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Chemical and Fatty acid composition of different cuts cooked or uncooked from yearling bulls fed oil sources

Emanuel Almeida de Oliveira[1*], Alexandre Amstalden Moraes Sampaio[1], Wignez Henrique[2], Thiago Martins Pivaro[1], Bruna Laurindo Rosa[1] and Alexandre Rodrigo Mendes Fernandes[3]

*[1]Departamento de Zootecnia, Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, Estrada Prof. Paulo Donato Castellane, s/n, 14884-900, Jaboticabal, São Paulo, Brazil. [2]Agência Paulista de Tecnologia dos Agronegócios, São José do Rio Preto, São Paulo, Brazil. [3]Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Dourados, Mato Grosso do Sul, Brazil.*Author for correspondence. E-mail: moroto.oliveira@hotmail.com*

ABSTRACT. This study evaluated the chemical and lipid composition of uncooked or cooked loin (*Longissimus thoracis*) and rump (*Biceps femoris*) in samples of 2.54 cm thick from 35 carcasses of Nellore young bulls finished in feedlot for 96 days and slaughtered at an average weight of 532.17 ± 30.25 kg and 24 months of age. The rump had the lowest level of protein and ash (18.57 and 0.90%, respectively) and the highest level of ether extract compared to loin (3.37 and 1.90%, respectively). Higher levels of cholesterol were found in rump compared to loin (40.91 e 30.93 mg 100 g^{-1}, respectively). The uncooked loin showed lower content of saturated fatty acids and higher content of polyunsaturated fatty acids. The best values for the omega-6: omega-3 ratio was observed in the uncooked beef. In the present study, the loin was healthier due to the higher amount of polyunsaturated fatty acids compared to rump. Cooking the meat decreases the levels of polyunsaturated fatty acids, omega-3, omega-6 and the omega-6: omega-3 ratio.

Keywords: Conjugated linoleic acid, cholesterol, ether extract, meat cuts, protein.

Composição química e lipídica de diferentes cortes cárneos *in natura* ou assados de tourinhos alimentados com fontes de óleo

RESUMO. Objetivou-se avaliar as diferenças na composição química e lipídica do contrafilé (*Longissimus thoracis*) e da picanha (*Biceps femoris*) *in natura* ou assados de bovinos alimentados com diferentes fontes de óleo. Para isto, foram utilizadas amostras, seccionadas em bifes de 2,54 cm, do contrafilé e da picanha, provenientes de 35 carcaças de tourinhos da raça Nelore, confinados por 96 dias e abatidos com peso médio de 532,17 ± 30,25 kg e 24 meses de idade. A picanha apresentou os valores mais baixos de proteína e cinzas (18,57 e 0,90%, respectivamente). No entanto, os maiores teores de extrato etéreo também foram encontrados para este corte comparado ao contrafilé (3,37 e 1,90%, respectivamente). Maiores teores de colesterol foram encontrados na picanha em relação ao contrafilé (40,91 e 30,93 mg 100 g^{-1}, respectivamente). O contrafilé *in natura* apresentou menores teores de ácidos graxos saturados e maiores quantidades de ácidos graxos poli-insaturados. Para as relações dos ácidos graxos ômega-6: ômega-3, os melhores valores foram encontrados na carne *in natura*. O contrafilé, no presente estudo, mostrou-se mais saudável pela maior quantidade de ácidos graxos poli-insaturados que a picanha. Assar a carne diminui os teores de ácidos graxos poli-insaturados, ômega-3 e ômega-6, além da relação ômega-6: ômega-3.

Palavras-chave: Ácido linoleico conjugado, colesterol, extrato etéreo, cortes cárneos, proteína.

Introduction

Currently, consumers are more concerned to find safe and healthy foods that have quality and convenience (Guerrero et al., 2013; Hocquette et al., 2012). Furthermore, beef is an important food with a high nutritional value, containing important and essential constituents, such as proteins and minerals. Besides, beef is considered an easily prepared food (Scollan et al., 2006).

