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Meat quality of crossbred bulls fed with sorghum silage or sugar cane and slaughtered at two levels of fat thickness

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ABSTRACT. This study was carried out to evaluate the performance and carcass characteristics of bulls from three genetic groups: Zebu (ZEB), ½ Limmousin *vs.* ½ Zebu (LIZ) and ½ Angus *vs.* ½ Zebu (ANZ). Bulls were finished in feedlot and fed two diets: sorghum silage + 1.0% concentrate of LW or sugar cane + 1.2% concentrate LW. The bulls were slaughtered at one of two fat thicknesses: 3.4 or 4.8 mm. The bulls of the LIZ and ANZ groups showed higher FBW and ADG. There were no differences in the feed intake and carcass characteristics among the groups. Bulls from LIZ group had a lower fat thickness and higher muscle deposition. There were no differences among groups on carcass characteristics. The bulls fed with sorghum silage had a higher FBW, ADG and carcass weight than those fed sugar cane, while the animals fed sugar cane had a higher DMI and lower feed efficiency. There was no difference in hot carcass dressing between the diets. The sorghum silage or sugar cane did not change carcass characteristics or the meat composition. The FBW and HCD were similar for the two levels of fat thickness. The ADG was higher in bulls with 3.4 mm of fat thickness.

Keywords: cattle, fat, genetic groups, silage, sugar cane.

Qualidade de carne de bovinos mestiços alimentados com silagem de sorgo ou cana-de-açúcar e abatidos com dois níveis de gordura de cobertura

RESUMO. Este trabalho foi realizado para avaliar o desempenho e características de carcaça de bovinos Zebu (ZEB); ½ Limousin *vs.* ½ Zebu (LIZ) e ½ Angus *vs.* ½ Zebu (ANZ). Foram utilizados 36 bovinos terminados com duas dietas: silagem de sorgo + 1,0% do PV de concentrado ou cana-de-açúcar + 1,2% do PV de concentrado. Os bovinos foram abatidos com dois graus de acabamento (3,4 ou 4,8 mm de espessura de gordura). Os grupos LIZ e ANZ apresentaram maior PVF e GMD. Não houve diferença para a ingestão de alimentos, peso e rendimento de carcaça. O grupo LIZ apresentou menor deposição de gordura e maior deposição de músculo. Não houve diferença entre grupos sobre características do músculo *Longissimus*. Os animais alimentados com silagem de sorgo apresentaram maior PVF, GMD e PCQ. Os animais alimentados com cana-de-açúcar apresentaram maior ingestão de matéria seca e pior conversão alimentar. Não houve diferença para o RCQ entre as dietas. As dietas não alteraram as características de carcaça e composição da carne. O PVF e rendimento de carcaça foram semelhantes para os graus de acabamento. O GMD foi maior nos animais abatidos com 3,4 mm de gordura.

Palavras chave: bovinos, gordura, grupos genéticos, silagem, cana-de-açúcar.

Introduction

The meat cattle produced in Brazil comes from animals raised in a pasture system (MOREIRA et al., 2003; PRADO et al., 2004; PADRE et al., 2007). It therefore becomes crucial to evaluate technological alternatives capable of raising efficiency in the industry and consequently restructuring the beef production chain. In Brazil, Zebu breeds are used for meat production (ROTTA et al., 2009b). However, European breeds are well known for their highly marbled meat, while Zebu breeds feature less fat and more connective tissue (MOREIRA et al., 2003; ROTTA et al., 2009a and b). Researchers have been conducting studies since the 1980s on a crossbreeding system with the objective of increasing animal productivity (KAZAMA et al., 2008; PEROTTO et al., 2000, 2001) and meat quality (ARICETTI et al., 2008; PADRE et al., 2006; PRADO et al., 2009a, b and c; ROTTA et al., 2009b). Crossbreds between Zebu and European breeds can be slaughtered at 20 to 24 months and feature better meat quality and low total cholesterol levels (PRADO et al., 2008b; ROTTA et al., 2009b).

During the last few years, the feedlot system for cattle has become an important practice. Feeding is a component that presents a variable cost which can greatly interfere with the profitability. Presently, the use of cereal grains (such as corn) has been the main source of energy in finishing diets (PRADO et al., 2008b). Alternative production systems that include the use of roughages could range from pasturing cattle, pasturing cattle with a limited amount of supplemental concentrates, pasturing cattle and then feeding them concentrates for a short period of time in a feedlot, or feeding roughages to cattle while they are in the feedlot (SCHAAKE et al., 1993). Carcasses of roughage-fed beef are lighter and have less marbling and lower quality grades than the carcasses of grain-fed bulls (ARICETTI et al., 2008; PRADO et al., 2008b and c). Roughage-fed cattle are generally older than their grain-finished counterparts when they reach a choice quality grade. Although studies have shown compositional differences among breed (PRADO et al., 2008b, c and d), it is important to understand how various cattle types can be optimally used to produce lean and high-quality beef (MAY et al., 1992).

This study was carried out to evaluate the performance and carcass characteristics of Zebu and crossbred bulls (½ Limousin *vs.* ½ Zebu or ½ Angus *vs.* ½ Zebu) fed with sorghum silage or sugar cane and slaughtered at two fat thickness (3.4 or 4.8 mm).

