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The Effects of Genetic Groups, Nutrition, Finishing Systems and Gender of Brazilian Cattle on Carcass Characteristics and Beef Composition and Appearance: A Review

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ABSTRACT: The aim of this review is to address some characteristics that influence meat quality. Genetic groups, nutrition, finishing systems and gender are the major factors that change carcass characteristics, chemical composition and fatty acid profile. Genetic groups that have zebu genes in their composition show higher hot carcass dressing than genetic groups without zebu genes. Genetic groups that have European breeds in their composition have higher marbling scores. On the other hand, genetic groups that have zebu breeds show low marbling scores. Bulls finished in feedlots present higher final weight than steers, cull cows and heifers. Fat thickness is one of the principal parameters that are affected by different gender. Cull cows (4.72 mm) and heifers (4.00 mm) present higher values than bulls (1.75 mm) and steers (2.81 mm). The major effects observed by different systems of termination are fat thickness and marbling. Crude protein presents variation due to nutrition. Nutrition influences variation of fatty acid profile. Genetic groups also influence fatty acid profile. Genetic groups that have zebu genes in their composition show high percentage of PUFA. The major class of fatty acids that is changed with nutrition is PUFA. The better ratios of PUFA/SFA and *n*-6/*n*-3 are found in *Longissimus* muscle of animals finished in pasture systems. (**Key Words :** Carcass Characteristics, Chemical Composition, Fatty Acid Profile, *Longissimus* Muscle, Cattle)

INTRODUCTION

Brazil has the largest commercial cattle herd in the world with approximately 170 million animals and a production of approximately 8.5 million tons of carcass each year (Anualpec, 2008). From this total, about 30% (2.5 million tons) is exported to several countries around the world.

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 relationship between beef consumption and heart disease, atherosclerosis, intestinal cancer and obesity, among other diseases (Katan et al., 1994; Kwiterovich, 1997).

There are several factors that influence the carcass characteristics, chemical composition and fatty acid profile in cattle. Genetic groups (Prado et al., 2008b; c; Ducatti et al., 2009; Prado et al., 2009a; b; c; Rotta et al., 2009), nutrition (Abrahão et al., 2005; Prado et al., 2008a), finishing systems (Padre et al., 2006; Aricetti et al., 2008) and gender (Padre et al., 2007) are some reasons for the variations in meat quality.

Genetic group is one of the most important factors for fat deposition and composition, which needs to be understood because of its genetic transmission. However, the detailed mechanisms of this variation, and whether or how they can be manipulated are not clearly known.

The aim here is to review some characteristics that can change the meat quality (carcass characteristics, chemical composition and fatty acid profile).

CARCASS CHARACTERISTICS

There are several factors that are responsible for the carcass quality. Carcass conformation, carcass length, leg length, cushion thickness, *Longissimus* muscle area, fat

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thickness, color, texture and marbling are characteristics responsible for carcass quality. The most important factor responsible for change in the carcass characteristics is the genetic group. Some papers (Prado et al., 2008b; c; Prado et al., 2008a; b; c; Rotta et al., 2009) have shown that different genetic groups influence the carcass characteristics.

CHEMICAL COMPOSITION

The chemical composition is represented by several factors such as: moisture, ash, crude protein, total lipids and total cholesterol.

Variations in moisture percentage occur when there is a variation in lipid percentage in *Longissimus* muscle (Prado et al., 2008a; b; Ducatti et al., 2009; Rotta et al., 2009).

Ash percentage is little influenced by nutrition or genetic group (Moreira et al., 2003, Padre et al., 2007; Prado et al., 2009a; b). Ash is important for the supply of sodium, potassium, phosphorus and magnesium which are of great nutritional importance to humans.

Some authors (Aricetti et al., 2008; Macedo et al., 2008; Prado et al., 2008a; b; c; d; Maggioni et al., 2009; Prado et al., 2009a; b; Rotta et al., 2009) reported crude protein percentage in *Longissimus* muscle varying between 21 and 24%. Thus, genetic groups, nutrition and gender can alter crude protein percentage in *Longissimus* muscle of bovines.

Total lipids in *Longissimus* muscle of cattle can vary from 2 to 5% (Padre et al., 2006; Padre et al., 2007; Kazama et al., 2008; Prado et al., 2008a; b; c; d; Rotta et al., 2009). This is the parameter that is most influenced by genetic groups, nutrition and gender.

Cholesterol is an essential compound for the body; it takes part in the synthesis of hormones and bile salts, with half of total cholesterol produced endogenously and the remainder derived from the diet (Campbell, 1995). Until 50 years ago, the solution for reducing blood cholesterol levels seemed simple: the recommendation was to eat foods low in cholesterol, such as replacing butter with vegetable margarine and eating less meat and eggs. However, after advances in the knowledge of the functions of the human body, it is now known that the amount of cholesterol in food does not necessarily determine blood cholesterol levels. The liver synthesizes and stores cholesterol and these processes are regulated by body needs and cholesterol availability in the diet (Campbell, 1995).

FATTY ACID PROFILE

Saturated, monounsaturated and polyunsaturated fatty acids

Fatty acids are "amphiphilic", i.e. they have a carboxyl group (hydrophilic) at the polar end and a hydrocarbon chain at the non-polar tail (hydrophobic) (Webb et al., 2008). Saturated fatty acids consist of only single bonds (Campbell, 1995) and unsaturated fatty acids have double bonds between carbons. Polyunsaturated fatty acids have more than one double bond. In vegetable oils there is a predominance of polyunsaturated fatty acids. On the other hand, in animal fat, there is a predominance of saturated fatty acids (Prado et al., 2008a; b; c; d; Maggioni et al., 2009).

The softness of the lipids is determined by two factors: the length of the predominant fatty acid chain and the presence or absence of double bonds (Campbell, 1995). In animal fat, there is a predominance of long chain fatty acids, with twelve or more carbons atoms (Prado et al., 2008a; b; c; d).

Essential fatty acids in diet

Some fatty acids are required in the human diet because they cannot be synthesized by the human organism (Webb et al., 2008) These fatty acids function as carriers of the fat soluble vitamins (Vitamin A, D, E and K) and realize an important role in the immune response of the animal organism (Webb et al., 2008). These fatty acids can be found in meat of cattle. Essential fatty acids are: linolenic acid (C18:3 *n*-3), linoleic acid (C18:2 *n*-6), arachadonic acid (C20:4 *n*-6), eicosapentanoic acid (C20:5 *n*-3) and docosahexaenoic acid (C22:6 *n*-3) (Prado et al., 2009a; b; c; Rotta et al., 2009).

Non-essential fatty acids in diet

The non-essential fatty acids are those fatty acids that can be synthesized by the animal organism (Webb et al., 2008). The major non-essential fatty acids found are saturated fatty acids (C16:0 and C18:0) and the monounsaturated fatty acid C18:1 *n*-9 (Prado et al., 2008a; b; c; d).

Conjugated fatty acid (CLA)

Trans unsaturated fatty acid is an important precursor for the formation of conjugated linoleic acid (CLA) in tissues (Webb et al., 2008) Due to its properties as an intermediary in the biohydrogenation process of linoleic acid (C18:2 *n*-6) in the rumen, this fatty acid can be transformed into CLA (C18:2 *c*-9, *t*-11) in the tissues of ruminants by the delta-9-desaturase enzyme after being absorbed (Griinari et al., 2000).

GENETIC GROUPS

Genetic group is an important factor that affects the meat quality (carcass characteristics, chemical composition and fatty acid profile) in cattle (Prado et al., 2008b; c; d; Prado et al., 2009a; b; c). For example, British cattle are well known for their highly marbled meat, while the zebu

breed contains less fat and more connective tissue (Silva et al., 2002; Moreira et al., 2003).