Over the last 15 years, beef consumption has been associated with several negative drawbacks, such as increased levels of cholesterol, incidence of coronary heart disease and cancer (Scollan et al., 2006). Thereby, researches on human nutrition suggest that the intake of fats derived from animal products should be between 15 and 30% of total calories, for saturated fats, the ingestion should not exceed 10%, and for cholesterol, should not exceed 300 mg daily (Chizzolini et al., 1999).

However, beef has important elements derived exclusively from ruminants, such as conjugated linoleic acid (Prado et al., 2008; Rotta et al., 2009),

which has proven benefits to human health, including tumor reduction, reduced risks for developing atherosclerosis, and increased immunity. In this sense, the manipulation of diets for ruminants with precursors of important fatty acids, such as C18:2 ω6 or C18:3 ω3, or even the addition of foodstuff rich in unsaturated fatty acids could be very interesting (Ito et al., 2010; Souza et al., 2007).

This study was performed to assess differences in chemical and fatty acid composition between two commercial cuts (loin and rump), common in Brazilian cuisine, uncooked or cooked, from Nellore young bulls finished in feedlot and fed diets rich in omega-3 and omega-6 fatty acids.

Material and methods

For this study, samples of loin (*L. thoracis)* and rump (*B. femoris*) were taken from 35 Nellore young bulls with an average body weight of 402.69 ± 14.90 kg and an average age of 18 ± 2 months. The experiment was conducted at the Beef Cattle Sector of the Department of Animal Sciences, College of Agrarian and Veterinary Sciences of Unesp (Jaboticabal, São Paulo State, Brazil). All experimental procedures were approved by the Committee for Ethics and Animal Welfare (Cebea), College of Agrarian and Veterinary Sciences (protocol 021167-07).

Prior to the experimental period, these animals were randomly assigned to different treatments, and subsequently adapted to specific management conditions and diets for 28 days. At the end of the experimental period, the animals were transported to a slaughterhouse 200 km away, stunned and slaughtered. At the time of slaughter, the bulls exhibited an average weight of 532.2 ± 30.2 kg, an average carcass dressing of 55.3 ± 1.30 %, and an average fat thickness of 7.0 mm.

The five experimental diets were formulated using the RLM® software (Esalq/USP), with nutritional demands estimated by the CNCPS system (Fox et al., 1992) with the aim of maximum weight gain (Table 1). The first diet was the Control with no oil added. The other four diets were composed of different lipid sources as follow: Soybean oil (unprotected soybean oil), Linseed oil (unprotected linseed oil), Megalac- E® (soybean oil protected from ruminal degradation) and PLO (linseed oil protected from ruminal degradation), all diets had sugar cane IAC 86-2480 at 40% DM as exclusive forage.

Since protected linseed oil is not commercially available, a method was developed to obtain this product from regular linseed oil at the Laboratory of Applied Enzymology of the College of Agrarian and Veterinary Sciences of Unesp.

Table 1. Composition (% of dry matter (DM)), nutritional characteristics, and fatty acid composition of the experimental diets.

