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Bermuda Grass Hay or Sorghum Silage with or without Yeast Addition on Performance and Carcass Characteristics of Crossbred Young Bulls Finished in Feedlot

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ABSTRACT : This experiment was carried out to evaluate performance and carcass characteristics of 40 crossbred young bulls (Zebu×European) finished in a feedlot under two roughage sources (Bermuda grass hay or sorghum silage) with or without the addition of yeast (*Saccharomyces cerevisae*). The bulls were 20 months old, their initial average weight was 356 kg and they were allocated into four groups of ten animals. The experimental diets were Bermuda grass, Bermuda grass+yeast, sorghum silage and sorghum silage +yeast. Animal performance and carcass characteristics were not influenced by roughage source or yeast addition. The average daily weight gain was 1.50 kg, dry matter intake (DMI) was 11.1 kg/d, DMI as percentage of liveweight was 2.60% and feed dry matter conversion was 7.70. The mean dressing percentage was 52.0% and hot carcass weight was 268 kg. Carcass conformation was classified between good-minus to good. Carcass length (137 cm), leg length (72.9 cm) and cushion thickness (26.6 cm) were not influenced by treatments. The average fat thickness was 3.80 mm and the *Longissimus* muscle area was 66.9 cm^2. The classification of color, texture and marbling were slightly dark red to red, fine and slight-minus to light-typical, respectively. The mean percentage of bone, muscle and fat in the carcass was 15.5%, 62.3% and 22.5%, respectively. Yeast addition increased γ-linolenic fatty acid (0.15 vs. 0.11%) deposition. Bermuda grass hay increased deposition of α-linolenic (0.49 vs. 0.41%), arachidonic (2.30 vs. 1.57%), eicosapentaenoic (0.41 vs. 0.29%), docosapentaenoic (0.80 vs. 0.62%), docosahexaenoic (0.11 vs. 0.06%) and *n*-3 fatty acids, and reduced *n*-6: *n*-3 ratio in meat, when compared to sorghum silage treatments. The treatments had no effect on saturated fatty acids (49.5%), polyunsaturated fatty acids (11.8%), *n*-6 fatty acids (9.87%), *n*-3 (1.61%) and PUFA:SFA ratio (0.24). Monounsaturated fatty acid levels were higher on sorghum silage (40.7 vs. 37.7%). The addition of yeast caused higher *n*-6: *n*-3 ratio (7.28 vs. 5.70) than treatments without yeast. (**Key Words :** Bos taurus×Bos indicus, Carcass, Bermuda Grass, Sorghum, Yeast)

INTRODUCTION

Brazil has the largest commercial cattle herd in the world, with approximately 159 million animals and a production of approximately 8.2 million tons of carcass each year (Anualpec, 2007). From this total, about 30% (2.4 million tons) is exported to several countries around the world. Nevertheless, it will be essential that Brazil employ new technologies in order to increase production and improve meat quality, aiming to satisfy domestic and foreign demand, and thus consolidating current markets and gaining access to new ones.

The consumer market for beef has become increasingly demanding as a result of negative factors associated with meat production and quality (Saucier, 1999). Among these factors is the relation between beef consumption and heart disease, atherosclerosis, intestinal cancer, obesity, among other diseases (Katan et al., 1994; Kwiterovich, 1997).

Lately, beef has experienced increased competition from other meat types (Prado and Souza, 2007). Brazil's prospects of consolidating its position in the world beef market have required that the beef industry constantly raise its standards to supply ever higher quality products (Prado, 2004). Meeting this goal is made more difficult by the stagnation in silage production, because 90% of beef produced in Brazil comes from animals raised in pasture systems (Prado and Moreira, 2002). It therefore becomes crucial to evaluate technological alternatives capable of

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Table 1. Percentage composition of experimental diets (% DM)

Parameters	Treatments			
	HAH[1]	HAY[2]	SOS[3]	SOY[4]
Sorghum silage			44.4	44.4
Bermuda grass hay	44.4	44.4		
Corn	43.0	43.0	43.0	43.0
Cotton meal	11.1	11.1	11.1	11.1
Urea	0.50	0.50	0.50	0.50
Limestone	0.50	0.50	0.50	0.50
Mineral salt	0.30	0.30	0.30	0.30
Total	100	100	100	100

[1] Bermuda grass Hay. [2] Hay+yeast. [3] Sorghum silage. [4] Silage+yeast.

raising efficiency in the industry, and consequently restructuring the chain of production for beef.