Material and methods

Animal management and sampling

This study was carried out at the Experimental Farm of the Agronomic Institute of Paraná (IAPAR), in the city of Paranavaí, Paraná State, south of Brazil, and followed the guiding principles of biomedical research with animals.

Thirty-six bulls (Zebu – ZEB, n = 10; ½ Limousin *vs.* ½ Zebu – LIZ, n = 12 and ½ Angus *vs.* ½ Zebu – ANZ, n = 14) were selected, all belonging to the experimental herd of the Agronomic Institute of Paraná, with an initial average age of 21 months and a live weight of 330 ± 44.0 kg. The mating plan established was to avoid consanguinity of the genetic groups by continuous maintenance of heterozygosis, using purebred bulls from the starter breeds (Zebu, Limousin and Angus).

From birth to the age of 21 months, the bulls were kept in a pasture of *Panicum maximum*. After that, the bulls were separated into individual pens (28 m^2 for each animal), and fed twice a day: sorghum silage + 1.0% LW of concentrate or sugar cane + 1.2% LW of concentrate. They were given access to a diet formulated to meet requirements for fattening beef cattle (NRC, 2000).

The concentrate used consisted of soybean meal, corn, urea, limestone and mineral salts. The diets were formulated with a 44:56 ratio of roughage to concentrate.

The chemical compositions of the silage and concentrate ingredients are presented in Table 1. Dry matter (DM), crude protein (CP), organic matter (OM), mineral matter (MM), ether extract (EE), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using the methods described by Silva and Queiroz (2002).

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

Feed	Diets	
	SIL[1]	SUG[2]
Sorghum silage	54.5	-
Sugar cane	-	36.8
Corn	35.4	49.2
Soybean meal	8.83	12.3
Urea	0.50	0.70
Limestone	0.50	0.70
Mineral salts	0.25	0.35
Parameters		
Dry matter, %	44.6	51.9
Crude protein, %	13.7	12.7
Neutral detergent fiber, %	41.5	32.9
Acid detergent fiber, %	22.5	15.8
Organic matter, %	94.6	96.8
Ash, %	5.40	3.20
Ether extract, %	3.50	3.10
Total digestible nutrient, %	63.3	67.4

[1]Sorghum silage + 1.0% LW of concentrate. [2]Sugar cane + 1.2% of concentrate.

The development of the fat thickness was monitored every 28 days after a period of adaptation for the animals, using an ultrasound device (Aloka 500 with a Ust-5049-3.5 transducer). After reaching a 3.4 or 4.8 mm fat thickness and an average age of 24 months, the animals were slaughtered.

Carcass characteristics

The bulls were slaughtered at a commercial slaughterhouse 20 km away from the IAPAR, following the usual practices of the Brazilian beef industry. Thereafter, the carcasses were identified, weighed and chilled at 4°C for 24h. After chilling, the right part of the carcass was used to determine the quantitative characteristics. Twenty-four hours later, *Longissimus* muscle (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 -20ºC for further analyses.

Laboratory beef analyses were carried out four months after sampling. The samples were thawing at 4°C, ground (cutter), homogenized, and analyzed in triplicate.

Hot carcass weight (HCW): HCW of the bulls was determined after slaughter and before carcass chilling.

Hot carcass dressing (HCD): The percentage of individual animal hot carcass dressing was defined as the ratio of hot carcass weight divided by live weight 14h before slaughter of animals.

Conformation (COF): COF was evaluated by the Müller points scale in which the highest value indicates the best conformation (MÜLLER, 1980). The carcass conformations were reported as superior, very good, good, regular, poor, and inferior; ratings may also have been reported as plus, mid, and minus.

Fat thickness (FAT): Fat thickness was measured by caliper by averaging three points between the 12 and the 13th ribs on *Longissimus* muscle (LM).

Longissimus muscle area (LMA): *Longissimus* area was measured by a tracing made on the right side of carcass, where a transversal cut was made between the 12 and 13th ribs, exposing the *Longissimus* muscle. After this, a compensating planimeter, an instrument that measures areas of irregularly shaped objects, was used to determine the area.

Color (COL): Muscle color was analyzed 24h after carcass chilling. Coloration was evaluated according by the Müller scale 30 min. after that a transversal section was made on the *Longissimus* between the 12 and 13th ribs.

Marbling (MAR): Intramuscular fat was measured in the *LM* between the 12 and 13th ribs according to the Müller scores (MÜLLER, 1980).

Percentage of carcass muscle (PCM), fat (PCF) bone (PCB): Muscle, fat and bone were physically separated from the *Longissimus* section, which corresponds to the 10, 11 and 12th ribs, and individually weighed according to Hankins and Howe (1946). The data were regressed using equations published by Müller (1980). The model converts data to values corresponding to the 9, 10, and 11th ribs as follows:

$\% M = 6.292+0.910X_1$

$\% F = 1.526+0.913X_2$

$\% B = 2.117+0.860X_3$

where the X_i represent muscle, fat and bone percentages.

The values corresponding to the 9, 10 and 11th ribs were then regressed using equations following the methods of Hankins and Howe (1946) to find the muscle (MP), fat (FP) and bone (BP) percentages as follows:

$MP = 15.56+0.81\ M$

$FP = 3.06+0.82\ F$

$BP = 4.30+0.61\ B$

where M, F and B are the muscle, fat, and the bone percentage estimates from the equations by Müller (1980).