Food	Diets (% of DM)				
	Control	Soybean oil	Linseed Oil	Megalac-E®	PLO[2]
Sugar cane	40.0	40.0	40.0	40.0	40.0
Corn grain	34.0	29.2	29.2	29.0	29.0
Soybean meal	12.0	13.0	13.0	13.0	13.0
Citrus pulp	10.0	10.0	10.0	10.0	10.0
Urea	1.0	1.0	1.0	1.0	1.0
Soybean oil	-	3.8	-	-	-
Linseed oil	-	-	3.8	-	-
Megalac-E®[1]	-	-	-	4.5	-
PLO[2]	-	-	-	-	4.5
Mineral core[3]	2.5	2.5	2.5	2.5	2.5
Limestone	0.5	0.5	0.5	-	-
	Nutritional characteristics[4]				
DM (%)	47.6	47.6	47.7	46.5	47.7
CP (% of DM)	13.5	13.5	13.5	13.5	13.5
TDN (% of DM)	71.5	76.7	76.7	76.5	76.5
EE (% of DM)	2.4	6.0	6.0	6.0	6.0
ME (MJ/kg DM)	11.5	12.2	12.2	12.2	12.2
Estimated gain (kg dia^{-1})	1.4	1.6	1.6	1.6	1.6
	Fatty acids composition of the experimental diets				
Fatty acids (%)	Treatments				
C12:0	0.14	0.05	0.31	0.06	0.09
C14:0	0.19	0.12	0.93	0.12	0.26
C16:0	16.44	14.25	24.88	13.45	23.32
C16:1	0.18	0.13	0.49	0.15	0.16
C17:0	0.21	0.14	0.27	0.18	0.29
C17:1	0.30	0.11	0.10	0.13	0.28
C18:0	3.05	3.74	7.61	6.13	10.48
C18:1n9c	30.27	27.14	23.51	30.74	28.48
C18:2n6c	45.45	49.36	38.04	26.06	25.68
C18:3n3	3.78	4.97	3.86	22.98	10.96

[1]Protected soybean oil. [2]Protected linseed oil. [3]Composition per kg of product: phosphorus=40 g; calcium=146 g; sodium=56 g; sulfur=40 g; magnesium=20 g; copper =350 g; zinc=1.300 mg; manganese= 900 mg; iron=1.050 mg; cobalt=10 mg; iodine=24 mg; selenium=10 mg; fluorine=400 mg. [4]Nutritional characteristics estimated by RLM® software. CP - Crude Protein; TDN - Total Digestible Nutrients; EE - Ether Extract; ME - Metabolizable Energy.

Linseed oil was saponified with sodium hydroxide in 65% ethanol using an unheated plastic drum and agitated until glycerol and soap was produced. Once saponification was complete, a saturated solution of calcium chloride was added to precipitate the soap. The mixture of water and glycerol was then collected and the calcium soap dried at room temperature. The resulting product contained large quantities of unsaturated fatty acids, with 85% protection at a pH level close to that of the rumen. Saponification of fat results in a product with a high total fat composition, a low content of free fatty acids, and almost no oxidation.

Immediately after slaughter, half-carcasses were stored at 4°C for 24h. From the left- half-carcasses, cuts between the 9th and 13th ribs and a triangular standard cut of the *B. femoris* muscle with about 1.5 kg were removed and taken to the laboratory for the proximate, cholesterol and fatty acids analysis.

For the cooked meat analysis, steaks with 2.54 cm from the 11th and 13th ribs of *L. thoracis* and the central part of *B. femoris* were taken. After, the steaks were cooked in a gas oven at 175°C until their geometric centers reached 71°C, measured by digital thermometer.

The proximate analysis for uncooked beef (moisture, protein, total lipids and ash) was performed according to AOAC (2005).

The determination of the cholesterol content of uncooked loin (*L. thoracis*) and rump (*B. femoris*) were performed by colorimetry as described by Bragagnolo and Rodriguez-Amaya (1995). The total lipid content was measured by extraction from approximately 10 g loin samples in 200 mL of a chloroform-methanol mixture (2:1). From this extract, 5 mL sample was dried using nitrogen gas, followed by addition of 10 mL 12% KOH in 90% ethanol. The solution was then placed in a water bath at 80°C and agitated for 15 min. At the end of this process, 5 mL water was added, and after cooling, 10 mL hexane was added and the solution was vortexing. After separation of the phases, a 10 mL sample was dried using nitrogen gas. Finally, 6 mL acetic acid saturated with concentrated ferrous sulfate was added. Once cooled, the absorbance was read at 538 nm.