The State of Paraná, located in south Brazil, features a temperate climate as compared to the Center-West, North and Northeastern regions of the country. Consequently, researchers have concentrated since the 1980s on crossbreeding between Zebu and European breeds, with the objective of increasing production and quality in the meat of offspring (Perotto et al., 1998; Perotto et al., 2000).

Addition of yeast (*Saccharomyces cerevisae*) to the diet of ruminants has been explored by researchers (Pereira et al., 2001). The use of cultures, such as *Saccharomyces cerevisae* or its extracts, can improve weight gain, as a result of the response to increased dry matter intake (Wallace, 1994). Yeasts, especially *Saccharomyces cerevisae*, have been used in animal diets for several decades and are considered sources of high-quality proteins and B-complex vitamins, selenium and zinc (Queiroz et al., 2004).

The fatty acid profile (and consequently the fat content) of beef can be altered through the animals' diet, although this is more complex in ruminants than in monogastric species (Padre et al., 2006). Animals finished in pasture systems produce lower carcass fat levels (Moreira et al., 2003) and higher percentages of *n*-3 acids and conjugated linoleic acid (CLA) (Padre et al., 2007), both of which reduce the negative effects of fats on human health. Conversely, feedlot finishing produces animals with higher levels of total carcass fat and *n*-6 acids, thus elevating the *n*-6:*n*-3 ratio.

The objective of this study was to evaluate the performance, carcass characteristics and fatty acid composition of the *Longissimus* muscle of crossbred young bulls finished in a feedlot on two roughage sources (Bermuda grass hay or sorghum silage) with or without the addition of yeast (*Saccharomyces cerevisae*).

MATERIALS AND METHODS

Animal management and sampling

The Committee of Animal Production at the State University of Maringá approved this experiment, which was carried out at the Paranavaí Research Farm, in the town of Paranavaí, northwestern Paraná, Brazil.

Forty bulls were used (1/2 Zebu×1/2 European), with an initial average age of 20 months and live weight of 356 kg. The meat analyses were carried out in the Chemical Laboratory of the State University of Maringá. The young bulls were allotted to four groups of ten animals each.

The proposed treatments consisted of four experimental diets, composed of a concentrate containing cottonseed meal, corn, urea and mineral salt, and two types of roughage (sorghum silage (AG 2002®) or Bermuda grass hay (*Cynodon spp.*)), with or without the addition of yeast (*Saccharomyces cerevisiae*). The diets were calculated according to NRC (1996), with the objective of allowing for a weight gain of 1.5 kg and formulated to provide a roughage:concentrate ratio of 44:56 kg/animal/d, besides being isoproteic and isoenergetic (Table 1).

The amounts of concentrate offered daily to the animals were adjusted every 21 days, when the bulls were weighed. From the feed ingredients, the levels of dry matter (DM), crude protein (CP), organic matter (OM), ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and ether extract (EE) were analysed, according to Silva and Queiroz (2002) (Table 1). The analyses were conducted at the Food Analysis and Animal Nutrition Laboratory of the Department of Animal Science at the State University of Maringá.

Carcass characteristics

The animals were slaughtered at a commercial slaughterhouse 40 km away from the Paranavaí Research Farm, according to industrial practices in Brazil. Following slaughter, the carcasses were identified and chilled for 24 h at 4°C. After chilling, the right part of the carcass was used to determine the quantitative characteristics. Twenty-four hours later, LM samples were taken by a complete cross-section between the 12th and 13th ribs. The fat thickness was discarded and the muscle portion was frozen at -20°C for further analyses.

Hot carcass weight (HCW) : This was determined before chilling. The percentage of individual animal dressing was defined by the ratio of hot carcass weight to live weight.

Carcass conformation (CC) : This was evaluated by Müller's point scale (Müller, 1980) in which the highest value indicates the best conformation; muscle development was considered after the exclusion of fat thickness. The carcass conformation is reported as superior, very good, good, regular, poor, and inferior; ratings may also be reported as plus, average, and minus. The carcass length was evaluated by measurements taken from the skull board to the pubic bone on the anterior side of the first rib.

Table 2. Scale for marbling evaluation

Marbling	Plus	Mean	Minus	Marbling	Plus	Mean	Minus
Abundant	18	17	16	Small	9	8	7
Moderate	15	14	13	Light	6	5	4
Mean	12	11	10	Traces	3	2	1

Müller (1980).

Leg length (LL) : This was evaluated using a wood compass with metallic edges that measured the distance from the anterior border of the pubis bone to a middle point at the tarsus bone.