Genetic variability consists of differences among species, breeds or lines, differences due to the crossing of breeds, and differences among animals within breeds (Perotto et al., 2000). The latter source of variation is estimated by heritability and genetic correlations. Breed effects may be influenced by the segregation of major genes, one of which is the double-muscled gene in cattle. It is sometimes difficult to assess the real contribution of genetics to differences in meat quality (Webb, 2006). Breed comparisons are often confounded by other effects, such as fat level, live weight, age at slaughter and production system (Webb, 2006).

Carcass characteristics

The animals used to compare carcass characteristics were finished in a feedlot and they had a similar slaughter age (20 to 22 months). In this review, animals were used from the follow genetic groups: Nellore×Aberdeen Angus (Nel×Ang), Canchin×Aberdeen Angus (Can×Ang), Charolais×Caracu (Cha×Car), Purunã first generation (Pur1), Nellore×Continental breed (Nel×Con), Purunã second generation (Pur2), Purunã×British breed (Pur×Bri) and Purunã×Canchin (Pur×Can).

Final weight (FWE) ranges between 450 to 558 kg (Table 1). Nel×Ang presents the higher FWE. This is the result of heterosis and of differences in the original breeds used for crossbreeding (Prado et al., 2008a). In this respect, the presence of genes from Aberdeen Angus in general, increased the advantage of these cattle. In the same way, hot carcass weight (HCW) ranges between 229 to 304 kg and Nel×Ang presents the higher value for HCW.

Conformation (CON), fat thickness (FAT), texture (TEX) and marbling (MAR) are also influenced by genetic groups (Table 1). These characteristics account for more than 35% of variation. On the other hand, hot carcass dressing (HCD), carcass length (CAL), leg length (LEL), cushion thickness (CUT), *Longissimus* muscle area (LMA) and color (COL) account for less than 20% of variation due to genetic groups.

Genetic groups that have zebu genes in their composition show higher HCD than genetic groups without zebu breeds. Prado et al. (2008b) suggest that heterosis is responsible for the higher value of HCD. However, CON is lower when zebu genes compound the genetic group. Prado et al. (2008b) affirm that genetic groups with zebu genes present a lower conformation because zebu breeds show irregular conformation.

FAT is a characteristic that represents excess energy stored as subcutaneous fat. FAT is influenced by genetic groups and its range is between 2.70 to 5.10 mm.

MAR is an important characteristic to meat export because some countries, such as the United States of America, Japan and China, prefer meat with much marbling. This parameter is influence greatly by genetic group. In this review, MAR ranges between 4.13 to 7.78 points. The score for this parameter is 1 to 18 points (Müller, 1980). Genetic groups that have European breeds in their composition have

Table 1. Effect of different crossbreeding types (means) on final weight (FWE), hot carcass weight (HCW), hot carcass dressing (HCD), conformation (CON), carcass length (CAL), leg length (LEL), cushion thickness (CUT), *Longissimus* muscle area (LMA), fat thickness (FAT), color (COL), texture (TEX) and marbling (MAR) of bulls finished in feedlot

Characteristics	Genetic groups							
	Nel×Ang[1]	Can×Ang[2]	Cha×Car[3]	Pur1[4]	Nel×Con[5]	Pur2[6]	Pur×Bri[7]	Pur×Can[8]
n	12	7	6	7	8	9	6	13
Age (months)	22	22	20	22	22	22	20	22
FEW (kg)	558	546	546	496	485	472	463	450
HCW (kg)	304	283	269	250	261	229	238	242
HCD (%)	52.1	49.5	49.2	50.4	54.1	48.5	51.3	53.7
CON (points)	9.08	5.29	13.6	12.4	7.25	12.8	12.8	12.5
CAL (cm)	142	137	144	134	131	132	135	132
LEL (cm)	73.2	68.9	72.9	68.9	75.1	68.2	72.1	70.0
CUT (cm)	28.4	25.9	ND	25.4	26.4	24.7	ND	27.1
FAT (mm)	5.10	4.40	2.70	3.71	2.40	3.00	3.80	3.50
LMA (cm^2)	72.4	72.3	69.0	64.6	65.8	66.7	62.0	64.2
COL (points)	4.17	3.86	3.70	3.57	4.25	3.56	4.00	3.77
TEX (points)	3.25	3.86	3.90	4.14	3.75	3.89	4.50	4.38
MAR (points)	5.75	5.71	4.90	7.14	4.13	7.78	6.20	6.85

[1] Nellore×Aberdeen Angus. [2] Canchin×Aberdeen Angus. [3] Charolais×Caracu. [4] Purunã first generation. [5] Nellore×Continental breed. [6] Purunã second generation. [7] Purunã×British breed. [8] Purunã×Canchin (Adapted from Prado et al., 2008a, Prado et al., 2008b and Prado et al., 2008c). ND = Not defined.

Table 2. Effect of different crossbreeding types (means) on chemical composition of *Longissimus* muscle of bulls finished in feedlot

Parameters	Genetic groups							
	Nel×Ang[1]	Can×Ang[2]	Cha×Car[3]	Pur1[4]	Nel×Con[5]	Pur2[6]	Pur×Bri[7]	Pur×Can[8]
n	12	7	6	7	8	9	6	13
Age (months)	22	22	20	22	22	22	20	22
Moisture (%)	73.7	72.8	73.6	74.2	73.7	73.0	73.9	73.8
Ash (%)	1.07	1.13	1.05	1.06	1.06	1.05	1.10	1.01
Crude protein (%)	24.2	24.9	23.3	23.6	23.1	24.2	22.8	23.5
Total lipids (%)	2.01	3.91	1.45	1.71	2.55	3.00	2.49	1.96
Total cholesterol[9]	41.1	34.1	52.9	41.7	52.5	52.7	48.9	36.5

[1] Nellore×Aberdeen Angus. [2] Canchin×Aberdeen Angus. [3] Charolais×Caracu. [4] Purunã first generation. [5] Nellore×Continental breed.
[6] Purunã second generation. [7] Purunã×British breed. [8] Purunã×Canchin. [9] mg/100 g of muscle (Adapted from Prado et al., 2008a, Prado et al., 2008b and Prado et al., 2008c).

higher MAR scores. On the other hand, genetic groups that have zebu breeds in their composition show lower MAR scores.

Chemical composition

Moisture percentage has little variation due to genetic groups, and changes from 72.8 to 74.2% (Table 2). Prado et al. (2008b) suggest that variations in moisture percentage occur when there is variation in percentage of total lipids. However, in this review, percentage of total lipids changes 170% among genetic groups.

Ash percentage has a variation around 12% due to genetic groups. Ash percentage ranges between 1.01 to 1.13% (Prado et al., 2008a; b; c).

In the same way, crude protein percentage changes around 9%. In this review, the lowest value is 22.8% and the highest value is 24.9% (Prado et al., 2008a; b; c). Prado et al. (2008c) suggest that crude protein percentage is not altered by genetic groups.

Total lipids percentage presents variation due to genetic groups. In general, total lipid levels in the *Longissimus* muscle of cattle finished in a feedlot is close to 3% (Rotta et al., 2009). Animals from genetic groups Can×Ang (3.91%) present the higher value for this parameter; on the other hand, animals from genetic groups Cha×Car (1.45%) present the lower value. However, percentage of total lipids observed in genetic groups is below the maximum level (±5%) regarded as acceptable for the prevention of diseases related to fat content in beef, according to recommendations from the English Health Department (HMSO, 1994).

Total cholesterol presents a variation of around 55% due to genetic groups. It changes between 34.1 to 52.9 mg/100 g in *Longissimus* (Prado et al., 2008a; b; c). Prado et al. (2009b) suggest that the presence of Zebu genes in the makeup of genetic groups appears to result in higher total cholesterol levels in *Longissimus* muscle, perhaps as a result of an increase in muscle membranes. Nevertheless, the average total cholesterol level observed is near that regarded as harmful to human health, which is set to ≥50 mg/100 g of muscle (Pensel, 1998; Saucier, 1999).