To determine the fatty acid composition of uncooked and cooked beef, samples of cross section were collected from the muscle, freeze-dried and grind with liquid nitrogen for lipid extraction and fatty acids methylation. The fatty material was extracted using a mixture of chloroform-methanol, as reported by Bligh and Dyer (1959) with modification performed by Fernandes et al. (2009). About 3 g of freeze dried sample was transferred to a 125 mL Erlenmeyer and then added 10 mL chloroform, 20 mL methanol and 8 mL of distilled water; the containers were shaken for 30 min in a shaker table. After this period, 10 mL chloroform and 10 mL 1.5% sodium sulfate were added and the Erlenmeyer were shaken again for 2 min. The material was filtered through a quantitative filter paper into a 50 mL falcon tube. After separation of the layers, the upper methanoic was discarded. From the remaining filtrate, 10 mL were transferred to a 50 ml weighed beaker. The beaker was taken to a forced air circulation oven at 55°C to evaporate the solvent, for 24h, and then cooled in a desiccator and weighed. The lipid content of the sample was calculated by the difference in weights.

For the transesterification of triglycerides, approximately 50 mg of extracted lipid matter was transferred to a 15 mL falcon tube, then, 2 mL n-heptane was added. The mixture was vortexed until complete dissolution of the fatty material. After this procedure, 2 mL of 2 mol KOH L^{-1} in methanol was added. This mixture was vortexed again for 5 min. After separation of the layers, 1 mL of the upper phase (heptane and fatty acids methyl esters) was transferred to 1.5 mL tubes. Tubes were tightly closed, protected from light and stored in a freezer at - 18°C for subsequent chromatographic analysis (Bligh & Dyer, 1959).

Qualitative and quantitative measurements of fatty acid content were performed by gas chromatography using a chromatograph (Shimadzu, GC-14B) with a flame ionization detector (FID) and fused silica capillary column (Omegawax 250), which was 30 m in length and 0.25 mm in diameter and a film thickness of 0.25 μm (Supelco SP-24136). Helium was used as a carrier gas at a flow of 1 mL min. A 1-μL aliquot of the sample was injected into a "split" at a division ratio of 1 100^{-1} and a temperature of 250°C. The temperature of the oven was programmed to remain at 100°C for 2 min and then increase to 220°C at 4°C min^{-1} for 25 min, while the detector was at 280°C. Identification and quantification of the methyl esters of the fatty acids was achieved by comparison with the retention times and concentrations of methyl esters of standard fatty acids.

The index of activity of the Δ9-desaturase enzyme on fatty acids with 18 carbons was obtained using the following equation: C18 = 100 (18:1/18:0 + 18:1), postulated by Malau-Aduli et al. (1997).

Results were subjected to analysis of variance using the general linear model (GLM) (SAS, 2004). A randomized block design was adopted for five

treatments with seven replications. Mean values were compared using t-test at 5% significance level.

Results and discussion

The cholesterol analysis (Table 2) indicated differences ($p < 0.05$) between the muscles in this study. The rump presented 32.5% more cholesterol than the loin. Cholesterol values found in this study (30.9 and 40.1 mg 100 g^{-1} for loin and rump, respectively) were lower than the values considered normal (58.3 to 83.4 mg 100 g^{-1}) for different beef cuts (Macedo et al., 2008; Maggioni et al., 2010; Rotta et al., 2009).

The use of diets containing sugar cane and vegetable oils, rich in polyunsaturated fatty acids, mainly, linoleic (C18:2 n6) and linolenic (C18:3 n3) acids, may have influenced the reduction in cholesterol in the animal body, reflecting the lower concentrations of this compound in the tissue (Prado et al., 2012).

The differences between the cuts in this study can also be associated with the anatomical location of the muscle (Macedo et al., 2008), probably due to different rates of development of muscle fibers, the structure and diameter that may affect the cholesterol synthesis rate among the different muscles of the carcass (Werdi Pratiwi et al., 2006).

Table 2. Chemical composition of *L. thoracis* (loin) and *B. Femoris* (rump) from Nellore young bulls fed diets rich in Omega-3 and Omega-6 fatty acids.