Cushion thickness (CT) : This was taken by a wood compass with metallic edges that measured the distance between the lateral face and the median at the superior part of the cushion.

Longissimus area (LA) : The right part of the carcass was measured after a cross-section cut was made between the 12th and 13th ribs using a compensating planimeter, which measures the areas of objects with irregular shapes.

Fat thickness (FT) : This was taken by a caliper averaging three points between the 12th and 13th ribs but over the LM.

Percentage of carcass muscle (MP), bone (BP) and fat (FP) : Muscle, bone, and fat were physically separated from the *Longissimus* section, which corresponds to the 10th, 11th and 12th ribs, and individually weighed according to Hankins and Howe (1946). The data were regressed to equations published by Müller et al. (1973) this model converts data to values corresponding to the 9th, 10th, and 11th ribs as follows:

$$\% M = 6.292+0.910X_1$$
$$\% B = 2.117+0.860X_2$$
$$\% F = 1.526+0.913X_3$$

in which:

X_i represents muscle, bone, and fat percentages.

The values corresponding to the 9th, 10th and 11th ribs were regressed to equations following the methods of Hankins and Howe (1946) to find the muscle (MP), bone (BP), and fat (FP) percentages, in which M, B, and F are the muscle, bone, and the fat estimates from the equations by Müller et al. (1980).

$$MP = 15.56+0.81\ M$$
$$BP = 4.30+0.61\ B$$
$$FP = 3.06+0.82\ F$$

Marbling (MAR) : This was measured in the *LM* between the 12th and 13th ribs, following the scores described by Müller (1980) (Table 2).

Texture (TXT) : This was determined through the size of the fascicle (muscle "grain" size) and evaluated subjectively with a point scale, similarly to that of marbling (Müller, 1980) (Table 3).

Table 3. Point scale for meat texture and color evaluation

Texture	Points	Coloration	Points
Very fine	5	Cherry red	5
Fine	4	Red	4
Slightly coarse	3	Slightly dark red	3
Coarse	2	Dark red	2
Very coarse	1	Dark	1

Müller (1980).

Color (COR) : Muscle color after 24-h carcass chilling was analyzed. Coloration was evaluated according to a point scale 30 min after a cross-sectional cut was made on the *Longissimus* between the 12th and 13th ribs (Müller, 1980) (Table 3).

Chemical composition

After 24 h, LM samples were taken by complete cross-section between the 12th and 13th ribs, and were immediately taken to the laboratory. Cover fat was discarded and the muscle portion was frozen at -20°C for later analysis.

Laboratory analyses of beef were carried out two months after sampling. The samples were thawed at room temperature (20°C), ground, homogenized and analyzed in triplicate.

Beef moisture and ash contents were determined according to AOAC (1998). Crude protein content was obtained through the Kjeldahl method (AOAC, 1998). Total lipids were extracted through the Bligh and Dyer method (1959) with a chloroform/methanol mixture. Fatty acid methyl esters (FAME) were prepared by triacylglycerol methylation, according to the ISO method (1978).

Cholesterol analysis was carried out by the method modified by Rowe et al. (1999). A 60% (w/v) solution of potassium hydroxide was added to the samples in quantities equivalent to 2 ml/h of sample under 1-h reflux. The residue was dissolved again in 2 ml hexane containing 0.2 mg/ml 5-α cholestane internal standard (IS) (Sigma, USA).

Chromatographic analysis and cholesterol quantification

Cholesterol content was analyzed in a 14-A gas chromatograph (Shimadzu, Japan), equipped with a flame ionization detector and a fused silica capillary column (25 m long, 0.25-mm internal diameter, and 0.20 μm Ohio Valley-30). Injector, column, and detector temperatures were 260, 280, and 280°C, respectively. Ultra-pure gas

Table 4. Effects of different roughage sources on initial weight (IW) and final weight (FW), daily weight gain (DWG), feed intake (FI), feed intake as percentage of liveweight (FI/LW), feed conversion (FC), hot carcass weight (HCW) and dressing percentage (DP) of crossbred bulls

Parameters	Treatments				SE[5]	P>F
	HAB[1]	HAY[2]	SOS[3]	SOY[4]		
IW (kg)	378	346	370	341	13.3	NS
FW (kg)	522	494	539	506	18.4	NS
DWG (kg/d)	1.37	1.41	1.61	1.57	0.09	NS
FI (kg/d)	11.5	10.5	11.7	10.9	0.45	NS
FI/LW (%)	2.55	2.52	2.57	2.58	0.07	NS
FC[6]	8.53	7.87	7.35	7.08	0.48	NS
HCW (kg)	268	258	278	269	9.89	NS
DP (%)	51.3	52.2	51.6	53.2	0.73	NS

[1] Bermuda grass Hay. [2] Hay+yeast. [3] Sorghum silage. [4] Silage+yeast. [5] Standard errors. [6] kg DM/kg gain.

fluxes (White Martins) of 1.5 ml/min H_2 as carrier gas, 30 ml/min N_2 as make-up gas, 300 ml/min synthetic gas and 30 ml/min N_2 for flame were used.