Fatty acid profile

Genetic groups influence variation of fatty acid profile (Table 3). Variation of around 60% can be observed in 14:0 (1.57 to 2.73%), 16:1 *n*-7 (1.72 to 2.94%), 17:0 (0.59 to 0.97%), 18:1 *t*-11 (0.85 to 2.50%), 18:2 *n*-6 (2.26 to 7.25%), 18:3 *n*-6 (0.01 to 0.20%), 18:3 *n*-3 (0.12 to 0.73%), 18:2 *c*-9 *t*-11 (0.17 to 0.49%), 20:4 *n*-6 (0.59 to 2.29%), 20:5 *n*-3 (0.09 to 0.68%), 22:5 *n*-3 (0.07 to 0.81%) and 22:6 *n*-3 (0.06 to 0.46%). Prado et al. (2008b; c) suggest that the major factor associated with the variation in fatty acid profile is the genetic groups.

The fatty acids 12:0, 14:0 and 16:0 are considered hypercholesterolemic; they are responsible for the increase in quantity of lipoproteins of low density - LDL (low density lipoprotein) - that are responsible for heart disease (Souza et al., 2006). So, foods with low amounts of these fatty acids are required. In *Longissimus* muscle of cattle the percentage of 14:0 and 16:0 is considered high (35% of the total fatty acids) (Prado et al., 2008b; c; Rotta et al., 2009). The genetic group Nel×Con presents the lowest levels to these fatty acids (Table 3).

Though the fatty acid 18:2 *n*-6 is considered an essential fatty acid, it is related to the imbalance of *n*-6/*n*-3 ratio. This occurs by high presence of this fatty acid in the *Longissimus* muscle of cattle in relation to *n*-3 fatty acids (Rotta et al., 2009). The highest percentage of this fatty acid is found in the genetic group Nel×Ang (7.25%) and the lowest percentage is present in the genetic group Pur2 (2.26%) (Table 3).

The fatty acid 18:3 *n*-3 is considered strictly essential and the presence of this fatty acid is important due to the capacity to form other important fatty acids (Wood et al., 2003). This fatty acid is found in the highest percentage in the genetic group Cha×Car (0.73%).

Saturated fatty acid (SFA) and monounsaturated fatty

Table 3. Effect of different crossbreeding types (percentage of relative area) on fatty acid profile of *Longissimus* muscle of bulls finished in feedlot

Fatty acids	Genetic groups							
	Nel×Ang[1]	Can×Ang[2]	Cha×Car[3]	Pur1[4]	Nel×Con[5]	Pur2[6]	Pur×Bri[7]	Pur×Can[8]
n	12	7	6	7	8	9	6	13
Age (months)	22	22	20	22	22	22	20	22
C14:0	2.05	2.73	1.57	1.77	1.69	1.89	1.95	1.95
C14:1 *n*-7	0.35	0.44	ND	0.34	0.36	0.29	ND	0.40
C16:0	26.9	30.5	24.8	29.3	24.2	29.1	25.8	25.3
C16:1 *n*-7	1.92	2.68	2.47	2.37	1.72	2.94	2.61	2.59
ai 17:0	0.22	0.23	0.58	0.23	0.29	0.24	0.62	0.26
i 17:0 iso	0.47	0.45	0.13	0.49	0.60	0.54	0.01	0.51
C17:0	0.72	0.81	0.95	0.71	0.96	0.59	0.97	0.72
C17:1 *n*-7	0.47	0.56	ND	0.54	0.56	0.50	ND	0.59
C18:0	19.0	19.7	19.2	19.2	21.3	19.3	19.0	17.5
C18:1 *n*-9	36.5	36.0	33.2	34.6	35.6	38.0	35.0	38.7
C18:1 *n*-7	2.09	2.32	1.04	2.68	2.63	3.23	0.67	3.22
C18:1 *t*-11	1.08	0.89	2.50	0.85	1.21	0.86	1.91	0.92
C18 :2 *n*-6	7.25	2.36	4.83	4.31	5.98	2.26	4.28	4.99
C18:3 *n*-6	0.11	0.11	0.01	0.11	0.20	0.11	0.01	0.14
C18:2 *c*-9 *t*-11	0.22	0.25	0.46	0.18	0.30	0.17	0.49	0.34
C18:3 *n*-3	0.34	0.12	0.73	0.25	0.40	0.18	0.38	0.26
C20:4 *n*-6	1.49	0.59	1.76	1.50	2.29	0.69	1.41	1.71
C20:5 *n*-3	0.24	0.68	0.31	0.12	0.31	0.09	0.18	0.32
C22:0	0.27	0.10	ND	0.22	0.45	0.13	ND	0.32
C22:5 *n*-3	0.44	0.38	0.81	0.15	0.79	0.07	0.46	0.22
C22:6 *n*-3	0.22	0.18	0.07	0.36	0.22	0.19	0.06	0.46
SFA[9]	49.6	52.6	47.1	51.6	50.0	50.4	47.3	46.4
MUFA[10]	40.6	42.3	38.6	39.0	38.4	42.5	40.2	39.3
PUFA[11]	8.92	4.95	9.73	6.50	10.9	3.99	8.37	8.29
n-6	7.56	4.29	6.92	5.19	9.23	3.44	5.96	6.78
n-3	1.15	0.48	2.56	0.72	1.38	0.53	1.58	1.13
PUFA/SFA	0.18	0.10	0.21	0.10	0.22	0.08	0.18	0.17
n-6/*n*-3	6.70	11.1	2.70	6.92	7.00	5.60	3.77	7.04

[1] Nellore×Aberdeen Angus. [2] Canchin×Aberdeen Angus. [3] Charolais×Caracu. [4] Purunã first generation. [5] Nellore×Continental breed.
[6] Purunã second generation. [7] Purunã×British breed. [8] Purunã×Canchin. [9] Saturated fatty acids. [10] Monounsaturated fatty acids.
[11] Polyunsaturated fatty acids (Adapted from Prado et al., 2008a, Prado et al., 2008b and Prado et al., 2008c). ND = Not defined.

acid (MUFA) show variation around 15% among different genetic groups (Table 3). On the other hand, polyunsaturated fatty acids (PUFA), *n*-6, *n*-3, PUFA/SFA and *n*-6/*n*-3 present variation due to different genetic groups.

PUFA has a variation from 3.99 to 10.9%. Genetic groups that have zebu genes in their composition show high percentages of PUFA. Prado et al. (2008b; c) suggest that zebu genes are responsible for more deposition of connective tissue which has a high content of polyunsaturated fatty acids.

n-6 percentage ranges between 3.44 to 9.23% (Table 3). The genetic groups that have the zebu breed in their composition show high percentages of this category of fatty acids. This is due to these genetic groups having more PUFA in their fatty acid profile.

Variation is present for *n*-3 percentage due to different genetic groups. The lower value found for *n*-3 is 0.48% and the higher value is 2.56%. The variation in fatty acid profile is responsible for variation of *n*-3 percentage.

PUFA/SFA ranges between 0.08 to 0.22 (Table 3). PUFA/SFA plays an important role in reducing the risk of coronary heart disease (Hu, 2001). The Department of Health (1994) recommends a ratio of. 0.45. The genetic groups that are near this value are those with zebu genes in their composition.

n-6/*n*-3 ranges between 2.70 to 11.1 (Table 3). Only two genetic groups (Cha×Car (2.70) and Pur×Bri (3.77)) show ideal ratios. This led to the *n*-6/*n*-3 ratio in the *Longissimus*

muscle being considered high when compared to the maximum of 4.0 recommended by the Department of Health (1994).

NUTRITION

Nutrition significantly affects the rate of conditioning and consequently carcass characteristics, chemical composition and fatty acid profile (Webb, 2006). Meat quality can be manipulated by a variety of nutritional interventions, many of which have been implemented successfully in feedlots world-wide (Webb, 2006). Although the positive effect of nutrition is usually greater in monogastric animals like chicken and swine, significant changes in meat quality have been reported in ruminants, particularly for fatty acid profile (Prado et al., 2008a; Maggioni et al., 2009).