Chemical composition	Loin	Rump	P[1]	CV[2](%)
	Uncooked			
Cholesterol, mg 100 g^{-1}	30.93B	40.97A	*	5.07
Moisture, %	76.85A	77.16A	*	4.13
Protein, %	20.15A	18.57B	*	7.11
Ether extract, %	1.90B	3.37A	*	28.16
Ash, %	1.01A	0.90B	*	11.65

[1]Probability; * - $p < 0.0001$. [2]Coefficient of variation.

Moreira et al. (2003); Rule et al. (1997) evaluated the cholesterol content of beef with different fat content in the carcass. These authors found that animals with greater amount of fat in the carcass had higher cholesterol levels on meat. Likewise, Chung et al. (2006) worked with Wagyu and Angus animals slaughtered at different feeding times and verified a strong correlation between marbling and cholesterol content.

There was no difference ($p < 0.05$) for moisture between the loin and rump (Table 2). Similar data were reported by Fernandes et al. (2009), who evaluated the chemical composition of Nellore and Canchim young bulls fed diets with different concentrate levels.

Higher levels for protein and ash ($p < 0.05$) were observed for the loin. However, the ether extract was higher ($p < 0.05$) for the rump. Probably, the higher amount of ether extract in the rump resulted in smaller amounts of protein and ash in this cut.

According to Rotta et al. (2009), the ether extract content is the most variable in meat and, once it increases, there is a decrease in the levels of moisture, protein and minerals. Beef has almost all important minerals for human nutrition and in quantitative terms, phosphorus and potassium predominate, followed by sodium and magnesium. In addition, the iron in beef is absorbed 3 to 5 times faster than when originating from vegetables.

There were significant differences ($p < 0.05$) for fatty acid composition between the two cuts (loin and rump) regardless of cooking. Lower values of saturated fatty acids C12:0, C14:0, C15:0 and C17:0 were found in loin (Table 3).

In this way, Bessa et al. (2009) emphasized the importance of lower levels of fatty acids, such as C12:0 and C14:0. These fatty acids are harmful to human health, causing hypercholesterolemia.

Raes et al. (2004) evaluated the fatty acid composition of beef cattle fed diets with similar levels of linoleic acid and found differences in the lipid composition between the *L. thoracis* and *T. brachii* muscles. The authors claimed that the differences were due to the amounts of triglycerides and phospholipids found in the muscles. According to these authors, phospholipids have large amounts of polyunsaturated fatty acids, while triglycerides consist mainly of saturated and monounsaturated fatty acids. Therefore, the differences found in this study may be related to differences in the fat composition.

Lower levels ($p < 0.05$) of monounsaturated fatty acids (Table 3) were observed for loin. Cifuni et al. (2004) reported that the monounsaturated fatty acids with *cis* configuration are hypocholesterolemic with the advantage of reducing the HDL cholesterol level, which protects against heart disease.

In this sense, Bessa et al. (2009) reported that the hypocholesterolemic properties of monounsaturated fatty acids are obtained only from the oleic acid (C18:1 cis-9) since monounsaturated fatty acids such as elaidic (C18:1 trans-9), palmitoleic (C16:1 cis-9), and myristoleic (C14:1 cis-9) fatty acids do not have the same properties.

Turk and Smith (2009) evaluated the fatty acid composition of different ground cuts and detected differences for monounsaturated fatty acids, wherein the brisket had the highest ($p = 0.0001$) values compared to other cuts. These authors claimed that the differences are related to the activity of Δ9-desaturase enzyme.

Table 3. Fatty acid composition of *L. thoracis* (loin) and *B. femoris* (rump), uncooked or cooked, from Nellore young bulls fed diets rich in Omega-3 and Omega-6 fatty acids.