Statistical analysis

The thirty-six animals were allocated in a completely randomized design with three genetic groups (ZEB, LIZ and ANZ), two diets (sorghum silage + concentrate at 1.0% of live weight or sugar cane + concentrate at 1.2% of live weight) and two fat thickness levels (3.4 or 4.8 mm). The data were submitted to an analysis of variance, and the means (when different) were compared using the Tukey test at 5% significance levels, using SAS statistical software (SAS, 2008).

Results and discussion

There was no interaction effect ($p > 0.05$) among genetic groups, diets and fat thickness levels for all characteristics. Thus, the data are presented and discussed separately (principal effects).

Genetic groups (Zebu, ½ Limousin *vs.* ½ Zebu and ½ Angus *vs.* ½ Zebu)

The initial live weight were similar ($p > 0.05$) among genetic groups; this was because the animals were previously selected for similar initial live weight (Table 2). Angus *vs.* Zebu (ANZ) bulls presented higher ($p < 0.05$) final live weight (547 kg) in comparison with Zebu (ZEB – 488 kg, Table 2). However, the final live weight of Limousin *vs.* Zebu (LIZ – 521 kg) and ANZ were similar ($p > 0.05$). Thus, the final live weight of the ZEB and LIZ genetic groups were also similar ($p > 0.05$). The higher final live weight of the ANZ and LIZ genetic groups could be due to the genetic effects of heterosis of these animals, as they were from the first generation (F1).

The ZEB group presented the lowest (1.27 kg) average daily gain in comparison with LIZ (1.53 kg) and ANZ (1.56 kg). The first generation of crossbreeding between Angus and Zebu presented an increase of 18.5% in average daily gain. The introduction of Limousin genes in the crossbreeding with Zebu resulted in an increase of 16.9% in average daily gain in comparison with Zebu bulls. These results demonstrate the effect of genetic differences between these two groups (European and Zebu) when they are crossbred to enhance weight gain.

Table 2. Performance (means ± means standard) of bulls of different genetic groups finished in the feedlot.

Parameters	Genetic Groups			p < F
	ZEB[1]	LIZ[2]	ANZ[3]	
n	10	12	14	
Initial live weight, kg	326 ± 13.7	321 ± 13.0	343 ± 11.6	NS
Final live weight, kg	488b ± 17.6	521ab ± 16.8	547a ± 14.9	0.05
Average daily weight gain, kg	1.27b ± 0.06	1.53a ± 0.05	1.56a ± 0.05	0.01
Dry matter intake, kg day^{-1}	10.5 ± 0.62	11.1 ± 0.46	11.63 ± 0.49	NS
Dry matter intake/live weight, %	2.59 ± 0.07	2.60 ± 0.05	2.59 ± 0.06	NS
NDF Intake kg	4.12 ± 0.25	4.29 ± 0.18	4.50 ± 0.19	NS
NDF Intake/live weight, %	1.01 ± 0.04	1.00 ± 0.03	1.00 ± 0.03	NS
Dry matter conversion	8.72 ± 0.53	7.83 ± 0.39	8.51 ± 0.41	NS
Hot carcass weight, kg	271 ± 10.8	283 ± 10.3	292 ± 9.1	NS
Hot carcass dressing, %	55.5 ± 1.15	54.4 ± 1.10	53.3 ± 0.98	NS
Conformation, points	12.3 ± 0.55	13.3 ± 0.52	13.1 ± 0.46	NS
Fat thickness, mm	4.75a ± 0.41	3.28b ± 0.39	4.21a ± 0.35	0.04
Longissimus muscle area, cm^2	65.5b ± 2.76	75.2a ± 2.63	65.2b ± 2.34	0.01
Longissimus muscle area 100 kg^{-1}	24.2b ± 0.74	26.5a ± 0.70	22.6b ± 0.62	0.01
Color, points	3.30 ± 0.28	3.61 ± 0.26	3.88 ± 0.23	NS
Marbling, points	4.40 ± 0.54	4.35 ± 0.52	4.55 ± 0.46	NS
Muscle, %	60.8b ± 1.52	66.4a ± 1.45	63.8ab ± 1.29	0.04
Fat, %	24.4a ± 1.13	19.9b ± 1.08	21.4b ± 0.96	0.02
Bone, %	15.4 ± 0.50	14.6 ± 0.47	15.4 ± 0.42	NS
Edible portion	5.70 ± 0.19	5.98 ± 0.18	5.57 ± 0.16	NS

[1]Sorghum silage + 1.0% of LW concentrate. [2]Sugar cane + 1.2% of LW of concentrate. [3]Means standard errors. NS – non-significant. Means followed by different letters differed significantly by Tukey test.

The dry matter intake, dry matter intake per live weight, neutral fiber detergent intake, neutral fiber detergent intake per live weight and dry matter conversion did not present differences (p > 0.05) among the genetic groups (Table 2). The dry matter intake is an important parameter in animal nutrition, because it determines the level of nutrient intake and it is important to the daily weight gain of the animals (MENEZES; RESTLE, 2005).