Manipulation of meat quality through nutrition is more practical and cost effective compared to new breeding strategies, management techniques or *post mortem* technologies used to improve meat quality (Webb et al., 2006). *Post mortem* techniques (e.g. cold storage or retiring excess carcass fat) to improve meat quality are often time consuming and extremely expensive compared to appropriate nutritional strategies (Webb, 2006).

The effects of nutrition on meat quality are more significant in terms of carcass characteristics and chemical composition (Abrahão et al., 2005; Prado et al., 2008a; Maggioni et al., 2009). On the other hand, the effects of nutrition on fatty acid profile are generally small but significant. The effects of nutrition on fatty acid profile, although small, are often very important in terms of nutritive value, color of the product, quality or consistency of fat (Webb, 2006).

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).

Carcass characteristics

The animals used to compare nutrition had similar age (20 to 22 months) and they were finished in feedlots. The treatments used to compare nutrition were: HAB (Bermuda grass hay+corn concentrate), SOS (sorghum silage+corn concentrate), HAY (Bermuda grass hay+corn concentrate+ yeast), SIY (sorghum silage+corn concentrate+yeast), COR (corn silage+corn concentrate), LIN (corn silage+linseed concentrate) and SOY (corn silage+soybean concentrate).

Final weight (FEW) is high for all treatments (Table 4). This elevated final live weight can be explained by the genotype used in these experiments (Zebu×European) (Prado et al., 2008a). A high slaughter weight is necessary in order to achieve satisfactory (fat thickness) finishing levels.

Table 4. Effect of nutrition (means) on final weight (FWE), hot carcass weight (HCW), hot carcass dressing (HCD), conformation (CON), carcass length (CAL), leg length (LEL), cushion thickness (CUT), Longissimus muscle area (LMA), fat thickness (FAT), color (COL), texture (TEX) and marbling (MAR) of bulls finished in feedlot

Characteristics	Nutrition						
	HAB[1]	SOS[2]	HAY[3]	SOY[4]	COR[5]	LIN[6]	SOY[7]
n	10	10	10	10	7	7	7
Age (months)	22	22	22	22	20	20	20
FEW (kg)	522	539	494	506	512	492	499
HCW (kg)	268	278	258	269	267	256	261
HCD (%)	51.3	51.6	52.2	53.2	52.7	52.1	52.3
CON (points)	11.1	10.9	10.5+	11.1	ND	ND	ND
CAL (cm)	139	140	132	137	ND	ND	ND
LEL (cm)	72.1	74.2	72.4	73.1	ND	ND	ND
CUT (cm)	27.2	26.6	26.1	26.6	ND	ND	ND
FAT (mm)	3.23	4.00	3.01	3.36	5.70	5.50	5.00
LMA (cm^2)	66.5	68.3	64.7	68.2	92.2	87.2	84.7
COL (points)	3.24	3.39	3.67	4.07	ND	ND	ND
TEX (points)	4.54	4.17	3.97	4.17	ND	ND	ND
MAR (points)	4.75	5.62	3.77	4.57	ND	ND	ND

[1] Bermuda grass hay. [2] Sorghum silage. [3] Hay+yeast. [4] Silage+yeast. [5] Corn concentrate. [6] Linseed concentrate. [7] Soybean concentrate (Adapted from Ito et al., 2009; Maggioni et al., 2009). ND = Not defined.

Table 5. Effect of nutrition (means) on chemical composition of *Longissimus* muscle of bulls finished in feedlot

Parameters	Nutrition						
	HAB[1]	SOS[1]	HAY[3]	SOY[4]	COR[5]	LIN[6]	SOY[7]
n	10	10	10	10	7	7	7
Age (months)	22	22	22	22	20	20	20
Moisture (%)	73.2	73.2	73.6	73.3	74.1	74.9	75.0
Ash (%)	1.10	1.00	0.90	1.10	1.03	1.06	1.00
Crude protein (%)	23.9	24.1	23.6	23.4	20.4	19.9	20.3
Total lipids (%)	1.80	2.10	1.30	2.20	2.31	1.86	2.73
Total cholesterol[8]	25.3	22.7	22.3	21.5	54.2	55.4	53.6

[1] Bermuda grass hay. [2] Sorghum silage. [3] Hay+yeast. [4] Silage+yeast. [5] Corn concentrate. [6] Linseed concentrate.
[7] Soybean concentrate. [8] mg/100 g of muscle (Adapted from Prado et al., 2008d and Maggioni et al., 2009).

Hot carcass weight (HCW), hot carcass dressing (HCD), conformation (CON), carcass length (CAL), leg length (LEL) and texture (TEX) present variation around 15% due to nutrition (Table 4).

Carcass conformation represents muscle development in the anterior and especially the posterior carcass regions (Müller, 1980). Carcass conformation is positively correlated with several characteristics that express muscle quality, such as CAL, LEL, *Longissimus* muscle area (LMA) and fat thickness (FAT).

FAT ranges between 3.01 mm to 5.70 mm (Table 4). Animals that receive corn silage+corn concentrate achieve higher values than animals that receive Bermuda grass hay +corn concentrate+yeast. This is because corn concentrate is more energetic. In this way, the excess energy provided by corn concentrate is stored as subcutaneous fat (Prado et al., 2008a).

Ito et al. (2009) found high values for LMA. This parameter changed from 64.7 to 92.2 cm^2. In general, authors find an average of 65.0 cm^2 for this parameter (Prado et al., 2008a; Maggioni et al., 2009).

Chemical composition

Moisture percentage has 2% of variation among different nutritional treatments. It ranges between 73.2 to 75.0% (Table 5) and thus moisture percentage is little influenced by nutrition.

Ash percentage ranges between 0.90 to 1.10%. HAB and SIY have the highest value and the lowest value is for HAY (Table 5). Prado et al. (2008a) suggest that ash percentage has little variation as a function of nutrition.

Crude protein percentage has around 21% of variation due to nutrition. LIN shows 19.9% and SOS presents 24.1% (Table 5). Prado et al. (2008a) suggest that the lowest value for LIN is because it is a concentrate with high levels of oil and it does not have high levels of crude protein. On the other hand, SOS has high levels of crude protein. This may be the reason for the high percentage of crude protein in *Longissimus* muscle of animals on SOS treatment.

The variation in total lipids percentage in *Longissimus* muscle is 110% between the diets HAY and SOY (Table 5). Animals fed with the HAY diet (1.30%) present the lowest value for total lipids. However, animals fed with the SOY diet (2.73%) present the highest percentage of total lipids in the *Longissimus* muscle.

Total cholesterol ranges between 21.5 to 55.4 mg/100 g of muscle (Table 5). The treatments that receive the diets HAB, SOS, HAY and SIY produce lower values than the treatments that receive the diets COR, LIN and SOY. The values obtained for the diets HAB, SOS, HAY and SIY 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). However, Silva et al. (2002) found levels of 18.4 mg/100 g meat from crossbred heifers (Nellore vs. Simmental) fed with corn and yeast addition. Perhaps these low values are associated with a method that does not extract all the cholesterol in muscle.

Fatty acid profile

Nutrition has an influence on variation of fatty acid profile (Table 6). Variation above 60% can be observed in 14:0 (1.27 to 2.79%), 16:1 *n*-7 (1.41 to 2.92%), 17:0 (0.63 to 1.03%), 18:1 *t*-11 (0.88 to 1.76%), 18:2 *n*-6 (3.87 to 8.47%), 18:3 *n*-6 (0.10 to 0.33%), 18:3 *n*-3 (0.24 to 0.64%), 18:2 *c*-9 *t*-11 (0.25 to 0.46%), 20:4 *n*-6 (0.76 to 2.53%), 20:5 n-3 (0.19 to 0.52%) and 22:6 *n*-3 (0.05 to 0.61%).