Fatty acid	*Loin*	*Rump*	*Loin*	*Rump*	P[1]	CV[2]
% of total fatty acids	Uncooked		Cooked			%
		Saturated				
C10:0	0.041B	0.041B	0.052A	0.051A	⋆	10.46
C12:0	0.058D	0.064C	0.072B	0.079A	⋆	9.57
C14:0	3.28B	3.38B	3.58A	3.57A	⋆	6.16
C15:0	0.27D	0.33B	0.30C	0.35A	⋆	8.03
C16:0	25.38B	24.50C	26.27A	25.10C	⋆	1.62
C17:0	0.69C	0.80A	0.71B	0.80A	⋆	5.89
C18:0	14.31A	14.05A	14.12A	13.48B	⋆	5.43
C20:0	0.107	0.104	0.106	0.099	NS	18.38
		Monounsaturated				
C14:1	0.82C	0.98B	0.97B	1.11A	⋆	7.16
C16:1	3.12D	3.55B	3.34C	3.80A	⋆	5.05
C17:1	0.60B	0.73A	0.58C	0.73A	⋆	4.55
C18:1ω7	2.97B	3.18A	3.19A	3.21A	⋆	5.20
C18:1 ω9	38.86C	39.70B	39.68B	40.32A	⋆	1.84
C20:1 ω9	0.20	0.20	0.20	0.19	NS	14.40
		Polyunsaturated				
C18:2 ω6	6.16A	5.43B	4.55C	4.59C	⋆	19.19
C18:2 c9, t11	0.65C	0.77A	0.67C	0.74B	⋆	8.48
C18:3 ω3	0.59A	0.47B	0.43BC	0.41C	⋆	17.72
C18:3 ω6	0.108A	0.101A	0.100B	0.09C	⋆	9.33
C20:2	0.07A	0.063AB	0.07A	0.056B	⋆	26.37
C20:3 ω3	1.16A	1.08A	0.64C	0.80B	⋆	30.67
C20:3 ω6	0.26A	0.22B	0.16C	0.17C	⋆	28.71
C20:5 ω3	022A	0.17B	0.13C	0.15BC	⋆	39.88
Δ^9- Dessat 18[3]	73.08C	73.86B	73.75B	74.95A	⋆	1.53

[1]Probability; ⋆ - < 0.0001; NS - Non-significant. [2]Coefficient of variation. [3]Δ^9- Dessat (18) - index of desaturase enzyme activity C18 = 100(18:1/18:0+18:1).

The results for Δ9-desaturase enzyme indicated that rump presented higher activity ($p < 0.05$) of this enzyme than loin (73.9 and 73.1, respectively). According to Turk and Smith (2009), cuts located closer to the surface of the body could present higher activity of Δ9-desaturase due the lower body temperature.

The loin presented higher ($p < 0.05$) levels of the polyunsaturated fatty acids C18:2 ω6, C18:3 ω3, C20:2, C20:3 ω6 and C20:5 ω3. Increasing concentration of these acids is a goal to be achieved due to their important roles against diseases. On the other hand, conjugated linoleic acid (C18:2 c9, t11) showed a higher concentration in the rump.

According to Griswold et al. (2003), the conjugated linoleic acid (CLA) is found exclusively in ruminant products and man needs to eat about 400 mg CLA daily to have a benefit. Thus, the daily diet with meat and milk can provide considerable amounts of this element.

In the present study, the difference found for CLA is related to the greater activity of Δ9-desaturase enzyme in the rump (Table 3). According to Griswold et al. (2003), there are two ways of CLA production, the first occurs with rumen biohydrogenation of linoleic acid and the second is the conversion of C18:1 t11 (trans vaccenic acid) into the CLA by means of the activity of Δ9-desaturase enzyme.

Beaulieu et al. (2002); Malau-Aduli et al. (1997) commented that this enzyme is responsible for the desaturation of saturated fatty acids with 16 and 18-carbon, converting them into their corresponding monounsaturated forms, by adding a double bond at the carbon 9. The production of CLA by Δ9-desaturase is performed using the trans vaccenic acid (C18:1 t11), product of the incomplete biohydrogenation of linoleic and linolenic acids by the rumen bacteria. As reported by the same authors, this enzyme has activity in the intestine epithelium and in muscles, but at lower intensity compared with adipose tissue; its activity can be influenced by animal breed, age, sex and degree of maturity.