Hot carcass weight, carcass dressing and carcass conformation were not influenced (p > 0.05) by genetic group (Table 2). The average score for carcass conformation was 12.9 points. Crossbred animals finished with the same age, gender and diet did not show alteration on carcass conformation (PRADO et al., 2008a and d; ROTTA et al., 2009b).

The fat thickness was lower (p < 0.04) for the LIZ (3.28 mm) genetic group in comparison with the ZEB (4.75 mm) and ANZ (4.21 mm) groups (Table 2). European genetic groups or European-crossbred groups presented higher fat thickness depositions compared to Zebu animals (ROTTA et al., 2009b).

A higher (p < 0.01) *Longissimus* muscle area was found in the LIZ (75.2 and 26.5 cm^2 100 kg^{-1} of carcass weight) group in comparison with ZEB (65.6 and 24.2 cm^2 100 kg^{-1} of carcass weight) and ANZ (65.2 and 22.6 cm^2 100 kg^{-1} of carcass weight). However, there was no difference (p > 0.05) between the ZEB and ANZ genetic groups (Table 2).

There was no difference (p > 0.05) in color among the genetic groups (Table 2). The average value for this characteristic was 3.59 points, which is "slightly dark red" by the Müller score. Other studies (DUCATTI et al., 2009; PRADO et al., 2008b, c and d; PRADO et al., 2009a, b and c) have also found there were no effects of genetic group on color. Marbling was similar (p > 0.05) among the genetic groups, and this characteristic presented an average of 4.43 points, matching "light" by the Müller score (Table 2).

LIZ (66.4%) and ANZ (63.8%) genetic groups presented higher (p < 0.04) muscle percentages than ZEB (60.8% - Table 2). However, there was no difference (p > 0.05) between LIZ and ANZ genetics group. ZEB (24.4%) presented a higher (p < 0.02) fat percentage in the carcass than LIZ (19.9%) and ANZ (21.4%). There was no difference (p > 0.05) between LIZ and ANZ genetics group. The LIZ genetic group normally presents higher muscle deposition than fat deposition. The genetic groups presenting the highest muscle percentages (LIZ and ANZ) also presented the lowest fat percentages, and these results are in accord with Metz et al. (2009), who demonstrated a negative correlation between these characteristics. There was no difference (p > 0.05) in bone percentages among genetic groups. In general, bulls slaughtered at around 20 months present about 15% bone in the carcass (MAGGIONI et al., 2009). The edible portions of the carcasses (muscle + fat) were similar (p > 0.05) among the genetic groups (Table 2). A carcass can be considered superior for the meat market when it presents a high quantity of muscle, a low quantity of bone and a good quantity of fat. However, the particular quantity of fat desired can vary with the meat market (WEBB, 2006).

Crossbreeding between European and Zebu animals produced descendents with high live weight when they are finished with high-energy-density diet (ABRAHÃO et al., 2005; ROTTA et al., 2009a and b). The lower final live weight of the ZEB genetic group were characteristic of the low weight gains normally seen in Zebu animals (D'OLIVEIRA et al., 1997; PRADO et al., 2000).

The higher *Longissimus* muscle area for LIZ could be due to the higher final live weight in this genetic group, and there is a positive correlation between these characteristics (KUSS et al., 2008). Prado et al. (2008b and c) undertook an evaluation of *Longissimus* muscle area and observed that ½ Limousin *vs.* ½ Zebu presented the higher values for this characteristic in relation to ½ Canchin *vs.* ½ Zebu, Brangus and Zebu. The lower ability of Zebu bulls to demonstrate carcass muscularity in comparison with crossbred bulls was also shown by Moreira et al. (2003).

Longissimus muscle presented low values for marbling; this could be associated with the slaughter age of these animals and the gender (bulls) (PRADO et al., 2009b). High averages for marbling can be observed when animals are slaughtered older (PRADO et al., 2009a) and bulls generally present lower fat in the carcass than steers (PRADO et al., 2009a).

Diets (sorghum silage *vs.* sugar cane)

The initial live weight were similar ($p > 0.05$) for animals fed with sorghum silage (323 kg) or sugar cane (337 kg, Table 3). However, the final live weight were higher ($p = 0.03$) for animals fed with sorghum silage (539 kg) than animals fed with sugar cane (498 kg). The higher final live weight for animals fed with sorghum silage was due to the higher ($p < 0.05$) average daily gain in these animals during the feedlot period (1.65 kg per day) than in animals fed with sugar cane (1.25 kg). An adjustment was made in the diet, with sugar cane given a higher concentrate supplement (1.20% LW) with the aim of making the diets more similar (Table 1). However, the diet with sorghum silage resulted in higher average daily gain by the animals.

The dry matter intakes were similar ($p > 0.05$) between treatments (11.1 kg of DM). Mertens (1994) suggested that the dry matter intake should be expressed in relation to the live weight. Thus, it was observed that animals fed with sugar cane (2.72%) presented higher ($p < 0.01$) dry matter intakes than animals fed with sorghum silage (2.47%). The dry matter intake is related to the neutral detergent fiber content of the feed because the fermentation and the transit of this fraction in the reticulo-rumen is lower than other dietary constituents and it effects rumen distension and the time of feed retention in the rumen (VAN SOEST, 1994).

