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Meat quality of the *Longissimus* muscle of bulls and steers (½ Nellore vs ½ Simmental) finished in feedlot

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ABSTRACT

The experiment was carried out to evaluate performance, carcass characteristics, chemical composition and fatty acid composition of bulls and steers (1/2 Nellore vs 1/2 Simmental) finished in feedlot. From 8 to 20 months the animals were raised conventionally. At 20 month of age 16 bulls were randomly selected of which 8 were surgically castrated. At 32 months of age the animals were transferred into a feedlot system with individual pens of 10 m^2. Both groups of animals were slaughtered at 35 months of age. The bulls were heavier initially and displayed higher final weight, higher average daily gain and hot carcass weight than steers, bulls also had higher moisture content, crude protein and cholesterol and lower total fat content than steers. The ratios of PUFA to SFA and of *n*-6 to *n*-3 in bulls were higher than in steers.

KEY WORDS: cattle, carcass, CLA, meat quality, MUFA, PUFA

INTRODUCTION

Brazil has the biggest commercial cattle herd of the world and has potential to become the greatest producer of bovine meat for export; there are 159 million of animals able to produce 8.2 million tons of carcasses each year (Anualpec, 2007) which make the control of the meat quality extremely important to maintain a long-term market.

Nowadays the food-industry prefers to buy steers because they have carcasses with higher fat deposits as already indicated by fat thickness and marbling

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(Moreira et al., 2003). On the other hand, ranchers prefer to raise bulls because they grow faster.

Castration alters the growth rate and the carcass characteristics due to modifications on the hormonal status (Hunt et al., 1991). Otherwise, the highest growth rate of bulls may be caused by the gradual increase of the hormonal secretion along their growth period. It seems that this higher growth rate is caused by anabolic hormones produced by the testicles (Lee et al., 1990). Additionally, some qualitative characteristics like protein and fat proportions are also influenced by steroid hormones (Gariépy et al., 1990).

The management of bulls in early-weaning system using high energetic diets enables early intramuscular deposits of fat, the fast and efficient animal growth, and the production of lean carcasses with high quality. The ability of bulls finished in feedlot to deposit intramuscular fat may be hindered because the hormone secretion is high and muscle deposits are more likely.

The objective of this experiment was to evaluate the effects of castration on animal performance, carcass characteristics, chemical composition, and fatty acid profile in the *Longissimus* muscle of crossbreed Nellore vs Simmental cattle finished in feedlot and slaughtered at the age of 35 month.

MATERIAL AND METHODS

Animals, management and sampling

The Committee of Animal Production at Maringá State University approved this experiment which was carried out at Iguatemi Research Farm, Iguatemi County, northwestern Paraná (Brazil).

The animals (½ Nellore vs ½ Simmental; meat cattle) were initially raised under usual pasture conditions from 8-to 32-month-old. However, at 20-month-old, sixteen animals within the local herd were randomly sampled and divided in two groups: the first had eight original bulls and the second had eight animals which were surgically castrated. Thereafter, both groups were fenced into grass pastures (*Brachiaria decumbens* Stapf) until the age of 32-month-old when they were transferred into a feedlot system with individual pens of 10 m^2. Both groups were fed twice a day for three months with an appropriate diet following the requirements for beef cattle fattening (NRC, 1996).

The diet components were, %: cotton hulls 50, cracked maize 20, cotton meal 13, maize germ 15, urea 1, limestone 0.5 and mineral salts 0.5. The animals were weighed every 28 days. At the last weighing the animals were fasted 24 h. On average, bulls and steers had 490±14.6 kg and 437±13.4 kg of initial liveweight and 578±15.9 kg and 506±15.3 kg of final liveweight, respectively.

Carcass characteristics

The animals were slaughtered at a commercial slaughterhouse 50 km away from the Iguatemi Research Farm following the usual practice of the Brazilian beef-industry. Thereafter, the carcasses were identified and weighted before chilling at 4°C for 24 h. After chilling, the right part of the carcass was used for determination of quantitative characteristics. Twenty-four h later, *Longissimus* muscle cut in the form of slices between the 12th and the 13th rib. The fat covering the slice was discarded and the muscle portion frozen and stored at -20°C for further analyses.

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

Hot carcass dressing (HCD). Dressing percentage for an individual animal was defined as hot carcass weight divided by liveweight.

Carcass length (CAL). Carcass length is the distance from the skull board to the pubic bone on the anterior side of the first rib, measured with a ribbon or a tape measure.

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

Cushion thickness (CUT). It was taken by a wood compass with metallic edges that measures the distance between the lateral face and the median at the superior part of the cushion.