Saturated fatty acids, mainly the hypercholesterolemic ones (C12:0, C14:0 and C16:0), presented the lowest levels in the uncooked cuts. Herein, the cooking process increased the levels of those fatty acids, probably due to loss of moisture and saturation of unsaturated fatty acids.

Differences were found ($p < 0.05$) for all fatty acids analyzed, except for the fatty acids C20:0 and C20:1 ω9. There was a significant increase ($p < 0.05$) in concentrations of C12:0 and C14:0 fatty acids after cooking the beef. These results corroborate those obtained by Alfaia et al. (2010), who examined steaks from Alentejano breed subjected to different cooking methods (grilled, stewed and microwave). The authors found an

increase in the concentration of C12:0 and C14:0 fatty acids.

According to Alfaia et al. (2010), there are many mechanisms responsible for changes in the lipid composition of beef, including loss of moisture loss and lipid oxidation. The same authors commented that the physical and chemical properties of beef undergo several changes during the heating process, especially its lipid composition, which, combined with the cooking method, provides great changes in the final meat quality.

Nevertheless, Scheeder et al. (2001) verified decrease in the concentration of some saturated fatty acids (C14:0, C16:0 and C18:0) and increased concentrations of polyunsaturated fatty acids, when they studied processed beef derived from animals fed diets with different oil sources.

The same authors reported that polyunsaturated fatty acids were less affected by the effects of cooking, such as oxidation, because they belong to the structure of cell membranes, whereas saturated fatty acids are mostly present in triglycerides of the adipose tissue, which suffer greater losses, mainly due to drip loss.

Thus, Rodriguez-Estrada et al. (1997) argued that heating can trigger unpleasant changes such as loss of essential fatty acids, reducing the nutritional value of beef, mainly due to the oxidation of lipids. Additionally, meat cuts with higher levels of polyunsaturated fatty acids are likely to suffer more oxidation.

There was a decrease ($p<0.05$) in the CLA level for cooked rump; however, no change was observed for uncooked or cooked loin. Ha et al. (1989) commented that the increase in CLA levels can be observed in cooked compared to uncooked beef. This probably occurs by the temperature and cooking methods that influence its concentration. However, CLA can also be denatured if the cooking temperatures are extremely high.

Shantha et al. (1994) commented that since the CLA assumed an important role as beneficial to health, there is a need to establish how meat must be prepared in order to not affect the CLA concentration.

There were no interactions for the sums of fatty acids (Table 4). There was higher ($p < 0.05$) amounts of saturated (SFA) and polyunsaturated (PUFA) fatty acids for loin compared to rump, however, the rump showed higher amounts of unsaturated (UFA) and monounsaturated (MUFA) fatty acids. The higher ($p < 0.05$) levels of Omega-3 and Omega-6 fatty acids were observed for the loin.

The differences detected for fatty acids between the muscles in the present study may be related to the amounts of phospholipids and triacylglycerols present in different locations. According to Raes et al. (2004), the highest amount of triacylglycerol compared to phospholipid provides higher levels of saturated and polyunsaturated fatty acids.

In this sense, Picard et al. (1998) reported that glycolytic muscles have lower levels of mitochondria, and thus lower amounts of phospholipids, which are restricted to membranes. The lower amounts of phospholipids result in lower amounts of polyunsaturated fatty acids and consequently higher amounts of saturated and monounsaturated fatty acids.

Higher amounts ($p < 0.05$) of saturated fatty acids were observed for the *L. thoracis* cooked. For the rump, there was no difference ($p > 0.05$) between uncooked and cooked cuts.

Table 4. Fatty acids ratios of *L. thoracis* (loin) and *Biceps femoris* (rump), uncooked or cooked, from Nellore young bulls fed diets rich in Omega-3 and Omega-6 fatty acids.