The diet with sugar cane presented lower ($p < 0.01$) dry matter feed efficiency (9.65) than with sorghum silage (7.05). The similarities in relation to dry matter intake and the higher average daily gain observed in animals that received sorghum silage was responsible for the results obtained for dry matter efficiency.

Table 3. Performance and carcass characteristics of bulls fed with sorghum silage or sugar cane finished on the feedlot.

Parameters	Diets		SEM[3]	p < F
	SIL[1]	SUG[2]		
n	18	18		
Initial live weight, kg	323	337	10.6	NS
Final live weight, kg	539a	498b	13.6	0.03
Average daily weight gain, kg	1.65a	1.25b	0.04	0.01
Dry matter intake, kg day^{-1}	10.7	11.4	0.44	NS
Dry matter intake/live weight, %	2.47b	2.72a	0.50	0.01
NDF intake kg	4.61a	4.00b	0.18	0.01
NDF intake/live weight, %	1.06a	0.95b	0.03	0.01
Dry matter conversion	7.05b	9.65a	0.38	0.01
Hot carcass weight, kg	296a	268b	8.34	0.01
Hot carcass dressing, %	55.0	53.8	0.88	NS
Conformation, points	13.2	12.6	0.42	NS
Fat thickness, mm	3.99	4.18	0.32	NS
Longissimus muscle area, cm^2	72.7a	64.6b	2.13	0.01
Longissimus muscle area 100 kg^{-1}	24.6	24.2	0.57	NS
Color, points	3.71	3.48	0.21	NS
Marbling, points	4.03	4.84	0.41	NS
Muscle, %	64.0	63.3	1.17	NS
Fat, %	22.0	21.7	0.87	NS
Bone, %	14.8	15.5	0.38	NS
Edible portion	5.90	5.60	0.14	NS

[1]Sorghum silage + 1.0% of LW concentrate. [2]Sugar cane + 1.2% of LW of concentrate. [3]Means standard errors. NS – non-significant. Means followed by different letters differed significantly by Tukey test.

The hot carcass weight was higher ($p < 0.01$) in animals fed with sorghum silage (296 kg) than in animals fed with sugar cane (268 kg) (Table 3). However, the carcass dressing was similar ($p > 0.05$) in animals fed with either sorghum silage or sugar cane (54.4%).

Carcass characteristics were similar ($p > 0.05$) between the sorghum silage and sugar cane groups with one exception, the *Longissimus* muscle area, that was higher ($p < 0.01$) in animals fed with sorghum silage (Table 3). However, the *Longissimus* muscle area 100 kg^{-1} was similar ($p > 0.05$) to SIL and SUG diets.

The color presented an average score of 3.60 points, classified as "slightly dark red" according to Müller score. The carcasses presented "light" marbling, with an average of 4.43 points according to the Müller score.

The diets (SIL and SUG) enabled an adequate fat thickness for the meat market (3.0 mm – minimum) and showed an average of 4.1 mm. Thus, sorghum silage and sugar cane are both able to produce a carcass with adequate fat thickness.

Fat thickness levels (3.4 vs. 4.8 mm)

The values observed between the initial and final live weight were similar ($p > 0.05$) in animals slaughtered with fat thicknesses of 3.4 mm (initial: 332 kg; final: 510 kg) or 4.8 mm (initial: 328 kg; final: 527 kg - Table 4). However, the average daily weight gain for animals slaughtered with 3.4 mm (1.54 kg per day) was higher ($p < 0.05$) than for animals with 4.8 mm of fat (1.36 kg).

Table 4. Performance and carcass characteristics of bulls (means ± means standard) slaughtered with different levels of fat thickness.

Parameters	Fat thickness, mm 3.40	4.80	p < F
n	14	22	
Feedlot days	115	147	
Initial live weight, kg	332 ± 11.8	328 ± 9.44	NS
Final live weight, kg	510 ± 15.2	528 ± 12.13	NS
Average daily weight gain, kg	1.54a ± 0.05	1.36b ± 0.04	0.05
Dry matter intake, kg day^{-1}	12.8a ± 0.43	11.2b ± 0.34	0.01
Dry matter intake/live weight, %	3.01a ± 0.06	2.61b ± 0.05	0.01
NDF intake kg	4.87a ± 0.22	4.30b ± 0.18	0.05
NDF intake/live weight, %	1.15a ± 0.04	1.00b ± 0.03	0.01
Dry matter conversion	8.30 ± 0.47	8.53 ± 0.37	NS
Hot carcass weight, kg	274 ± 9.31	289 ± 7.45	NS
Carcass dressing, %	53.8 ± 0.99	55.0 ± 0.79	NS
Conformation, points	11.9b ± 0.47	13.9a ± 0.37	0.01
Fat thickness, mm	3.37b ± 0.35	4.80a ± 0.28	0.01
Longissimus muscle area, cm^2	69.0 ± 2.37	68.3 ± 1.90	NS
Longissimus muscle area 100 kg^{-1}	25.1 ± 0.63	23.7 ± 0.51	NS
Color, points	3.82 ± 0.24	3.37 ± 0.19	NS
Marbling, points	4.82 ± 0.46	4.05 ± 0.37	NS
Muscle, %	62.8 ± 1.31	64.5 ± 1.04	NS
Fat, %	21.4 ± 0.97	22.3 ± 0.78	NS
Bone, %	16.1a ± 0.43	14.2b ± 0.37	0.01
Edible portion	5.35b ± 0.16	6.15a ± 0.13	0.01

[1]Sorghum silage + 1.0% of LW concentrate. [2]Sugar cane + 1.2% of LW of concentrate. [3]Means standard errors. NS – non-significant. Means followed by different letters differed significantly by Tukey test.