Fat thickness (FAT). It was taken by a caliper averaging three points between the 12th and the 13th rib but over the LM.

Longissimus muscle area *(LMA)*. The area of the *Longissimus* was measured at the right part of the carcass after a transversal cut between the 12th and the 13th rib using a compensating planimeter, which measures the area of objects with irregular shapes.

Colour (COL). The muscle colour measurements were performed after the chilling for 24 h. Colour was evaluated by a point scale (Müller, 1980) (Table 1) within 30 min after a transversal section between the 12th and the 13th rib of the *Longissimus* muscle.

Table 1. Point scale evaluation for meat colour and texture

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

source: Müller, 1980

Texture (TXT). It was determined through sensorial measurements and expressed using a point scale (Table 1) according to Müller (1980).

Marbling (MAR). It was measured in the LM between the 12th and the 13th rib following the scores in the Table 2.

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

source: Müller, 1980

Chemical composition

Laboratory analyses of beef were carried out two months after sampling. The samples were thawed at room temperature (20ºC), grounded, homogenized, and analysed in triplicate.

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

Chromatographic analysis and cholesterol quantification

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^{-1} of sample under 1-h reflux. The residue was dissolved again in 2 ml hexane containing 0.2 mg ml^{-1} 5-α cholestane internal standard (IS) (Sigma, USA).

Cholesterol content was analysed in a 14-A gas chromatograph (Shimadzu, Japan), equipped with a flame ionization detector and a fused silica capillary column (25 m, 0.25 mm i.d., 0.20 μm thickness SE-30 Quadrix USA). Injector, column, and detector temperatures were 260, 280 and 280ºC, respectively.

Fatty acid methyl esters analysis

The fatty acids methyl esters (FAME) were analysed in a gas chromatograph (Varian, USA) equipped with a flame ionization detector and fused silica capillary column CP-select CB - FAME (100 m, 0.25 mm i.d., 0,25 μm film thockmess, Varian, USA) Select Fame. Column temperature was programmed at 165ºC for 18 min, 180ºC (30ºC min^{-1}) for 22 min, and 240ºC (15ºC min^{-1}) 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^{-1} for the carrier gas (H_2), 30 ml min^{-1} for the make-up gas (N_2) and 30 ml min^{-1} and 300 ml min^{-1} for H_2 and the synthetic flame gas, respectively. Sample injection split mode was 1/80.

Experimental design and statistical analysis

The experimental design with 2 treatments (bulls and steers) and 8 replications (animals) were completely at random. The estimates were compared by the Tukey test at 5 and 1% significance levels, using SAS statistical software (2000).

RESULTS AND DISCUSSION

Animal performance and carcass evaluation. Animal performance and the carcass characteristics of bulls and steers are given in Table 3. Bulls had the initial weight, final weight, average daily gain and hot carcass weight higher

Table 3. Animal performance and carcass traits of bulls and steers finished on feedlot (n=16)[a]

Parameters	Bulls	Steers	SEM	Effect
Initial liveweight, kg	490	437	15.9	**
Final liveweight, kg	578	504	18.5	**
Average daily weight gain, kg	1.36	1.02	0.13	**
Hot carcass weight, kg	307	269	9.79	**
Hot carcass dressing, %	53.4	53.3	0.94	NS
Carcass length, cm	138	137	1.68	NS
Leg length, cm	78.9	78.0	0.63	NS
Cushion thickness, cm	25.3	24.0	0.39	NS
Fat thickness, mm	1.75	2.81	0.32	*
Colour, points	3.50	3.38	0.13	NS
Texture, points	3.25	3.25	0.11	NS
Marbling score	1.50	2.88	0.38	*
Longissimus muscle area, cm^2	65.1	61.6	1.66	*
pH	5.61	5.51	0.03	NS

NS - no significant difference; SEM - standard error of mean
* significant at level of 5% by Tukey-test; ** significant at level of 1% by Tukey-test

(P<0.01) than steers. This highest growth of bulls in comparison with steers or even female cattle seems to be due by the highest production of anabolic hormones by the testicles (Lee et al., 1990). However, bulls had the hot carcass dressing, the carcass length the leg length, and the cushion thickness similar (P>0.05) to steers. The presence of male hormone does not change the qualitative characte-

ristics of the cattle carcass. Otherwise, bulls had fat thickness lower ($P<0.05$) than steers suggesting that such performance is due by the lowest production of testosterone by steers. The physiological condition of both animal groups did not alter ($P>0.05$) the colour, the texture, and the pH of the carcasses. Steers achieved superior marbling score ($P<0.05$) and probably this performance was due by fat deposits because their fat thickness were higher ($P<0.05$). Steers and bulls achieved 2.81 mm and 1.75 mm, respectively; but the bulls had the highest area of the LM ($P<0.05$) which might be due by the highest deposit of muscles.