These data show that there is an influence of nutrition on fatty acid profile. More than 60% of fatty acids percentage had variation due to nutrition. The principal class of fatty acids that suffers with nutrition is PUFA. The lower percentage is for COR treatment and the highest percentage is for HAB treatment. SOY is a concentrate with high levels of monounsaturated fatty acids (Prado et al., 2008d) and HAB is a roughage with high levels of polyunsaturated fatty acids (Maggioni et al., 2009). The fatty acid profile of the diet is important to know as the factor that influences fatty acid profile in *Longissimus* muscle.

The sum of the percentages of the fatty acids 14:0 and

Table 6. Effect of nutrition (percentage of relative area) on fatty acid profile of *Longissimus* muscle of bulls finished in feedlot

Fatty acids	Nutrition						
	HAB[1]	SOS[1]	HAY[3]	SOY[4]	COR[5]	LIN[6]	SOY[7]
n	10	10	10	10	7	7	7
Age (months)	22	22	22	22	20	20	20
14:0	1.27	1.40	1.89	1.49	2.79	2.43	2.31
C16:0	25.2	26.1	24.3	24.9	29.2	25.2	25.6
C16:1 *n*-7	1.41	1.83	1.71	1.53	2.92	2.35	2.12
C17:0	0.83	0.83	1.03	0.94	0.81	0.63	0.66
C17:1 *n*-7	0.47	0.51	0.61	0.47	0.63	0.51	0.49
C18:0	22.0	19.4	22.1	22.4	16.0	17.6	18.5
C18:1 *t*- 11	1.15	1.43	1.29	1.17	0.88	1.03	1.76
C18:1 *n*-9	34.1	36.9	34.7	35.6	38.7	38.5	39.2
C18:2 *n*-6	8.47	7.43	7.85	7.42	3.87	5.62	4.87
C18:3 *n*-6	0.12	0.10	0.15	0.16	0.26	0.33	0.30
C18:3 *n*-3	0.56	0.49	0.42	0.33	0.24	0.64	0.51
C18:2 *c*-9 *t*-11	0.25	0.31	0.31	0.26	0.26	0.39	0.46
C20:4 *n*-6	2.07	1.32	2.53	1.82	0.76	1.17	0.89
C20:5 *n*-3	0.52	0.29	0.31	0.29	0.19	0.33	0.23
C22:5 *n*-3	0.90	0.62	0.71	0.62	ND	ND	ND
C22:6 *n*-3	0.13	0.05	0.09	0.07	0.40	0.61	0.45
SFA[8]	49.8	48.6	49.3	50.2	49.2	46.9	47.3
MUFA[9]	37.2	40.7	38.3	38.	44.8	44.0	45.0
PUFA[10]	13.1	10.7	12.4	11.0	5.99	9.10	7.71
n-6	10.7	8.87	10.5	9.41	4.90	7.11	6.07
n-3	2.12	1.47	1.54	1.32	0.83	1.58	1.19
PUFA/SFA	0.28	0.22	0.25	0.22	0.12	0.20	0.16
n-6/*n*-3	5.07	6.33	7.08	7.48	6.47	4.83	5.36

[1] Bermuda grass hay. [2] Sorghum silage. [3] Hay+yeast. [4] Silage+yeast. [5] Corn concentrate. [6] Linseed concentrate. [7] Soybeen concentrate.
[8] Saturated fatty acids. [9] Monounsaturated fatty acids. [10] Polyunsaturated fatty acids (Adapted from Prado et al., 2008d; Maggioni et al., 2009).
ND = Not defined.

16:0 found in *Longissimus* muscle of cattle is lower in diet SOS (26.4) (Table 6). Thus, if the objective is to obtain meat with low percentages of hypercholesterolemic fatty acids, the diet of sorghum silage with corn concentrate and yeast can be an alternative.

n-6 and *n*-3 percentages change due to nutrition. *n*-6 ranges between 4.90 to 10.7%. COR (4.90%), SOY (6.07%) and LIN (7.11%) show the lowest percentages (Table 6). The diets HAB (10.7%), HAY (10.5%), SIL (9.41%) and SLL (8.87%) produce the highest percentages of *n*-6. Thus, nutrition influences *n*-6 percentage in *Longissimus* muscle of cattle. In the same way, *n*-3 has a variation due to nutrition and ranges between 0.83 to 2.12%.

Animals fed with HAB (0.28), HAY (0.25), SOS (0.22), SIY (0.22) and LIN (0.20) present higher values of PUFA/SFA in relation to animals fed with SOY (0.16) and COR (0.12) (Table 6). This characteristic changes around 110%. The English Department of Health (HSMO, 1994) recommends a ratio of about 0.45.

The best ratio of *n*-6/*n*-3 is found in animals that received the diets LIN (4.83), HAB (5.07) and SOY (5.36). However, no diet presents the ideal ratio recommended by the English Department of Health (HSMO, 1994) of 4.0 or less.

FINISHING SYSTEMS

As the ethanol and renewable fuel industries grow, the availability of distiller's grains and other by-products continues to increase. These by-products are valuable feedstuffs for ruminants because of their high protein content and also their high fiber content. However, as more acres are dedicated to corn production, less pasture will be available for grazing livestock and less corn may be available for use as feed. As such, supplementing pasture-fed cattle with distillers grains may be an option for some producers to utilize.

Feedlot has been a cost-effective alternative for raising beef cattle in regions where either the price of grassland or dietary components are inflating operating costs.

Consequently, both conditions require the use of intensive systems to produce high-quality meat. Presently, the use of cereal grains (such as corn) has been the main source of energy in finishing diets, but oils and fats can also be used as alternative components (Prado et al., 2008b).

Consumers demand beef with most of the fat removed but with a quality grade to ensure high palatability. Producers must continue to find new systems for producing cattle that reach a quality grade and still have minimal carcass fat (Camfield et al., 1999). Alternative production systems that include the use of roughages could range from pasturing cattle, pasturing cattle with a limited amount of 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 but have higher cutability than carcasses of grain-fed bulls (Prado et al., 2008b; c). Roughage-fed cattle are generally older than their grain-finished counterparts when they reach a choice quality grade. Carcass cutability varies (Schaake et al., 1993) and European breeds normally have higher yields of lean edible product than *Bos indicus* breeds. Although studies have shown compositional differences among breed types (Prado et al., 2008b; c; Ducatti et al., 2009; Rotta et al., 2009), it is important to understand how various cattle types can be optimally used to produce lean and high-quality beef (May et al., 1992). Cattle growth type and end point of production are critical in order for producers to successfully target carcass characteristics (Wheeler et al., 1996).

Carcass characteristics

The animals used to compare finishing systems had a similar age (20 to 27 mo). The treatments used were a pasture system with supplementation and a feedlot. In the pasture system two genetic groups were compared: Purunã and Nellore×Aberdeen Angus. In the feedlot system the same genetic groups were used to compare the influence of finishing systems.

Table 7 shows carcass characteristics of different finishing systems. FWE ranges between 494 to 558 kg. Bulls finished in a feedlot present the highest average for FWE. This is because animals kept in a feedlot receive a high energy diet and lose less energy from moving because of the restricted size of the pens (generally 5 m^2).

In the same way, HCW has a variation due to the finishing systems. Bulls finished in a feedlot show the highest average for HCW. This is due to the high average that these animals show for FWE.

CON has a variation of 68.3% (Table 7). Animals finished in pasture systems present a better average than animals finished in a feedlot.

