass weight was used to calculate carcass shrink loss (CSL). Dressing percentage was calculated by dividing hot carcass weight by final SBW, and then multiplying the result by 100. After 24 h postmortem chill, final pH, 12th rib fat thickness (RFT), and 12th rib *longissimus* muscle area (LMA) were measured on the left side of each carcass. The final pH was measured at approximately 4 cm depth on the *longissimus*

Table 1 - Proportion of ingredients and composition of the experimental diets (DM basis)

	Diet		
	CS	SC	SB
Ingredient,% DM			
Corn silage	28.8		
Sugar cane		27.5	
Sugar cane bagasse			17.3
Corn	35.7	33.7	45.1
Soybean meal	22.5	25.8	24.6
Crude glycerin	10.0	10.0	10.0
Mineral supplement[1]	3.00	3.00	3.00
Chemical composition			
Dry matter, kg	70.97	73.66	84.29
Organic matter, % DM	90.95	91.80	92.00
Crude protein, % DM	18.13	17.86	17.89
NDF, % DM	31.69	30.70	33.27
NDFf, % DM	15.0	15.0	15.0
Ether extract, % DM	2.64	2.12	2.60
Gross energy, MJ	17.53	17.34	17.41
Metabolizable energy[2], MJ	10.15	10.39	10.91
Fatty acid profile, g/100 g fatty acid methyl esters			
C14:0	0.15	0.61	0.34
C16:0	13.8	16.4	16.2
C17:0	0.24	0.29	0.53
C18:0	3.31	3.45	3.74
C18:1 *c*9	29.0	24.6	27.9
C18:2	44.4	40.5	39.5
C18:3	2.62	2.14	2.16
Saturated fatty acids	19.5	23.1	23.4
Unsaturated fatty acids	77.5	73.3	73.0
Monounsaturated fatty acids	30.5	26.8	30.6
Polyunsaturated fatty acids	47.0	46.5	42.4

CS - corn silage; SC - sugar cane; SB - sugar cane bagasse; NDF - neutral detergent fiber; NDFf - NDF from forage.

[1] Composition of product expressed in g or mg per kg of supplement: calcium - 210 g; phosphorus - 20 g; sulfur - 37 g; sodium - 80 g; copper - 490 mg; manganese - 1.424 mg; zinc - 1.830 mg; iodine - 36 mg; cobalt - 29 mg; selenium - 9 mg; fluorine (max) - 333 mg.

[2] Metabolizable energy estimated as total apparent digestibility of gross energy × 0.82 (AFRC, 1993).

In the experimental studies used in our database, the digestibility energy of the diet was measured by Ribeiro (2015).

muscle of the left side of each carcass (12th rib) using a pH-meter (Testo 230, Texto GmbH & Co, Germany). *Longissimus* muscle area was traced on transparencies and measured later with a planimeter (Greiner et al., 2003). Rib fat thickness measurements were taken at the 3/4 mark along the ventral length of the *longissimus* muscle, using a digital caliper.

A boneless *longissimus* section, 10 cm thick, was removed from the posterior end of the wholesale rib. *Longissimus* muscle samples were vacuum-packaged individually and stored at −20 °C for two days. Each frozen *longissimus* sample was standardized from the posterior end into one 2.54-cm thick steak sample (American Meat Science Association (AMSA), 1995) for Warner–Bratzler shear force measurement, and into two 1-cm thick steaks for other analyses. All steaks were vacuum-packaged and held at −20 °C for 10 days, prior to analysis.

For proximate analysis, the epimysium was removed from the samples prior to lyophilization for 36 h. Samples were then ground and analyzed for ether extract (EE; Association of Official Agricultural Chemists (AOAC) Official Method No. 920.85) (AOAC, 1990) to determine the chemical composition of each *longissimus* sample.

Meat and fat color were determined as described by Houben et al. (2000), using a Hunterlab colorimeter (Hunterlab MiniScan EZ, Hunterlab, Reston, Virginia, USA) evaluating lightness (L*), redness (a*), and yellowness (b*). The color aspects were assessed by the CIE L*a*b* color system using 0°/45°. Thirty minutes prior to the assessment, cross sections were made at the surface of the samples to expose the myoglobin to oxygen; the same steps were followed for the fat color measurement. Color was measured at three different points and average values were calculated. Black and white standards were used to calibrate the colorimeter before sample analysis.