Chemical composition of LM (Table 4). Steers had the lowest ($P<0.05$) meat moisture, crude protein and cholesterol contents. On the other hand, the lipid content was higher ($P<0.01$) in the LM of steers and the meat moisture was inversely related to lipid content. The lowest fat and the highest protein contents found in bulls is due to the testosterone because this hormone is related to the highest capacity of muscle growth. Bulls and steers had different levels of LM cholesterol; in this case, Rule et al. (1997) suggested that some differences in cholesterol contents might be associated with changes in the cellular structure of the muscle.

Table 4. Chemical composition of the *Longissimus* muscle of bulls and steers finished on feedlot (n=16)[a]

Item	Bulls	Steers	SEM	Effect
Moisture, %	75.0	72.8	0.54	*
Ash, %	1.08	1.06	0.02	NS
Crude protein, %	24.3	23.3	0.44	*
Total lipids, %	0.91	1.46	0.12	**
Cholesterol, mg/100 g muscle	62.3	52.0	2.31	**

NS - no significant difference; SEM - standard error of mean; * significant at level of 5% by Tukey-test; ** significant at level of 1% by Tukey-test

Fatty acid profile. The proportion of fatty acids in the intramuscular fat is indicated in Table 5. The diversity of fatty acids is partly explained by biohydrogenation reactions in the rumen (Tamminga and Doreau, 1991). Oleic (C18:1 *n*-9) and cis vaccenic (C18:1 *n*-7) acids were lower ($P<0.05$) in bulls muscles; unlike the octadecenoic (C18:1 *t*-11), linoleic (C18:2 *n*-6), α-linolenic (C18:3 *n*-3), paullinic (C20:1 *n*-7), arachidonic (C20:4 *n*-6), clupadonic (C22:5 *n*-3 - DPA), and cervonic (C22:6 *n*-3 - DHA) acids that were higher ($P<0.05$) in bulls. The percentage of others fatty acids were similar ($P>0.05$) in both groups (Table 6). Steers LM's had the highest content of vaccenic acid (C18:1 *t*-11); an important intermediate produced by microorganisms in the rumen and transformed into CLA (C18:2 *c*-9, *t*-11 - rumenic acid) in the muscular tissue of ruminants (Bauman et al., 1999).

Table 5. Fatty acids profiles (percentage of the total) from the *Longissimus* muscle of bulls and steers finished on feedlot (n=16)[a]

Fatty acids	Bulls	Steers	SEM	Effect
C14:0 - miristic acid	1.54	1.71	0.17	NS
C16:0 - palmitic acid	21.3	23.4	0.65	NS
C16:1 *n*-7 - palmitoleic acid	1.15	1.82	0.16	NS
C17:0 - anti-iso	0.42	0.32	0.02	NS
C17:0 - iso	0.57	0.58	0.02	NS
C17:0 - margaric acid	0.84	0.71	0.04	NS
C17:1 *n*-7 - heptadecenoic acid	0.42	0.52	0.03	NS
C18:0 - estearic acid	20.3	17.9	0.63	NS
C18:1 *n*-9 - oleic acid	27.8	34.4	1.37	*
C18:1 *n*-7 - cis-vaccenic acid	1.85	2.98	0.27	**
C18:1 *t*11 - octadecenoic acid	2.24	1.54	0.17	*
C18:2 *n*-6 - linoleic acid	12.6	7.62	1.03	**
C18:3 *n*-6 - linolenic acid	0.16	0.16	0.01	NS
C18:2 *c*-9 t-11 - CLA	0.46	0.44	0.03	NS
C18:3 *n*-3 - α-linolenic acid	1.23	0.73	0.11	*
C20:1 *n*-7 - paullinic acid	0.30	0.23	0.03	*
C20:4 *n*-6 - arachidonic acid	3.14	2.35	0.25	*
C20:5 *n*-3 - timnodonic acid - EPA	0.79	0.71	0.06	NS
C22:0 - behenic acid	0.71	0.67	0.05	NS
C22:5 *n*-3 - clupadonic acid - DPA	1.53	1.14	0.10	*
C22:6 *n*- 3 - cervonic acid - DHA	0.22	0.12	0.10	*

NS - no significant difference; SEM - standard error of mean; * significant at level of 5% by Tukey-test; ** significant at level of 1% by Tukey-test