The principal effect observed by different finishing systems is FAT and MAR. Animals finished in a feedlot show higher averages for FAT and MAR than animals finished on pasture (Padre et al., 2006). Prado et al. (2008c) suggest that the higher value found for FAT and MAR in animals finished in a feedlot is because these animals receive high amounts of concentrate with high energy, and the excess energy is synthesized into fat that is stored in subcutaneous muscle. MAR is synthesized after the FAT. When an animal has stored high quantities of FAT, synthesis

Table 7. Effect of different systems of termination (means) on carcass characteristics of bulls

Characteristics	Systems of termination			
	Pasture system		Feedlot	
	Pur[1]	Nel×Ang[2]	Pur[3]	Nel×Ang[4]
n	11	10	7	20
Age (months)	20	27	22	22
Final weight (kg)	494	502	496	558
Hot carcass weight (kg)	241	252	245	304
Hot carcass dressing (%)	48.8	50.1	50.4	52.1
Conformation (points)	13.3	ND	12.4	9.08
Carcass length (cm)	139	ND	134	142
Leg length (cm)	71.6	ND	69.0	73.2
Cushion thickness (cm)	ND	ND	25.4	28.4
Fat thickness (mm)	2.60	1.90	3.71	5.10
Longissimus muscle area (cm^2)	61.8	64.4	64.6	72.4
Color (points)	3.60	3.33	3.57	4.17
Texture (points)	4.20	4.12	4.14	3.25
Marbling (points)	4.50	3.80	7.14	5.75

[1] Purunã = Pasture system. [2] Nellore×Aberdeen Angus = Pasture system. [3] Purunã = Feedlot. [4] Nellore×Aberdeen Angus = Feedlot. (Adapted from Aricetti et al., 2008; Prado et al., 2008a; Prado et al., 2008b; Prado et al., 2008c). ND = Not defined.

Table 8. Effect of different systems of termination (mean) on chemical composition of *Longissimus* muscle of bulls

Parameters	Systems of termination			
	Pasture system		Feedlot	
	Pur[1]	Nel×Ang[2]	Pur[3]	Nel×Ang[4]
n	11	10	7	20
Age (months)	20	27	22	22
Moisture (%)	74.9	76.2	74.2	73.7
Ash (%)	1.02	1.01	1.06	1.07
Crude protein (%)	23.9	22.9	23.6	24.2
Total lipids (%)	1.13	0.95	1.71	2.01
Total cholesterol (mg/100 g of muscle)	48.4	45.8	42.0	41.1

[1] Purunã = Pasture system. [2] Nellore×Aberdeen Angus = Pasture system. [3] Purunã = Feedlot. [4] Nellore×Aberdeen Angus = Feedlot. (Adapted from Aricetti et al., 2008; Prado et al., 2008a; Prado et al., 2008b ; Prado et al., 2008c).

of MAR starts (Prado et al., 2008b).

Chemical composition

In this review, the variations for moisture, ash and crude protein percentages are lower than 6% due to the different finishing systems (Table 8).

The different finishing systems seem to influence percentage of total lipids (Table 8). Animals finished in a feedlot present higher percentages of total lipids than animals finished in a pasture system (Aricetti et al., 2008; Prado et al., 2008a). Total lipids percentage ranges between 0.95 to 2.01%; these percentages are considered low due to the age of these animals (around 24 mo). The oldest animals present a high percentage of total lipids (Prado et al., 2009a).

On the other hand, the variation for total cholesterol is lower than for total lipids. It ranges between 41.1 to 48.4 mg/100 g of muscle (Table 8). There is 15% of variation in total cholesterol due to finishing systems; animals finished in a pasture system show high values for total cholesterol.

Fatty acid profile

Finishing systems have an influence on variation of fatty acid profile (Table 9). Variation can be observed for 18:3 *n*-6 (0.01 to 0.11%), 18:3 *n*-3 (0.25 to 1.14%), 18:2 *c*-9 *t*-11 (0.17 to 0.58%), 20:4 *n*-6 (1.49 to 2.54%), 20:5 *n*-3 (0.12 to 0.42%), 22:5 *n*-3 (0.15 to 0.98%) and 22:6 *n*-3 (0.06 to 0.36%). Almost 50% of fatty acids are highly influenced by the finishing system. This is because of the diet given to animals and the physiological alterations due to animal movement. Animals kept in a pasture system have to walk more in looking for feed than animals kept in a feedlot. This acts in the animal organism to change the metabolism so that more energy is expended in moving (Prado et al., 2008c).

The variation of the fatty acids 14:0 and 16:0 are 58 and 25%, respectively (Table 9). Animals finished in a pasture system with supplementation present low percentages for 14:0 and 16:0 in comparison to animals finished in a feedlot. However, the variation in 18:0 is low (around 1%) between the finishing systems (Prado et al., 2008c).

The percentage of 18:3 *n*-3 is four times higher in *Longissimus* muscle of animals finished on pasture with supplementation in comparison with animals finished in a feedlot.

The higher percentage of this fatty acid found in *Longissimus* muscle of animals finished in a pasture system with supplementation also influences the percentage of 20:5 *n*-3. This occurs due to 18:3 *n*-3 being the precursor of 20:5 *n*-3 (Campbell, 1995). However, the higher percentage of 22:6 *n*-3 is observed in animals finished in a feedlot. This fatty acid also can be produced by the process that converts 18:3 *n*-3 into 22:6 *n*-3 (Campbell, 1995). However, the high percentage of this fatty acid can be due to its high percentage in the diet given to the animals finished in a feedlot.

The principal alteration can be observed in PUFA (Table 9). Animals kept in a pasture system present with a higher percentage of polyunsaturated fatty acids than animals kept in a feedlot. Prado et al. (2008d) suggest that this difference is due to the fatty acid profile of pasture that is rich in polyunsaturated fatty acids. Silva et al. (2008), working with supplementation of Nellore steers, studied the effect of levels of supplementation in these animals and fatty acid profile was higher for PUFA in pasture (*Brachiaria brizantha*) than in the concentrate given to the animals.

In the same way, variation can be observed in *n*-6 and *n*-3 percentages. These two classes of fatty acid are present in high percentages in *Longissimus* muscle of animals finished in a pasture system. This is because pasture has a greater percentage of these fatty acids than the concentrate given in the feedlot (Prado et al., 2008b).

The better ratios of PUFA/SFA and *n*-6/*n*-3 are found in *Longissimus* muscle of animals finished in pasture systems. Animals kept on pasture present a PUFA/SFA near that recommended by the Department of Health (1994) of more than 0.45, and *n*-6/*n*-3 of less than 4.0 found in animals kept

Table 9. Effect of different systems of termination (percentage of relative area) on fatty acid profile of *Longissimus* muscle of bulls

Fatty acids	Systems of termination			
	Pasture system		Feedlot	
	Pur[1]	Nel×Ang[2]	Pur[3]	Nel×Ang[4]
n	11	10	7	20
Age (months)	20	27	22	22
C14:0	1.35	1.30	1.77	2.05
C16:0	23.4	23.5	29.3	26.9
C16:1 *n*-7	2.27	2.22	2.37	1.92
C17:0	1.10	0.99	0.71	0.72
C17:1 *n*-7	0.59	0.56	0.54	0.47
C18:0	19.4	19.1	19.2	19.0
C18:1 *t*- 11	3.07	2.63	3.23	1.08
C18:1 *n*-9	32.4	31.9	34.6	36.5
C18:2 *n*-6	5.72	6.62	4.31	7.25
C18:3 *n*-6	0.01	0.01	0.11	0.11
C18:3 *n*-3	1.14	1.23	0.25	0.34
C18:2 *c*-9 *t*-11	0.58	0.50	0.17	0.22
C20:4 *n*-6	2.42	2.54	1.50	1.49
C20:5 *n*-3	0.43	0.42	0.12	0.24
C22:5 *n*-3	0.83	0.98	0.15	0.44
C22:6 *n*-3	0.06	0.07	0.36	0.22
SFA[5]	46.6	46.1	51.6	49.6
MUFA[6]	36.9	36.2	39.0	40.6
PUFA[7]	11.7	14.1	6.50	8.92
n-6	7.50	8.48	5.19	7.56
n-3	3.19	3.56	0.72	1.15
PUFA/SFA	0.25	0.29	0.10	0.18
n-6/*n*-3	2.35	2.38	6.92	6.70

[1] Purunã = Pasture system. [2] Nellore×Aberdeen Angus = Pasture system. [3] Purunã = Feedlot. [4] Nellore×Aberdeen Angus = Feedlot.
[5] Saturated fatty acids. [6] Monounsaturated fatty acids. [7] Polyunsaturated fatty acids (Adapted from Aricetti et al., 2008; Prado et al., 2008a; Prado et al., 2008b ; Prado et al., 2008c).

in pasture systems is ideal according to the recommendation of the Department of Health (1994),. This ratio appears to have positive effects on membrane fluidity, gene expression, cytokine formation, level and composition of serum lipids, and modulation of immune responses (Simopoulos, 1996). The two different genetic groups kept in a pasture system have a ratio of 2.35 (Purunã) and 2.38 (Nellore×Aberdeen Angus). The same breeds finished in a feedlot present high ratios (6.92 (Purunã) and 6.70 (Nellore×Aberdeen Angus)).