Warner-Bratzler shear force (WBSF) steaks were thawed at 4 °C for 24 h, then oven-broiled in an electric oven (LTedesco, Caxias do Sul, RS, Brazil) preheated to 175 °C. Internal steak temperatures were monitored by 20-gauge copper-constantan thermocouples (Omega Engineering, Stamford, CT, USA) placed in the approximate geometric center of each steak, and attached to a digital monitor. When internal steak temperature reached 35 °C, the steak was turned over and allowed to reach an internal temperature of 70 °C before removal from the oven. Cooked WBSF steaks were then cooled for 24 h at 4 °C (AMSA, 1995). Five round cores (1.27-cm diameter) were removed from each steak, parallel to the long axis of the muscle fibers (AMSA, 1995). Each core was sheared once through the center, perpendicular to the fiber direction, by a Warner-Bratzler shear machine (G-R Manufacturing Company, Manhattan, KS, USA). Cooking loss was evaluated on the steaks used for WBSF measurement. Total cooking loss was calculated as the difference between the weight of the steaks before and after oven broiling; thawing loss was calculated as the difference between the weight of the steaks before and after thawing, and total loss was calculated by adding cooking loss and thawing loss values together.

For the determination of thiobarbituric acid (TBA) reactive substances, meat samples (50 g) were collected, identified, and vacuum-packaged in polyethylene bags. A 10-g sample was ground in a multiprocessor and 0.2 mL of antioxidant BHT (0.03%) was added, along with 50 mL of distilled water, and 1 mL of an antifoaming solution (Sigma A5758, São Paulo, Brazil). The samples were then ground again and homogenized for 1 min. After homogenization, the samples were transferred to a 250-mL volumetric flask containing pieces of porcelain, to which 50 mL of a 4 M HCl solution were added. Subsequently, the samples were distilled in a blanket heater at 100 °C until 50 mL of the distillate was collected. From the distillate, 5 mL were transferred to a test tube and 5 mL of a 0.02 M TBA solution were then added. The test tubes remained in a water bath at the boiling point for 35 min. Test tubes were then cooled with tap water, and absorbance was measured at 530 nm with a spectrophotometer. The TBA reactive substance values, expressed in milligrams of malondialdehyde per kilogram of meat, were obtained by multiplying the absorbance by 7.8.

To determine the fatty acid composition of the fresh meat, samples of the transversal section were collected from the *longissimus* muscle, freeze-dried, and then frozen for lipid extraction and methylation. The fatty material was extracted using a mixture of chloroform-methanol, as described by Bligh and Dyer (1959), and the fatty acid methyl esters (FAME) were obtained by ISO 12966 method (ISO 12966-2, 2011). Qualitative and quantitative measurements of fatty acid content were performed by gas chromatography using a chromatograph (Shimadzu, Kyoto, Japan - Model GC-14B with a Communication Bus Module-CBM 102) with a flame ionization detector and fused silica capillary column (Omega wax 250), which was 30 m in length, 0.25 mm in diameter, and had a film thickness of 0.25 μm (Supelco SP-24136). Helium was used as a carrier gas at a flow of 1 mL/min. A 1 μL aliquot of the sample was injected into a "split" at a division ratio of 1/100, and at a temperature of 250 °C. The temperature of the oven was programmed to remain at 100 °C for 2 min, and then increased to 220 °C by 4 °C/min for 25 min, while the detector was set at 280 °C. Methyl esters of the fatty

acids were identified and quantified by comparison with the retention times and concentrations of methyl esters of standard fatty acids.

The experimental design was completely randomized, using the 30 animals, three treatments, and ten replications. The data were analyzed using the PROC MIXED procedure of SAS (Statistical Analysis System, version 9.1), with fixed effects: diets (2 degrees of freedom (df)) and a residual error as random effect. Tukey's test was used to compare the least square means. In all the comparisons, significance was declared at P<0.05. The following model was used:

$$Y_{ij} = \mu + T_i + e_{ij},$$

in which Y_{ij} = observation of animal *j* subjected to treatment *i*; μ = overall mean; T_i = effect of treatment *i* (*i* = 1; ... 5); and e_{ij} = residual experimental error.