The sample injection split mode was: 1:150. Peak integration was carried out with a CG-300 computing integrator (CG Instruments, Brazil) and cholesterol was identified by comparison with standards from Sigma (USA). Sample cholesterol quantification was carried out after verification of method linearity. Standard cholesterol solutions (Sigma, USA) were prepared with concentrations of 0.0, 0.4, 0.8, 1.6 and 2.0 mg/ml, all containing 0.20 mg/ml 5α-cholestane (Sigma, USA), and analyzed.

The ratio of the areas of cholesterol and 5-α cholestane was plotted against the cholesterol concentration for injected volumes of 0.0, 2.0, 3.0, 4.0 and 5.0 μl. The curve obtained was used for cholesterol analysis in mg 100 g^{-1}.

Analysis of fatty acid methyl esters

The fatty acid methyl esters (FAMEs) were analyzed in a gas chromatograph (Varian, USA) equipped with a flame ionization detector and a fused silica capillary column CP-7420 (100 m, 0.25 mm and 0.39 μm o.d., Varian, USA) Select Fame. Column temperature was programmed at 165°C for 18 min, 180°C (30°C/min) for 22 min and 240°C (15°C/min) for 30 min, with 45-psi pressure.

The injector and detector were kept at 220°C and 245°C, respectively. The gas fluxes (White Martins) used were: 1.4 ml/min for the carrier gas (H_2); 30 ml/min for the make-up gas (N_2) and 30 ml/min and 300 ml/min for H_2 and the synthetic flame gas, respectively. Sample injection split mode was 1/80.

Fatty acids were identified by comparing the relative retention times of FAME peaks of the samples with fatty acid methyl ester standards from Sigma (USA) by spiking samples with standard. The peak areas were determined by Star software (Varian).

The data were expressed as percentages of the normalized area of fatty acids (Rowe et al., 1999; Milinsk et al., 2005).

Experimental design and statistical analysis

The experiment design consisted of 4 treatments and 10 replicates (animals) per treatment. The results were submitted to Analysis of Variance (ANOVA) at significance levels of 10%. The data were submitted to an analysis of variance using SAS statistical software (2000), according to the following mathematical model:

$$Y_{ij} = \mu + t_i + e_{ij}$$

In which:

Y_{ij} = observation of animal j, subjected to treatment i;

μ = overall constant;

t_i = treatment effect i = 1;...4;

e_{ij} = random error associated with each observation.

RESULTS AND DISCUSSION

Animal performance and carcass evaluation

The average initial live weight of bulls in all four treatment groups (Table 4) at the beginning of the experimental period did not differ ($p>0.10$) among groups, nor did final live weight (FLW). FLW can be considered high (515 kg) compared with the final live weight of animals finished in feedlots in Brazil (Costa et al., 2002; Pacheco et al., 2005). This elevated final live weight can be explained by the genotype used. A high slaughter weight is necessary in order to achieve satisfactory (fat thickness) finishing levels.

The roughage source and the presence/absence of yeast did not influence ($p>0.10$) dry matter intake (DMI). However, Wallace (1994) observed that the addition of yeast aims at increasing feed intake, and consequently provides greater weight gains.