Ratios[3]	*Loin*	*Rump*	*Loin*	*RumpBiceps femoris*	P[1]	CV[2]
	Uncooked		*Cooked*			%
Sat	44.16B	43.29C	45.24A	43.55C	⋆	2.79
Unsat	55.83B	56.70A	54.75C	56.44A	⋆	2.20
Mono	46.58C	48.36B	47.99B	49.39A	⋆	1.84
Poly	9.25A	8.34B	6.09C	6.30C	⋆	19.18
Unsat:sat	1.27B	1.32A	1.21C	1.30AB	⋆	5.18
Mono:sat	1.06B	1.12A	1.06B	1.13A	⋆	3.68
Poly:sat	0.21A	0.19A	0.13B	0.14B	⋆	22.57
Omega-3	1.98A	1.73B	1.21C	1.37C	⋆	25.29
Omega-6	6.54A	5.76B	4.82C	4.86C	⋆	19.18
Omega-6:Omega-3	3.49C	3.50C	4.15A	3.65B	⋆	8.57

[1]Probability; ⋆ - $p < 0.0001$; NS – Non-significant. [2]Coefficient of variation. [3]Sat – *saturated* – C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0. Unsat - *Unsaturated* - C14:1+ C16:1+ C17:1+ C18:1ω7+ C18:1ω9 + C18:2 ω6+ C18:2 c9, t11+ C18:3ω3+ C18:3ω6+ C20:1ω9+ C20:2+ C20:3 ω3+ C20:3ω6+ C20:5 ω3. *Mono* – *monounsaturated* – C14:1+ C16:1+ C17:1+ C18:1ω7+ C18:1ω9+ C20:1ω9. Poly – *polyunsaturated* - C18:2 ω6+ C18:2 c9, t11+ C18:3ω3+ C18:3ω6+ C20:2+ C20:3ω3+ C20:3ω6+ C20:5 ω3. Omega-3 – Omega-3 fatty acids - C18:3ω3+ C20:3ω3+ C20:5ω3. Omega-6 – Omega-6 fatty acids - C18:2 ω6+ C18:3ω6+ C20:3ω6. Unsat:Sat – Ratio between *unsaturated* and *saturated* fatty acids. Mono:Sat – Ratio between *monounsaturated* and *saturated* fatty acids. Poly:Sat – Ratio between *polyunsaturated* and *saturated* fatty acids. Omega-6:Omega-3– Ratio between Omega-6 and Omega-3 fatty acids.

Also, significant losses ($p < 0.05$) of polyunsaturated, Omega-3 and Omega-6 fatty acids were observed when those two cuts were cooked. Alfaia et al. (2010) found similar results with reduction of polyunsaturated fatty acid. These results may be related to higher susceptibility to oxidation of polyunsaturated fatty acid.

The rump had the best ($p < 0.05$) ratios UFA:SFA and MUFA:SFA, while the PUFA:SFA and Omega-6:Omega-3 ratios were better ($p < 0.05$) for the loin. These results are mainly associated with the individual value of each fatty acid (Table 3).

According to Alfaia et al. (2010), there are recommendations for the fatty acids ratios, the PUFA:SFA ratio should not be less than 0.45 and the omega-6:omega-3 ratio should not exceed 4. The results obtained for the PUFA:SFA ratio was far from ideal, however, the omega-6:omega-3 ratio met the ideal standards, even with cooked meat.

Conclusion

Cooking meat decreases its moisture and consequently concentrates its protein, ether extract and minerals in loin and rump.

The rump has higher levels of myristic fatty acid, and the higher levels of conjugated linoleic acid.

The loin showed the best fatty acid composition when uncooked. The cooking process causes loss of important fatty acids.

Regardless of the cut, cooking meat affects negatively the amounts of polyunsaturated, omega-3 and omega-6 fatty acids as well as the omega-6:omega-3 ratio.

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