Results

The carcass traits of the Nellore young bulls were not significantly influenced (P>0.05) by different sources of forage in diets with crude glycerin (Table 2).

Similar results were found for values of pH (P = 0.64), meat color (L* (P = 0.20); a* (P = 0.43); b* (P = 0.39)), and fat color (L* (P = 0.59); a* (P = 0.12)). The CS diet increased b* of fat (P = 0.03), but did not differ significantly from animals fed the SC diet (Table 3). The sources of forage in diets with crude glycerin did not significantly influence (P>0.05) any of the variables related to meat quality of the *longissimus* muscle (Table 3).

The sources of forage in diets with crude glycerin did not influence (P>0.05) the profile of saturated and monounsaturated fatty acids (MUFA) in the *longissimus* muscle (Table 4), with the exception of heptadecenoic acid (P = 0.04), which was lower in animals fed the SB diet. None of the treatments affected (P>0.05) the polyunsaturated fatty acid profile of *longissimus* muscle (Table 4).

Table 2 - Means for cold carcass weight (CCW), cold carcass dressing (CCD), 24-h carcass shrink loss (CSL), rib fat thickness (RFT), and *longissimus* muscle area (LMA) of Nellore young bulls fed different sources of forage in high-concentrate diets with crude glycerin

Parameter	Diet			SEM	P-value
	CS	SC	SB		
Number of bulls	10	10	10		
CCW, kg	288	298	295	8.33	0.71
CCD, %	53.2	53.4	53.0	0.74	0.90
CSL, %	2.94	2.82	2.55	1.04	0.12
RFT, mm	5.09	4.24	4.87	0.36	0.18
LMA, cm^2	75.9	80.2	79.2	1.59	0.53

CS - corn silage; SC - sugar cane; SB - sugar cane bagasse; SEM - standard error of the mean.

Discussion

The NDF contents of the forages used in this study were different: 86.5%, 55.5%, and 54.4%, for SB, CS, and SC, respectively. It is known that this fraction affects the energy utilization of a feedstuff by the animals. We chose to fix NDFf at 15%. According to the recommendations of Goulart and Nussio (2011), this level of NDFf ensures the minimum requirements for rumen health and maximizes the efficiency of the animal feed. Therefore, forage:concentrate ratios were different across the diets: CS = 28%, SC = 27%, and SB = 17%, to supply appropriate NDFf levels.

Carcass traits were not influenced by the different sources of forage in diets with crude glycerin. This may be attributed to similarity of growth rate, due to the similar genetic and nutritional history among the animals used in this study. Thus, the lack of differences for cold carcass dressing (CCD) may be attributed to similarity of CCW. Macitelli et al. (2007) also reported no differences in CCD among crossbreed bulls fed CS or SC. Furthermore, the inclusion of crude glycerin as a replacement for corn (10% DM) in beef cattle diets did not change carcass traits,

Table 3 - Means for pH, Warner-Bratzler shear force (WBSF), cooking loss (CKL), ether extract (EE), and malonaldehyde (MDA mg/kg of meat), and color characteristics (L*, a*, b*) of meat and subcutaneous fat of the *longissimus dorsi* of Nellore young bulls fed different sources of forage in high-concentrate diets with crude glycerin

Parameter	Diet			SEM	P-value
	CS	SC	SB		
Number of bulls	10	10	10		
pH	5.34	5.92	5.81	0.79	0.64
WBSF, kgf	3.50	3.52	3.74	0.13	0.73
CKL, %	12.94	12.82	12.55	0.08	0.12
EE, %	3.90	3.52	4.53	0.21	0.17
MDA, mg/kg	0.49	0.44	0.49	0.02	0.39
Meat color					
L*	41.7	38.1	39.4	0.83	0.20
a*	17.3	16.4	17.0	0.28	0.43
b*	14.7	13.3	13.8	0.41	0.39
Fat color					
L*	67.7	67.7	69.1	0.63	0.59
a*	10.0	9.70	8.20	0.39	0.12
b*	17.8a	16.7ab	15.5b	0.35	0.03

a, b - within a row, means with different letters differ by Tukey's test (P<0.05).
CS - corn silage; SC - sugar cane; SB - sugar cane bagasse; SEM - standard error of the mean; L* - luminosity (0 = black and 100 = white); a* - index from green (−) to red (+); b* = index from blue (−) to yellow (+).