GENDER

Nowadays, the food-industry prefers to buy steers because they have carcasses with higher fat deposits as already indicated by fat thickness and marbling (Moreira et al., 2003; Prado et al., 2009a). On the other hand, ranchers prefer to raise bulls because they grow faster.

Castration alters the growth rate and carcass characteristics due to modifications of hormonal status (Hunt et al., 1991). Otherwise, the higher growth rate of bulls may be caused by the gradual increase of hormonal secretion throughout 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, such as protein and fat proportions are influenced by steroid hormones (Gariépy et al., 1990).

The management of bulls in an early-weaning system using high-energy diets enables early intramuscular deposits of fat, fast and efficient animal growth, and the production of lean carcasses of high quality (Schoonmaker et al., 1999). The ability of bulls finished in a feedlot to deposit intramuscular fat may be hindered because hormone secretion is high and deposition of muscle is more likely (Lee et al., 1990).

Cull cows from dairy herds are of considerable economic importance to the producer and beef food chain (Jurie et al., 2007). However, producers want to maximize

Table 10. Effect of gender (means) on carcass characteristics of animals finished in a feedlot

Characteristics	Gender			
	Bulls	Steers	Female	
n	8	8	14	11
Age (months)	35	35	102	18
Final weight (kg)	578	504	465	317
Hot carcass weight (kg)	307	269	245	171
Hot carcass dressing (%)	53.4	53.3	52.7	53.9
Carcass length (cm)	138	137	135	114
Leg length (cm)	78.9	78.0	ND	68.2
Cushion thickness (cm)	25.3	24.0	24.4	21.0
Fat thickness (mm)	1.75	2.81	4.72	4.00
Longissimus muscle area (cm^2)	65.1	61.6	50.3	57.3
Color (points)	3.50	3.38	3.62	4.00
Texture (points)	3.25	3.25	3.36	4.40
Marbling (points)	1.50	2.88	5.40	3.70

Adapted from Kuss et al., 2005a; Marques et al., 2006; Prado et al., 2009a. ND = Not defined.

the value of cull cows to their business. Ensuring that animals are finished and the requirements of the processors are achieved is essential to optimize farm gate returns for these cattle (Lee et al., 2009).

The value of culls cow is highly sensitive to specific market conditions but maximizing returns from dairy cull cows is also sensitive to the costs associated with feeding to achieve slaughter weight (Lee et al., 2009).

Dairy farmers have three options when the fertility of dairy cows decline: i) remove cows from the milking herd and finishing for slaughter; ii) sell cull cows at salvage value for milking or to the slaughter house; iii) carry out extended lactations with rebreeding to facilitate calving at 18 or 24 month intervals (Auldist et al., 2007).

Carcass characteristics

The age of the crossbred animals (1/2 Zebu×1/2 European) used for this review on carcass characteristics were: bulls and steers (35 mo old), female cattle (102 mo old and 18 mo old). All animals were finished in feedlot.

Bulls show the highest FWE than other genders (steers and female cattle) (Table 10). This highest growth of bulls in comparison with steers or even female cattle seems to be due to the higher production of anabolic hormones by the testicles (Lee et al., 1990). There is a big variation among animals of different physiological condition. FWE ranges between 317 to 578 kg. Heifers have the lowest value. Marques et al. (2006) suggest that the low FWE is due to this gender having less muscle deposition.

HCW is influenced by FWE (Prado et al., 2009a). Thus, heifers show low values for HCW (171 kg) and bulls present high values (307 kg). Steers (269 kg) and cull cows (245 kg) present intermediate values.

CAL has more variation for heifers. This gender presents the lowest value for carcass length due its size; heifers are smaller than bulls, steers and cull cows (Prado et al., 2009a). In the same way, LEL and CUT have low values for heifers (68.2 cm; 21.0 cm). Bulls (78.9 cm; 25.3 cm) and steers (78.0 cm; 24.0 cm) do not show variation (Table 10).

FAT is one of the principal parameters that is affected by different physiological conditions. Cull cows (4.72 mm) and heifers (4.00 mm) present higher values than bulls (1.75 mm) and steers (2.81 mm). This is because the female deposits more fat than the male (Prado et al., 2009a). Steers have higher FAT than bulls because of the lower production of testosterone by steers (Prado et al., 2009a).

LMA has variation among animals of different physiological condition. It ranges between 50.3 to 65.1 cm^2 (Table 10). Bulls have a high value due to their capacity to deposit muscle. Cull cows present a low value because of their deficient deposition of muscle; they deposit more fat than muscle (Lee et al., 2009).

COL and TEX present little variation. However, MAR shows variation among bulls, steers, cull cows and heifers (Table 10). Cull cows (5.40 points) and heifers (3.70 points) present more marbling due to their capacity to deposit fat. Marbling is the last fat to be deposited and females have genes that control the deposition efficiently (Lee et al., 2009). Bulls have a low value for MAR of 1.50 points. For steers, this value is 2.88 points.

Chemical composition

The ages of the crossbred animals (1/2 Zebu×1/2 European) used for this review on chemical composition were: bulls and steers (35 mo old), female cattle (60 mo old and 20 mo old). All animals were finished in a feedlot.

Moisture percentage has variation among bulls (75.0%),

Table 11. Effect of gender (means) on chemical composition of *Longissimus* muscle of animals finished in a feedlot

Parameters	Gender			
	Bulls	Steers	Female	
n	8	8	14	11
Age (months)	35	35	102	18
Moisture (%)	75.0	72.8	71.4	74.4
Ash (%)	1.08	1.06	1.40	1.13
Crude protein (%)	24.3	23.3	21.0	21.2
Total lipids (%)	0.91	1.46	7.10	2.42
Total cholesterol (mg/100 g of muscle)	62.3	52.0	ND	49.7

Adapted from Macedo et al., 2008; Minchin et al., 2009; Prado et al., 2009a. ND = Not defined.

steers (72.8%), cull cows (71.4%) and heifers (74.4%) (Table 11). This variation between bulls and cull cows is due to the high percentage of total lipids present in their *Longissimus* muscle. Prado et al. (2008b) suggest that the variation on moisture percentage is due to the variation in total lipids.

Usually, ash percentage does not change due to genetic groups, nutrition and finishing systems (Prado et al., 2008a; b; c; d). However, gender is a factor that has influence on ash percentage. Cull cows (1.40%) present a higher ash percentage than other categories (bulls (1.08%), steers (1.06%) and heifers (1.13%)). The high value found for cull cows is because these animals were slaughtered at 60 mo old and the other categories were slaughtered earlier (30 mo old) (Minchin et al., 2009).

Crude protein percentage presents variation between male and female. Bulls (24.3%) and steers (23.3%) do not have variation (Table 11). In the same way, cull cows (21.1%) and heifers (21.2%) do not have variation, but males have higher crude protein percentage than females.