The animals slaughtered with 3.4 mm of fat thickness presented higher ($p < 0.05$) dry matter intakes (12.8 kg), dry matter intake/live weight (3.01%), neutral fiber detergent intake (4.87 kg) and neutral fiber detergent intake/live weight (1.15%) than animals slaughtered with 4.8 mm (11.2 kg; 2.61%; 4.30 kg and 1.00%, respectively - Table 4). However, there was no difference ($p > 0.05$) in dry matter conversion between the animals with different fat thickness levels.

The lower dry matter and nutrient intake by animals having 4.8 mm of fat thickness could be related to the lower abdominal displacement available for the rumen due to the higher body fat deposition in these animals (NRC, 2000).

Hot carcass weight and carcass dressings were similar ($p > 0.05$) between the two levels of fat thickness, with averages of 282 kg and 54.4%, respectively (Table 4). The 4.8 mm fat thickness level was responsible for a better carcass conformation ($p < 0.01$), according to the Müller guidelines. There was no difference ($p > 0.05$) in *Longissimus* muscle area and *Longissimus* muscle área 100 kg^{-1} between carcass with different fat thickness levels. Color was similar ($p > 0.05$) in both fat thickness levels. The average for color was 3.59 points, according to the Müller scale. Marbling was similar ($p > 0.05$) in the different fat thickness levels, presenting an average of 4.43 points according to the Müller score (Table 4); both fat thickness levels presented low marbling values.

Muscle and fat percentages were not influenced ($p > 0.05$) by fat thickness levels and showed averages of 63.7 and 21.9%, respectively. Although the fat thickness was higher than 4.8 mm, this did not have an influence on carcass fat percentage deposition. The 3.4 mm fat thickness group had an increased ($p < 0.01$) bone percentage (16.1%) relative to the 4.8 mm (14.2%; Table 4). This could be explained by the high averages for muscle and fat percentage in animals finished with 4.8 mm of fat thickness. Animals slaughtered with 4.8 mm of fat thickness presented higher ($p < 0.01$) edible portions (6.15 kg of muscle + fat kg of bone^{-1}) than animals slaughtered with 3.40 mm (5.35 kg of muscle + fat kg of bone^{-1}). This could be due to the better conformation and the lower bone percentage found in animals finished with 3.4 mm of fat thickness. Animals slaughtered with a 4.8 mm fat thickness were kept for more time on the feedlot (147 days). Thus, this could be the reason for the alteration in animal tissue. During the period of highest growth, more deposition of muscle tissue occurs than of fat tissue. After this period, more deposition of fat tissue occurs than of muscle tissue. The fat tissue requires more energy intake to complete its deposition, reducing the daily weight gain. The hot carcass weight is related to the commercial value of the animal in Brazil. Thus, it is important to produce high hot-weight carcasses. The residence of these animals for an extended period on the feedlot with the aim of producing higher fat thickness (4.8 mm) did not have influence on final live weight, hot carcass weight or carcass dressing.

Conclusion

The evaluation of the crossbreeding potential between Limousin *vs.* Zebu and Angus *vs.* Zebu cattle demonstrated that the resulting animals are more efficient for the meat market. The kind of roughage used (sorghum silage or sugar cane) influenced the performance. A better performance was noted with sorghum silage, although this resulted in only minor changes in the carcass characteristics. However, before choosing a type of roughage, it remains important to undertake an economic analysis. The slaughter of animals with a high fat thickness affected the performance by lowering weight gain efficiency. However, these thicker-fat animals presented better carcass characteristics. Thus, animals with a high fat thickness are less efficient but can produce a superior carcass.

References

ABRAHÃO, J. J. S.; PRADO, I. N.; PEROTTO, D.; MOLETTA, J. L. Effects of replacing corn with increasing levels of cassava starch by-products on carcass characteristics and meat for young bulls. **Revista Brasileira de Zootecnia**, v. 34, n. 5, p. 1640-1650, 2005.

ARICETTI, J. A.; ROTTA, P. P.; PRADO, R. M.; PEROTTO, D.; MOLETTA, J. L.; MATSUSHITA, M.; PRADO, I. N. Carcass characteristics, chemical composition and fatty acid profile of *Longissimus* muscle of bulls and steers finished in a pasture system. **Asian-Australasian Journal of Animal Science**, v. 21, n. 10, p. 1441-1448, 2008.

D'OLIVEIRA, P. S.; PRADO, I. N.; SANTOS, G. T.; ZEOULA, L. M.; DAMASCENO, J. C.; MARTINS, E. N.; SAKAGUTI, E. S. Effect of replacing soybean meal with canola meal on the performance of Nellore feedlot heifers. **Revista Brasileira de Zootecnia**, v. 26, n. 3, p. 568-574, 1997.