Table 4 - Means for main saturated, unsaturated, and polyunsaturated fatty acids (%) found in the *longissimus* of Nellore young bulls fed different sources of forage in high-concentrate diets with crude glycerin

Fatty acid	Lipid number	Diet			SEM	P-value
		CS	SC	SB		
Number of bulls		10	10	10		
Saturated fatty acids (SFA)						
Capric	10:0	0.05	0.04	0.04	0.03	0.77
Lauric	12:0	0.05	0.05	0.05	0.03	0.77
Myristic	14:0	2.57	2.3	2.31	0.16	0.93
Palmitic	16:0	24.3	24.1	26	0.47	0.2
Margaric	17:0	1.01	0.89	0.48	0.09	0.15
Stearic	18:0	16.4	16	16.2	0.52	0.96
Monounsaturated fatty acids (MUFA)						
Myristoleic	14:1 *cis*-9	0.48	0.58	0.6	0.05	0.92
Palmitoleic	16:1 *cis*-9	2.5	2.66	2.7	0.12	0.79
Heptadecenoic	17:1	0.83a	0.88a	0.70b	0.03	0.04
Oleic	18:1 *cis*-9	38.6	39.4	36.8	0.93	0.51
Eicosenoic	20:1 *cis*-9	0.18	0.2	0.14	0.01	0.12
Polyunsaturated fatty acids (PUFA)						
Linoleic	18:2 *cis*-9, *cis*-12	6.33	6.44	7.22	0.42	0.93
α-linolenic	18:3 n-3	0.41	0.37	0.44	0.03	0.72
CLA	18:2 *cis*-9, *trans*-11	0.33	0.29	0.29	0.01	0.20
Eicosatrienoic	20:3 n-6	0.54	0.64	0.82	0.03	0.63
Arachidonic	20:4 n-6	0.10	0.10	0.10	0.16	0.99
EPA	20:5 n-3	0.30	0.29	0.39	0.02	0.65
DTA	22:4 n-6	0.34	0.44	0.58	0.02	0.41
DHA	22:6 n-3	0.07	0.09	0.12	0.01	0.85
Total SFA[1]		43.7	40.8	40.6	0.84	0.75
Total MUFA[2]		44.8	46.0	43.2	1.01	0.52
Total PUFA[3]		11.0	12.0	14.4	0.66	0.81
Total UFA[4]		56.3	59.1	59.4	0.84	0.75
UFA/SFA		1.30	1.45	1.43	0.04	0.71
n-6/n-3[5]		12.4	13.3	12.3	0.40	0.49

a, b, c - within a row, means with different letters differ by Tukey's test (P<0.05).
CS - corn silage; SC - sugar cane; SB - sugar cane bagasse; SEM - standard error of the mean; CLA - conjugated linoleic acid; EPA - eicosapentaenoic acid; DTA - docosatetraenoic acid; DHA - docosahexaenoic acid.
[1] SFA - saturated fatty acids = C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; C18:0; C20:4 n6.
[2] MUFA - monounsaturated fatty acids = C14:1c9; C16:1c9; C17:1; C18:1c9, C18:1n7; C20:1c9:C24:1n9.
[3] PUFA - polyunsaturated fatty acids = C18:2c9c12; C18:3n6; C18:3n3 C18:2c9t11; C20:2; C20:3n6; C20:4n6; C20:5n3; C22:4n6; C22:6n3.
[4] UFA - unsaturated fatty acids = MUFA + PUFA.
[5] n-6 = C18:2c9c12; C18:3 n6; C20:3 n6; C20:4n6; C22:4n6; n-3 = C18:3 n3 + C20:6 n3 + C20:5n3.

such as CCW, CCD, RFT, and LMA, of animals finished in the feedlot (Lage et al., 2014). This could be because glycerin has a similar energy content to corn: approximately 1.04 MJ/kg (San Vito et al., 2015).