The parameter of chemical composition that is more influenced by gender is percentage of total lipids. Cull cows (7.10%) have more total lipids percentage than bulls (0.91%), steers (1.46%) and heifers (2.42%) (Table 11). Minchin et al. (2009) suggest that the higher percentage for total lipids in cows is due to their high deposition of fat. The low percentage of total lipids in bulls is explained by testosterone; this hormone is related to the higher capacity for muscle growth in bulls and the lower capacity for fat deposition (Rule et al., 1997).

Total cholesterol has variation among bulls (62.3 mg/100 g of muscle), steers (52.0 mg/100 g of muscle) and heifers (49.7 mg/100 g of muscle) (Table 11). The difference between bulls and steers is explained by changes in the cellular structure of the muscle (Rule et al., 1997). Thus, bulls present with more total cholesterol content than other animal categories.

Fatty acid profile

The age of the crossbred animals (1/2 Zebu×1/2 European) used for this review on fatty acid profile were: bulls and steers (35 mo old), female cattle (60 mo old and 20 mo old). All animals were finished in a feedlot.

Most fatty acids (70%) show variation around 60% due to gender: 14:0 (1.54 to 2.54%), 16:1 *n*-7 (1.15 to 4.39%), 17:1 *n*-7 (0.42 to 0.74%) 18:1 *t*-11 (0.91 to 2.24%), 18:2 *n*-6 (1.87 to 12.6%), 18:3 *n*-3 (0.53 to 1.23%), 18:2 *c*-9 *t*-11 (0.22 to 0.46%), 20:4 *n*-6 (0.93 to 3.14%), 20:5 *n*-3 (0.26 to 0.79%), 22:5 *n*-3 (0.55 to 1.53%) and 22:6 *n*-3 (0.05 to 0.22%) (Table 12). This demonstrates that fatty acid profile is influenced by gender.

The percentages of saturated fatty acids C14:0 and C16:0 are higher in females than males, but there is no variation in percentage of these fatty acids between bulls and steers or between cull cows and heifers. However, C18:0, an abundant saturated fatty acid, is higher in males than females. Cull cows present the lowest percentage of this fatty acid. The low percentage present in *Longissimus* muscle of this animal category is partly explained by biohydrogenation reactions in the rumen (Tamminga and Doreau, 1991). The majority of adipose deposits in animal tissues are synthesized by lipogenesis because ruminant diets are poor in fat components; fatty acids are elongated up to 18:0 and converted into 18:1 by desaturation (Rule et al., 1997). The deposition of 18:1 is also increased while 18:0 is reduced during the deposition period; this could explain the higher levels of 18:1 in steer muscles.

C18:2 *n*-6 presents variation among gender. Cull cows (1.87%) have the lowest percentage of this fatty acid (Table 12). Bulls (12.6%) have the highest percentage of C18:2 *n*-6. There is a high variation (674%) between these classes. In the same way, C20:4 *n*-6 has the highest percentage for bulls (3.14%) and the lowest percentage for heifers (0.93%). This demonstrates that males have a greater percentage of essential fatty acids than females.

SFA does not present variation among gender. MUFA is influenced by this characteristic and bulls present the lower value. On the other hand, cull cows (47.0%) have a high percentage of MUFA (Table 12). SFA have been implicated in diseases associated with modern life, especially in

Table 12. Effect of gender (percentage of relative area) on fatty acid profile of *Longissimus* muscle of animals finished in feedlot

Fatty acids	Gender			
	Bulls	Steers	Female	
n	8	8	14	11
Age (months)	35	35	102	18
C14:0	1.54	1.71	2.54	2.15
C16:0	21.3	23.4	27.1	27.0
C16:1 *n*-7	1.15	1.82	4.39	2.70
C17:0	0.84	0.71	ND	0.86
C17:1 *n*-7	0.42	0.52	ND	0.74
C18:0	20.3	17.9	13.1	16.9
C18:1 *t*- 11	2.24	1.54	0.91	0.99
C18:1 *n*-9	27.8	34.4	37.9	41.2
C18:2 *n*-6	12.6	7.62	1.87	3.33
C18:3 *n*-6	0.16	0.16	ND	ND
C18:3 *n*-3	1.23	0.73	0.71	0.53
C18:2 *c*-9 *t*-11	0.46	0.44	0.22	0.31
C20:4 *n*-6	3.14	2.35	ND	0.93
C20:5 *n*-3	0.79	0.71	0.31	0.26
C22:5 *n*-3	1.53	1.14	0.55	ND
C22:6 *n*-3	0.22	0.12	0.05	ND
Saturated fatty acids	45.3	44.7	44.3	44.1
Monounsaturated fatty acids	34.3	41.9	47.0	46.6
Polyunsaturated fatty acids	20.3	13.4	4.57	5.16
n-6	16.7	10.1	2.97	4.37
n-3	4.03	2.70	1.77	0.79
PUFA/SFA	0.46	0.30	0.11	0.13
n-6/*n*-3	4.33	3.71	1.70	5.60

Adapted from Macedo et al., 2008; Lee et al., 2009; Prado et al., 2009a. ND = Not defined.

developed countries; these include various cancers and especially coronary heart disease (Wood et al., 2003). MUFA is a class of fatty acids that have a positive influence on health. C18:1 *n*-9 (oleic acid) increases the level of HDL-cholesterol (High Density Lipoprotein) and reduces the level of LDL-cholesterol (Low Density Lipoprotein) in human blood (Katan et al., 1994) and studies in humans have demonstrated a strong relationship of LDL-cholesterol to HDL-cholesterol and higher risk of cardiovascular disease (Kwiterovich, 1997).

Bulls present a high value for *n*-6 of 16.7%; steers present 10.1%, cull cows present 2.97% and heifers present 4.37% (Table 12). There is variation for this fatty acid due to gender. In the same way, bulls have a high *n*-3 percentage of 4.03%. Steers present 2.70%, cull cows present 1.77% and heifers 0.79%.

The Department of Health (1994) recommends that PUFA/SFA should be higher than 0.45. In this case, only bulls present the ideal ratio, namely 0.46. The other categories present low values for this ratio. Meat cattle usually have PUFA/SFA lower than 0.45 (Prado et al., 2008a; b; c; d) so, meat has been implicated as a cause of the imbalanced fatty acid intake of today's consumers (Wood et al., 2003). For this reason, ways to improve PUFA/SFA during meat production are required. Researchers have focused on the type of PUFA and the balance in the diet between *n*-3 formed from linolenic acid (C18:3) and *n*-6 formed from linoleic acid (C18:2) (Williams, 2000).

n-6/*n*-3 presents better values for steers (3.71) and cull cows (1.70) (Table 12). The other genders obtained high values. The recommendation by the Department of Health (1994) is less than 4.00. The *n*-6/*n*-3 value is also a risk factor in cancers and coronary heart disease, especially in the formation of blood clots leading to a heart attack (Enser, 2001).

IMPLICATIONS

The carcass characteristics, chemical composition and fatty acid profile are influenced by genetic groups, nutrition, finishing systems and gender. Bulls reach final weight faster

than steers and females. Genetic groups that contain zebu genes in their composition present high hot carcass dressing. However, the *Longissimus* muscle of genetic groups with zebu genes present low marbling. The crude protein content is altered by nutrition. High crude protein percentage is observed in animals fed with sorghum silage. The *Longissimus* muscle of cull cows presents a high percentage of total lipids in relation to other genders. Nutrition also influences the fatty acid profile. Animals fed with Bermuda grass hay+corn concentrate present high values for polyunsaturated fatty acids, *n*-6, and *n*-3 fatty acids, and better ratios of PUFA/SFA and *n*-6/*n*-3. Better ratios are also found in the *Longissimus* muscle of animals finished on pasture with supplementation compared with animals finished in feedlot. Females present inferior meat quality in relation to the percentage of hypercholesterolemic fatty acids (14:0 and 16:0), lower percentage of essential fatty acids and less PUFA.

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