DUCATTI, T.; PRADO, I. N.; ROTTA, P. P.; PRADO, R. M.; PEROTTO, D.; MAGGIONI, D.; VISENTAINER, J. V. Chemical composition and fatty acid profile in crossbred (*Bos taurus vs. Bos indicus*) young bulls finished in feedlot. **Asian-Australasian Journal of Animal Science**, v. 22, n. 3, p. 433-439, 2009.

HANKINS, O. G.; HOWE, P. E. **Estimation of the composition of beef carcasses and cuts**. Washington: United States Department of Agriculture, 1946. (Technical Bulletin, 926, p. 20)

KAZAMA, R.; ZEOULA, L. M.; PRADO, I. N.; SILVA, D. C.; DUCATTI, T.; MATSUSHITA, M. Quantitative and qualitative carcass characteristics of heifers fed different energy sources on a cottonseed hulls and soybean hulls based diet. **Revista Brasileira de Zootecnia**, v. 37, n. 2, p. 350-357, 2008.

KUSS, F.; MOLETTA, J. L.; PEROTTO, D.; PAULA, M. C.; MARTINS, A. S.; SILVA, N. L.; LEME, M. C. J. Feedlot performance and carcass and meat traits of crossbred Braunvieh x Canchim and Purunã x Canchim. **Ciência Rural**, v. 38, n. 4, p. 1061-1066, 2008.

MAGGIONI, D.; MARQUES, J. A.; PEROTTO, D.; ROTTA, P. P.; DUCATTI, T.; MATSUSHITA, M.; SILVA, R. R.; PRADO, I. N. Bermuda grass hay or sorghum silage with or without yeast addition on performance and carcass characteristics of crossbred young bulls finished in feedlot. **Asian-Australasian Journal of Animal Science**, v. 22, n. 2, p. 206-215, 2009.

MAY, S. G.; MIES, W. L.; EDWARDS, J. W.; WILLIAMS, F. L.; WISE, J. W.; MORGAN, J. B.; SAVELL, L. W.; CROSS, H. R. Beef carcass composition of slaughter cattle differing in frame size, muscle score and external fatness. **Journal of Animal Science**, v. 70, n. 8, p. 2431-2445, 1992.

MENEZES, L. F. G.; RESTLE, J. Performance of feedlot finished steers from advanced generations of rotational crossbreeding between Charolais and Nellore. **Revista Brasileira de Zootecnia**, v. 34, n. 6, p. 1927-1937, 2005.

MERTENS, D. R. Regulation of forage intake. In: FAHEY JUNIOR, G. C. (Ed.). **Forage quality, evaluation and utilization**. Wisconsin: American Society of Agronomy, 1994. p. 450-493.

METZ, P. A. M.; MENEZES, L. F. G.; ARBOITTE, M. Z.; BRONDANI, I. L.; RESTLE, J.; CALLEGARO, A. M. Different finishing initial weight on carcass and meat characteristics of Nellore × Charolais crossbred steers. **Revista Brasileira de Zootecnia**, v. 38, n. 2, p. 346-353, 2009.

MOREIRA, F. B.; SOUZA, N. E.; MATSUSHITA, M.; PRADO, I. N.; NASCIMENTO, W. G. Evaluation of carcass characteristics and meat chemical composition of *Bos indicus* x *Bos taurus* crossbred steers finished in pasture systems. **Brazilian Archives of Biology and Technology**, v. 46, n. 4, p. 609-616, 2003.

MÜLLER, L. **Normas para avaliação de carcaças e concurso de carcaça de novilhos**. 1st ed. Santa Maria: Imprensa Universitária, UFSM, 1980.

NRC-National Research Council. **Nutrient requirements of beef cattle**. 6th ed. Washington, D.C.: National Academic Press, 2000.

PADRE, R. G.; ARICETTI, J. A.; MOREIRA, F. B.; MIZUBUTI, I. Y.; PRADO, I. N.; VISENTAINER, J. V.; SOUZA, N. E.; MATSUSHITA, M. Fatty acids profile and chemical composition of *Longissimus* muscle of bovine steers and bulls finished in pasture system. **Meat Science**, v. 74, p. 242-248, 2006.

PADRE, R. G.; ARICETTI, J. A.; GOMES, S. T. M.; GOES, R. H. T. B.; MOREIRA, F. B.; PRADO, I. N.; VISENTAINER, J. V.; SOUZA, N. E.; MATSUSHITA, M. Analysis of fatty acids in *Longissimus* muscle of steers of different genetic breeds finished in pasture systems. **Livestock Science**, v. 110, p. 57-63, 2007.

PEROTTO, D.; ABRAHÃO, J. J. S.; MOLETTA, J. L. Características Quantitativas da Carcaça de Bovinos Charolês, Caracu e Cruzamentos Recíprocos Terminados em Confinamento. **Revista Brasileira de Zootecnia**, v. 29, n. 1, p. 117-124, 2000.

PEROTTO, D.; CUBAS, A. C.; ABRAHÃO, J. J.; MELLA, S. C. Daily gain from weaning to yearling weight of purebred and crossbred Nellore cattle. **Revista Brasileira de Zootecnia**, v. 30, n. 3, p. 730-735, 2001.

PRADO, I. N.; PINHEIRO, A. D.; ALCALDE, C. R.; ZEOULA, L. M.; NASCIMENTO, W. G.; SOUZA, N. E. Substitution levels of corn by orange peel on performance and carcass traits of feedlot bulls. **Revista Brasileira de Zootecnia**, v. 29, n. 7, p. 2135-2141, 2000.