Dry matter intake is directly related to natural detergent fiber (NDF) content of the feed and diet (Mertens, 1994; Van Soest, 1994). Although diets containing Bermuda grass hay featured higher levels of NDF (43.6%) than those with sorghum silage (35.6%), there was no observable decrease

Table 5. Effects of different roughage sources on conformation (COF), carcass length (CL), leg length (LL), cushion thickness (CT), *Longissimus* muscle area (LDA), subcutaneous fat thickness (SFT), color (COL), texture (TEX), marbling (MAR), percentage of fat (PEF), of muscle (PEM) and bone (PEB) of crossbred bulls

Parameters	Treatments				SE[5]	P>F
	HAB[1]	HAY[2]	SOS[3]	SOY[4]		
COF, points	11.1	10.5	10.9	11.1	0.75	NS
CL, cm	139	132	140	137	2.16	NS
LL, cm	72.1	72.4	74.2	73.1	1.06	NS
CT, cm	27.2	26.1	26.6	26.6	0.68	NS
LDA, cm^2	66.5	64.7	68.3	68.2	2.25	NS
SFT, mm	3.23	3.01	4.00	3.36	0.42	NS
COL, points	3.24	3.67	3.39	4.07	0.23	NS
TEX, points	4.54	3.97	4.17	4.17	0.16	NS
MAR, points	4.75	3.77	5.62	4.57	0.65	NS
PEF, %	21.9	23.7	23.4	21.2	2.18	NS
PEM, %	62.6	60.9	62.1	63.7	1.97	NS
PEB, %	15.9	15.8	15.1	15.5	0.29	NS

[1] Bermuda grass Hay. [2] Hay+yeast. [3] Sorghum silage. [4] Silage+yeast. [5] Standart errors.

in the intake of Bermuda grass by animals.

There were no differences (p>0.10) among treatments for final live weight (FLW) and hot carcass weight (HCW) (Table 4). Carcass yield (CY) was not influenced by treatments (p>0.10). According to Prado et al. (2000), carcass yield - in addition to other inherent oscillation factors (genotype, rumen fill, fasting period and transportation) - can be influenced by the finishing location, as a result of the varying degree of thoroughness employed during the carcass cleaning process. However, in this study there was no influence of the carcass cleaning process, because all treatments had the same process.

Average carcass conformation, which represents the muscle development in the anterior and especially the posterior carcass regions, was not influenced by the test treatments (p>0.10) (Table 5). The carcass featured an average value of 10.9 points. Carcass conformation is positively correlated with several characteristics that express muscle quality, such as carcass length (CL), leg length (LL), *Longissimus* area (LA) and fat thickness (FT).

Carcass length (CL), leg length (LL) and cushion thickness (CT) were not influenced by treatment (p>0.10), featuring average values of 137, 72.9 and 26.6 cm, respectively (Table 5).

The *Longissimus* muscle (LM) area was not influenced by treatment (p>0.10) (Table 5). The average value was 66.9 cm^2. The LM area expresses carcass muscle development, and is thus directly correlated to hot carcass weight (Costa et al., 2002).

Fat thickness was not influenced (p>0.10) by treatment (Table 5) and featured an average value of 3.40 mm, with little variation among treatments. This value meets the guidelines of the Brazilian market, which requires that carcasses have between 3 and 6 mm of fat thickness.

The value attributed to color (COR) did not differ (p<0.10) among treatments (Table 5), with an average score of 3.84 points, which is equivalent to a score between "slightly dark red" to "red" coloration.

Like color, the texture (TEX) of *Longissimus* muscle meat was similar among treatments (p>0.10), featuring an average of 4.21 points (Table 5), which corresponds to "fine" texture.

No difference was observed (p>0.10) among treatments for marbling (MAR), with an average score of 4.67 points, which corresponds to "light minus" to "light" (Table 5). It is known that MAR is related to sensory characteristics of meat that can be noticed and appreciated by the consumer.

The percentage of carcass fat (FP), muscle (MP) and bone (BP) did not differ (p>0.10) among treatments (Table 5) and featured average values of 22.6; 62.3 and 15.6%, respectively.

Chemical composition

The percentages of moisture, ash, crude protein and total cholesterol levels were similar (p>0.10) among treatments (Table 6). Conversely, total lipid levels were higher (p<0.10) for animals in the HAB, SOS and SOY treatments than in the HAY treatment.

Average values for moisture, ash and crude protein were 73.4%; 1.04% and 23.8%, respectively. Overall, the levels of moisture, ash and crude protein featured little variation in the *Longissimus* muscle of bovines, even under different finishing conditions, diet (Silva et al., 2003; Prado et al., 2008a), breeds (Silva et al., 2003; Lee et al., 2007) and physiological condition of animals (Silva et al., 2002a; Moreira et al., 2003). This shows that different diets offered to animals usually do not change the values for moisture, ash and crude protein.