Longissimus muscle area is indicative of the muscle development of animals, and increases as the edible portion of carcass increases. In addition, LMA is correlated with CCW and high commercial value cuts. Thus, we can infer that there was no significant difference in muscle development in animals fed different sources of forage in diets with crude glycerin (Table 3). The RFT of a carcass acts as a thermal insulator that directly affects carcass cooling rate and rigor mortis, i.e., the conversion of muscle into meat (Savell et al., 2005). In the present study, a similar deposition of RFT was observed among diets (Table 3): it was greater than 3 mm, which is the minimum value recommended in Brazil (Diniz et al., 2010). Agreeing with our results, Brondani et al. (2006) did not report significant differences for LMA and RFT of animals finished in the feedlot, when fed CS or SC diets. Moreover, Lage et al. (2014), in a study using CS with or without crude glycerin, also found no significant differences in LMA and RFT.

The 12th rib fat thickness can play a significant role in reducing CSL, e.g., by reducing carcass dehydration rate during the chilling process (Dolezal et al., 1982). So, according to similar deposition of RFT in the present study, no differences were observed for CSL values.

The lack of effects of diet on final pH (Table 3) in the carcass reflects accumulated lactic acid due to the ATP resulting from metabolism of glycogen reserves. It has been shown that cattle finished in feedlots have a greater availability of glycogen at the time of slaughter, and therefore lower final pH in the meat (Neath et al., 2007). In addition, crude glycerin, as a gluconeogenic precursor, could

preserve the reserves of glycogen of the animal. Carcass pH is directly correlated with meat quality traits, such as meat color (Jeremiah et al., 1991). Nevertheless, pH values in the present study fell outside the optimum range suggested for beef cattle (5.4-5.8), as previously reported by Abularach et al. (1998) and Mach et al. (2008). According to Felício (1997), this could be due to stressor factors during pre-slaughter handling, such as long starvation, transportation, and sexual behavior of non-castrated males.

The values of WBSF obtained in the present study were within the range proposed by Shackelford et al. (1991), who classified tender *longissimus* muscle as having less than 4.5 kg of shear force. Average WBSF values were lower (3.58 kgf) than those obtained by Zorzi et al. (2013), who reported 4.25 kgf WBSF from Nellore bulls finished in the feedlot. According to Crouse et al. (1993), meat from *Bos indicus* cattle has also been shown to be more variable in tenderness than meat from *Bos taurus* cattle.

The meat juiciness, aroma, and tenderness are traits related to lipid content; these showed no difference between diets in the present study. Additionally, marbling fat is the fat deposit of most interest, in relation to fatty acid, due to its average composition of saturated (0.45-0.48%), monounsaturated (0.35-0.45%), and polyunsaturated of up to 0.05% of total fatty acids (Scollan et al., 2006).

Color is the attribute of meat that has most influence in the decision of consumers to buy, and it could vary according to age and sexual condition of the animal (Costa et al., 2002; Ramos and Gomide, 2007). In the present study, animals had similar age and sexual condition, and we observed no significant differences in meat color.

The color of bovine subcutaneous adipose tissue (carcass fat) is an important component of the beef carcass quality (Wood and Fisher, 1997). The b* values (Table 3) are higher in the fat of animals fed CS and SC than those fed SB. This can be explained by the fact that CS and SC forages contain higher levels of carotene than SB (Krishna, 1985; Pickworth et al., 2012). Deposition of carotenoids in the fat comes strictly from diet in ruminants, since they are incapable of *de novo* synthesis of carotenoids (Goodwin, 1992). Dunne et al. (2009) stated that the yellow coloration of fat is related to the amount of carotenoids in the diet. Carotenoids are present in most photosynthetic organisms, including higher plants such as the whole plant of the corn used to make silage, and the sugar cane used in this study. This supports the results of the present study (Table 3).