Table 6. Sum and ratios of fatty acid groups in the *Longissimus* muscle of steers and bulls finished on feedlot (n=16)[a]

Fatty acids	Bulls	Steers	SEM	Effect
Polyunsaturated fatty acids (PUFA)	20.3	13.4	1.62	**
Monounsaturated fatty acids (MUFA)	34.3	41.9	1.73	**
Saturated fatty acids (SFA)	45.3	44.7	1.08	NS
Omega – 6 fatty acids (*n*-6)	16.7	10.1	1.32	*
Omega – 3 fatty acids (*n*-3)	4.03	2.70	0.17	**
PUFA/SFA	0.46	0.30	0.04	*
n-6/*n*-3	4.33	3.71	0.14	*
CLA	0.46	0.44	0.03	NS

NS - no significant difference; SEM - standard error of mean; * significant at level of 5% by Tukey-*test*; ** significant at level of 1% by Tukey-*test*

The majority of adipose deposits into animal tissues are synthesized by lipogenesis because ruminant diets are poor in fat components; fatty acids are elongated up to C18:0 and converted into C18:1 by dessaturation (Rule et al., 1997).

The deposits of C18:1 is also increased while the C18:0 is reduced along the deposit period; this could be an explaination for the higher levels of C18:1 in steer muscles.

Moreover, the oleic acid increases the level of HDL-cholesterol (high density lipoprotein) and reduces the level of LDL-cholesterol (low density lipoprotein) in the human blood and studies have demonstrated a strong relation of LDL-cholesterol to HDL-cholesterol and the highest risk of cardiovascular diseases (Kwiterovich, 1997). Also, Padre et al. (2006) observed the highest content of linoleic acid in the LM of Nellore crossbred bulls finished on pasture.

In the current study, bulls had the content of linoleic acid in the LM (12.6%) higher ($P<0.01$) than steers (7.62%). The same animal group had higher content ($P<0.01$) of total polyunsaturated fatty acids (PUFA) in the LM (20.3%) than steers (13.4%). Macedo et al. (2008), Prado et al. (2008a,b,c,d), Ducatti et al. (2009), Maggioni et al. (2009), Prado et al. (2009) and Rotta et al. (2009) also observed a similar response; but in present study, the content of PUFA taken from steers was higher than 5.35% (French et al., 2000), 10.4% (Prado et al., 2003), and 5.82% (Padre et al., 2006). Also, the contents of PUFA were higher than estimates reported by French et al. (2000) and Padre et al. (2006) who evaluated bulls that were raised on pasture conditions.

Bull muscles had lower ($P<0.01$) contents of monounsaturated fatty acids (MUFA - 34.3%) than steer muscles (41.9%), a contrast with the contents of PUFA (Table 6). Similarly, Padre et al. (2006) also observed a lower content of MUFA in the bull muscles. In this study, the contents of MUFA were similar to the results reported by Padre et al. (2006) and Aricetti et al. (2008).

Saturated fatty acid (SFA) level evaluated in intramuscular fat from bull (45.3%) and steer muscles (44.7%) were similar ($P>0.05$). These high SFA estimates were caused by biohydrogenation in the rumen although the animal diet had high levels of PUFA. Also, bull had a higher ($P<0.05$) PUFA/SFA ratio (0.46) than steer muscles (0.30). The mean SFA/MUFA ratio was 0.38; this value is similar to 0.40 which is recommended by the English Health Department (HMSO, 1994). This ratio PUFA/SFA has been significant for health care because it reduces the risk of coronary diseases although the optimal ratio has been a matter of debates.

Ruiz et al. (2005) observed a higher PUFA/SFA ratio in the bull (0.25) than in the steer muscles (0.16); both values were lower than found in the current study which were close to the results (0.13) of French et al. (2000) who studied steers finished on pasture conditions and unlike the highest results reported by Prado et al. (2003) who found 0.28 for Nellore steers finished on pasture conditions.

Bulls had a higher *n*-6/*n*-3 ratio than steer muscles with the mean 4.02 ($P<0.05$); this ratio is also similar to 4.0; the *n*-6 and *n*-3 fatty acids have had a significant role in reducing the risk of coronary heart disease but it is still a matter of debates.

CONCLUSIONS

This study indicates that bulls must be fed up with a high energetic diet in the old age to achieve a high level of intramuscular fat deposits. On other hand, the steers still have the ability to deposit fat when entering a feedlot at an intermediate age.

Castration alters the weight gain and the meat quality of cattle finished in feedlot. However, in Brazil beef cattle are castred at the age 20 months exclusively to facilitate management.

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