Total lipid levels were higher (p<0.10) (28.5%) for animals fed sorghum silage than those fed Bermuda grass hay. Total lipid levels can vary due to carcass cleaning levels (Rule et al., 1997), feeding strategies (Silva et al.,

Table 6. Effects of different roughage sources on percentage of moisture, ash, crude protein and total lipids and cholesterol concentration in the *Longissimus* muscle of crossbred bulls

Parameters	Treatments				SE[5]	P>F
	HAB[1]	HAY[2]	SOS[3]	SOY[4]		
Moisture (%)	73.2	73.6	73.2	73.3	0.35	NS
Ashes (%)	1.10	0.90	1.00	1.10	0.06	NS
Crude protein (%)	23.9	23.6	24.1	23.4	0.41	NS
Total Lipids (%)	1.80^{ab}	1.30^{b}	2.10^{a}	2.20^{a}	0.25	0.10
Total cholesterol (mg/100 g muscle)	25.3	22.3	22.7	21.5	1.53	NS

[1] Bermuda grass Hay. [2] Hay+yeast. [3] Sorghum slage. [4] Silage+yeast. [5] Standard errors. Different letters in the same line are significantly different.

2002b; Prado et al., 2008b), bloodline (Silva et al., 2002b; Moreira et al., 2003, Prado et al., 2008c; Prado et al., 2008d) and physiological conditions (Marques et al., 2005).

Cholesterol levels did not differ (p>0.10) among bovines under the different treatments. The average level was 23 mg/100 g of meat. This value can be considered low in comparison to cholesterol levels cited in the literature (Greghi et al., 2003; Moreira et al., 2003; Padre et al., 2006; Aricetti et al., 2008; Prado et al., 2008b, Prado et al., 2008c; Prado et al., 2008d)). However, Silva et al. (2002b) found levels of 18.4 mg/100 g of meat from crossbred heifers (Nellore vs. Simmental) fed with corn and yeast. The variations observed among treatments can be explained by the age (20 months old) and physiological condition of the animals.

Fatty acid profile

As for the fatty acid profile of the *Longissimus* muscle, an effect of the treatments was observed (p<0.10) on the levels of some fatty acids in intramuscular fat (Table 7).

The different roughage sources and the presence/absence of yeast had no effect on the saturated fatty acid profile (p>0.10). Palmitic acid (16:0) presented the greatest concentration (25.1%) within this group, followed by stearic acid (18:0) with 21.5%; myristic acid (14:0) with 1.51%, margaric acid (17:0) with 0.90%; and behenic acid (22:0) with 0.40%. A similar composition was observed by Greghi et al. (2003), Padre et al. (2006) and Aricetti al. (2008) in cattle.

The levels of monounsaturated fatty acids (8-heptadecenoic acid (17:1 *n*-9), trans-vaccenic acid (18:1 *trans* 11) and oleic acid (18:1 *n*-9)) were similar (p>0.10) among treatments (Table 7).

Trans unsaturated fatty acids, in general, raise LDL-cholesterol levels (Mensink and Zock, 1998). As such, meat should not only have low levels of saturated fat, but should also be low in trans-fatty acids. However, trans-vaccenic acid acts differently. Although its importance has not yet been recognized, it is known to be an important precursor for the formation of conjugated linoleic acid (CLA) in tissues. Due to its properties as an intermediary in the biohydrogenation process of linoleic acid (18:2 *n*-6) in the rumen, this fatty acid can be transformed into CLA (18:2 *c*-9, *t*-11) by the delta-9-desaturase enzyme (Griinari et al., 2000) in the tissues of ruminants after being absorbed.

Oleic acid (18:1 *n*-9) is able to reduce LDL-cholesterol

Table 7. Effects of different roughage sources on fatty acid profile in the *Longissimus* muscle of crossbred bulls (%)