In the present study, there was no significant difference in the fatty acid profile of meat from animals fed different sources of forage in diets with crude glycerin. Changes in passage of dietary components from the rumen could be related to changes in DMI resulting from differences in forage source and level. If NDFf increases the passage of the grain portion of the diet, less fermentation would occur in the rumen (Galyean and Defoor, 2003). Thus, we could infer that different sources of forages, used on an equal forage level basis in the diets with high percentages of concentrate, prevent digestive upsets and promote low ruminal biohydrogenation, thus leading to a greater passage of unsaturated fatty acids to the intestine. Moreover, according to Zinn and Ware (2007), ruminal fiber digestion may be more limited by ruminal fibrolytic capacity (condition of ruminal pH), which is related to biohydrogenation, than by the native degradability of the fiber (digestive quality of the fiber). Thus, low-quality forage, such as SB and SC, in diets with crude glycerin, could be used in feedlots, promoting similar meat quality to animals fed CS, which is considered good-quality forage.

Meat of animals fed different sources of forage in diets with crude glycerin showed a similar amount of saturated fatty acids. This result is important because these fatty acids can raise low-density lipoprotein (LDL) in human blood (Wood et al., 2004) and they could interfere with the normal operation of the LDL receptors in the liver, increasing LDL concentration in the plasma (Woollet et al., 1992). Despite the status of stearic acid (C18:0) as a saturated fatty acid, it has a neutral role on cardiovascular disease risk. Furthermore, considering that humans can convert stearic acid to oleic acid, whose consumption has been associated with several health benefits (Covas, 2007), meat with higher amounts of this fatty acid is desirable.

The PUFA and MUFA are generally regarded as beneficial for human health (Scollan et al., 2006). Among the PUFA, linoleic (C18:2 c9c12) and α-linolenic (C18:3 n3) fatty acids are considered the most important because they are not synthesized in the body, and they are the main precursors of CLA (Oliveira et al., 2011). The meat of animals fed different sources of forage in diets with crude glycerin showed similar amounts of oleic and linoleic fatty acids. These are important results because of the relationship of these fatty acids with health, e.g., hypocholesterolemic properties (Mir et al., 2003).

Similar deposition of MUFA was observed among the studied diets, except for heptadecenoic fatty acid (C17:1); which showed similar amounts in meat of animals fed CS and SC. This could be due to the greater amount of the precursor C17:0 (margaric acid), which although not statistically different, was twice larger in CS and SC than SB. The greater amount of C17:0 in the intestinal tissues was desaturated to C17:1 by the enzyme delta-9 desaturase (Fievez et al., 2003) in muscles of animals fed CS and

SC. According to Mir et al. (2003) this fatty acid is highly desirable because it has hypocholesterolemic properties.

Ruminant products such as beef and milk are dietary sources of CLA (Ritzenthaler et al., 2001). The dominant CLA in beef is the cis-9, trans-11 isomer, which has been identified as possessing a range of health-promoting biological properties including antitumoral and anticarcinogenic properties (De la Torre et al., 2006). The CLA (cis-9, trans-11) content in ruminant products is a consequence of two processes: a partial biohydrogenation of the dietary fatty acids (linoleic and linolenic), or an endogenous desaturation by Δ^9-desaturase enzyme of trans-vaccenic fatty acid (subcutaneous or intramuscular fat tissue). Thus, we could infer that the lack of differences in CLA levels in the meat of animals fed different sources of forage in diets with crude glycerin may be due to the similar amount of NDFf among diets, which decreased ruminal biohydrogenation of total UFA without changing the flow of UFA (Ribeiro, 2015) consequently not altering their deposition in the muscle.

Meat from animals fed different sources of forage in diets with crude glycerin presented similar values for malondialdehyde. The average value was 0.47 for all treatments, less than the 2.28 considered critical by Campo et al. (2006), which indicates a level of lipid-oxidation products that produce a rancid odor and taste detectable by consumers.

Conclusions

Sugar cane and sugar cane bagasse, included at 15% of neutral detergent fiber from forage in diets with crude glycerin, can be used as alternative forages for corn silage in the feedlot without altering carcass traits, meat quality, or the *longissimus* fatty acid profile.

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