PRADO, I. N.; MOREIRA, F. B.; ZEOULA, L. M.; WADA, F. Y.; MIZUBUTI, I. Y.; NEVES, C. A. In Situ dry matter, crude protein, and neutral detergent fiber degradability of some grasses in continuous grazing. **Revista Brasileira de Zootecnia**, v. 33, n. 5, p. 1332-1339, 2004.

PRADO, I. N.; ITO, R. H.; PRADO, J. M.; PRADO, I. M.; ROTTA, P. P.; MATSUSHITA, M.; VISENTAINER, J. V.; SILVA, R. R. The influence of dietary soyabean and linseed on the chemical composition and fatty acid profile of the *Longissimus* muscle of feedlot-finished bulls. **Journal of Animal and Feed Science**, v. 17, p. 307-317, 2008a.

PRADO, I. N.; PRADO, R. M.; ROTTA, P. P.; VISENTAINER, J. V.; MOLETTA, J. L.; PEROTTO, D. Carcass characteristics and chemical composition of the *Longissimus* muscle of crossbred bulls (*Bos taurus* indicus vs *Bos taurus* taurus) finished in feedlot. **Journal of Animal and Feed Science**, v. 17, p. 295-306, 2008b.

PRADO, I. N.; ROTTA, P. P.; PRADO, R. M.; VISENTAINER, J. V.; MOLETTA, J. L.; PEROTTO, D. Carcass characteristics and chemical composition of the *Longissimus* muscle of Purunã and ½ Puruna vs. ½ Canchin bulls. **Asian-Australasian Journal of Animal Science**, v. 21, n. 9, p. 1296-1302, 2008c.

PRADO, I. N.; ARICETTI, J. A.; ROTTA, P. P.; PRADO, R. M.; PEROTTO, D.; VISENTAINER, J. V.; MATSUSHITA, M. Carcass characteristics, chemical composition and fatty acid profile of the *Longissimus* muscle of bulls (*Bos taurus* indicus vs. *Bos taurus* taurus) finished in pasture systems. **Asian-Australasian Journal of Animal Science**, v. 21, n. 10, p. 1449-1457, 2008d.

PRADO, J. M.; PRADO, I. N.; VISENTAINER, J. V.; ROTTA, P. P.; PEROTTO, D.; MOLETTA, J. L.; PRADO, I. N.; DUCATTI, T. The effect of breed on chemical composition and fatty acid composition on *Longissimus dorsi* muscle of Brazilian beef cattle. **Journal of Animal and Feed Science**, v. 18, p. 231-240, 2009a.

PRADO, R. M.; PRADO, I. N.; MARQUES, J. A.; ROTTA, P. P.; VISENTAINER, J. V.; SILVA, R. R.; SOUZA, N. E. Meat quality of the *Longissimus* muscle of bulls and steers (1/2 Nellore vs ½ Simenthal) finished in feedlot. **Journal of Animal and Feed Science**, v. 18, p. 221-230, 2009b.

PRADO, I. N.; OLIVEIRA, A. N.; ROTTA, P. P.; PEROTTO, D.; PRADO, R. M.; SILVA, R. R.; SOUZA, N. E.; MOLETTA, J. L. Chemical and fatty acid composition of *Longissimus* muscle of crossbred bulls finished in feedlot. **Asian-Australasian Journal of Animal and Feed Science**, v. 22, n. 7, p. 1054-1059, 2009c.

ROTTA, P. P.; PRADO, I. N.; PRADO, R. M.; MOLETTA, J. L.; SILVA, R. R.; PEROTTO, D. Carcass characteristics and chemical composition of the *Longissimus* muscle of Nellore, Caracu and Holstein-friesian bulls finished in a feedlot. **Asian-Australasian Journal of Animal Science**, v. 22, n. 4, p. 598-604, 2009a.

ROTTA, P. P.; PRADO, R. M.; PRADO, I. N.; VALERO, M. V.; VISENTAINER, J. V.; SILVA, R. R. The effects of genetic groups, nutrition, finishing systems and gender of Brazilian cattle on carcass characteristics and beef composition an appearance: a review. **Asian-Australasian Journal of Animal Science**, v. 22, n. 12, p. 1718-1734, 2009b.

SAS-Statistical Analyses System. **User´s guide**: Cary: SAS Institute Inc., 2008. (Version 9.2, v. 2).

SCHAAKE, S. L.; SKELLEY, G. C.; HALPIN, E.; GRIMES, L. W.; BROWN, R. B.; CROSS, D. L.; THOMPSON, C. E. Carcass and meat sensory traits of steers finished on fescue and clover, summer forage, or for different periods in drylot. **Journal of Animal Science**, v. 71, n. 12, p. 3199-3205, 1993.

SILVA, D. J.; QUEIROZ, A. C. **Análise de alimentos (métodos químicos e biológicos)**. Viçosa: Universidade Federal de Viçosa, 2002.

VAN SOEST, P. J. **Nutritional ecology of the ruminant**. 2nd ed. Ithaca: Cornell University Press, 1994.

WEBB, E. C. Manipulating beef quality through feeding. **South African Journal of Food Science and Nutrition**, v. 7, p. 1-24, 2006.

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