Fatty acids	Treatments				SE[5]	P>F
	HAB[1]	HAY[2]	SOS[3]	SOY[4]		
14:0	1.27	1.40	1.89	1.49	0.23	NS
16:0	25.2	24.3	26.1	24.9	1.05	NS
16:1 *n*-7	1.41	1.71	1.83	1.53	0.19	NS
17:0	0.83	1.03	0.83	0.94	0.10	NS
17:1 *n*-9	0.47	0.61	0.51	0.47	0.05	NS
18:0	22.0	22.1	19.4	22.4	1.52	NS
18:1 (trans 11)	1.15	1.29	1.43	1.17	0.11	NS
18:1 *n*-9	34.1	34.7	36.9	35.6	1.05	NS
18:2 *n*-6	8.47	7.85	7.43	7.42	1.00	NS
18:3 *n*-6	0.12^{bc}	0.15^{ab}	0.10^{c}	0.16^{a}	0.01	0.10
18:3 *n*-3	0.56^{a}	0.42^{ab}	0.49^{ab}	0.33^{b}	0.06	0.10
18:2 cis-9, trans-11-CLA	0.25^{b}	0.31^{a}	0.31^{a}	0.26^{ab}	0.02	0.10
22:0	0.42	0.45	0.29	0.47	0.07	NS
20:4 *n*-6	2.07^{ab}	2.53^{a}	1.32^{b}	1.82^{ab}	0.45	0.10
20:5 *n*-3 (EPA)	0.52^{a}	0.31^{b}	0.29^{b}	0.29^{b}	0.08	0.10
22:5 *n*-3 (DPA)	0.90^{a}	0.71^{ab}	0.62^{b}	0.62^{b}	0.11	0.10
22:6 *n*-3 (DHA)	0.13^{a}	0.09^{ab}	0.05^{b}	0.07^{b}	0.02	0.10

[1] Bermuda grass Hay. [2] Hay+yeast; [3] Sorghum silage. [4] Silage+yeast. [5] Standard errors. Different letters in the same line are significantly different.

Table 8. Effects of different roughage sources on proportion (%) of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), fatty acids *n*-6, fatty acids *n*-3, PUFA: SFA and *n*-6:*n*-3 ratio in the *Longissimus* muscle of crossbred bulls

Fatty acids	Treatments				CV[5]	P>F
	HAB[1]	HAY[2]	SOS[3]	SOY[4]		
SFA	49.8	49.3	48.6	50.2	1.32	NS
MUFA	37.2[b]	38.3[ab]	40.7[a]	38.7[ab]	1.12	0.10
PUFA	13.1	12.4	10.7	11.0	1.42	NS
n-6	10.7	10.5	8.87	9.41	1.21	NS
n-3	2.12[a]	1.54[ab]	1.47[b]	1.32[b]	0.24	0.10
PUFA:SFA	0.28	0.25	0.22	0.22	0.03	NS
n-6:*n*-3	5.07[b]	7.08[a]	6.33[a]	7.48[a]	0.49	0.10

[1] Bermuda grass Hay. [2] Hay+yeast. [3] Sorghum silage. [4] Silage+yeast. [5] Standard errors. Different letters in the same line are significantly different.

levels and raise HDL-cholesterol in the bloodstream (Mensink and Zock, 1998). Thus, the production of meat rich in oleic acid can be beneficial to human health (Padre et al., 2006).

Among polyunsaturated fatty acids (PUFA), the levels of linoleic acid (18:2 *n*-6) did not differ (p>0.10) among treatments. This acid presented the highest percentage (7.79%) among all PUFA. Prado et al. (2003); Indurain et al. (2006) and Padre et al. (2006) also observed that, among all PUFA, linoleic acid has the greatest concentration in the *Longissimus* muscle of bovines.

In animals fed with Bermuda grass hay, the levels of α-linolenic acid (18:3 *n*-3), arachidonic acid (20:4 *n*-6), eicosapentaenoic acid (20:5 *n*-3), docosapentaenoic acid (22:5 *n*-3) and docosahexaenoic acid (22:6 *n*-3) were greater (p<0.10) as compared to animals fed with sorghum silage. These differences could be attributed to the type of fermentation that takes place in the rumen-reticulum compartment (Tamminga and Doreau, 1991; Zhang et al., 2006).

Approximately 53% of identified fatty acids featured concentrations lower than 1%. Those acids found in high concentrations in all treatments were oleic acid (35.3%), palmitic acid (25.1%) and stearic acid (21.5%). These acids made up approximately 80% of detected acids. Similar percentages were also found by Greghi et al. (2003), Silva et al. (2003) and Indurain et al. (2006) under different handling, feeding, weight and gender conditions.

The percentage of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), *n*-6 and *n*-3 fatty acids, as well as the AGPI:AGS and *n*-6:*n*-3 ratios of the *Longissimus* muscle are presented on Table 8.

Most identified fatty acids were saturated and did not differ (p>0.10) among treatments. MUFA featured the second highest concentration and were not affected (p>0.10) by the addition of yeast. However, when comparing the treatments made up of Bermuda grass hay (HAB) and sorghum silage (SOS) without the addition of yeast, it was observed that there was greater deposition (p<0.10) of MUFA in animals fed with silage.

Although there were no observed differences in the MUFA profile (16:1 *n*-7; 17:1 *n*-9; 18:1 t-11 and 18:1 *n*-9), it was observed that the SOS featured greater percentages of these acids than did the HAB treatment. Therefore, when these MUFA were totaled, higher values were found for the SOS treatment. This diet, with high levels of concentrate, increases acidity in the rumen, which in turn reduces lipolysis and biohydrogenation (Demeyer and Doreau, 1999). Therefore, grain-based diets (such as sorghum silage) produce animals with a more unsaturated lipid profile.

The PUFA presented the lowest percentage (11.8%) among all fatty acids and did not differ (p>0.10) among treatments. Nevertheless, it is important to highlight that this concentration of PUFA can be considered high in comparison to other studies (Greghi et al., 2003; Silva et al., 2003; Padre et al., 2006).

Approximately 66% of PUFA was linoleic acid and 16% was arachidonic acid. Linoleic acid, α-linolenic acid and arachidonic acid are considered essential fatty acids, given that humans, like all mammals, cannot synthesize them, and thus depend on dietary supply (Specher, 1981). However, arachidonic acid can be synthesized from linoleic acid.

The levels of omega-3 fatty acids were higher (p<0.10) for animals fed with Bermuda grass hay than those fed sorghum silage. Further, the addition of yeast reduced levels of omega-3 for animals fed with hay. However, the addition of yeast did not alter the omega-3 profile of animals fed with sorghum silage. Therefore, the reduction in omega-3 levels with the use of hay can perhaps be attributed to the alterations in ruminal fermentation that take place when yeast is present. On the other hand, the use of hay or silage and the presence or absence of yeast had no effect (p>0.10) on the composition of omega-6 fatty acids.

No difference was observed (p>0.10) for the PUFA:SFA ratio among treatments, with an average value of 0.24. The PUFA:SFA ratio found in this study is below the value of

Table 9. Fatty acid composition of Bermuda grass hay and Sorghum silage

Fatty acids	Bermuda grass hay	Sorghum silage	P>F
16:0	30.5	14.8	0.10
16:1 *n*-7	0.60	0.35	0.10
18:0	5.91	2.25	0.10
18:1 *n*-9	14.6	22.2	0.10
18:2 *n*-6	29.0	42.7	0.10
18:3 *n*-3	19.3	17.8	NS
AGPI	48.4	60.5	0.10
AGMI	17.2	22.5	0.10
AGS	36.5	17.0	0.10
n-6	29.1	42.7	0.10
n-3	19.3	17.8	NS
AGPI:AGS	1.33	3.56	0.10
n-6:*n*-3	1.52	2.40	0.10

0.45 recommended by the Department of Health (1994), which is considered beneficial to human health. The low PUFA:SFA ratio can be explained by the biohydrogenation process undergone by dietary unsaturated fatty acids in the rumen by microorganisms.

Regarding the *n*-6:*n*-3 ratio, the HAB treatment presented the lowest ($p<0.10$) value of all treatments (Table 6). This ratio is directly related to the percentages of *n*-6 and *n*-3 present in the muscle. Thus, given that the HAB treatment featured higher levels of *n*-3 and similar levels of *n*-6 compared to the other treatments, consequently the *n*-6:*n*-3 ratio of this treatment should be lower.

The inclusion of sources of *n*-3 in animal diets increased total *n*-3 concentration, while at the same time decreasing intramuscular deposition of *n*-6 fatty acids; as the diet supply of w-6 diminishes, the *n*-6:*n*-3 decreases. Analysis of the fatty acid profiles of Bermuda grass hay and sorghum silage showed higher levels of *n*-3 for hay (Table 9).

The deposition of *n*-6 fatty acids was greater than that of *n*-3 (Table 8). This led to the *n*-6:*n*-3 ratio in the *Longissimus* muscle being considered high. When the *n*-6:*n*-3 ratio is compared to the maximum of 4.0 recommended by the Department of Health (1994), it is apparent that, although all treatments produced ratios above that, treatments without addition of yeast gave the best results.

IMPLICATIONS

The type of roughage used (Bermuda grass hay or sorghum silage) and the supplementation (or not) of the diet with yeast (15 g/animal/d) did not influence animal performance and carcass characteristics of crossbred young bulls. Therefore, either hay or silage can be considered good-quality roughages for feedlot finishing, without altering the performance of these animals. Since yeast did not affect performance and carcass characteristics, its use for beef cattle in feedlot can be eliminated, especially given its high cost. Yeast negatively influenced meat quality, as it increased the *n*-6:*n*-3 ratio to levels above those recommended by several health authorities.

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