

Lipid composition of raw and grilled beef cattle slaughtered at four body weights
Composição lipídica da carne fresca e grelhada de bovinos de corte abatidos com quatro pesos corporais

Composición lipídica de la carne fresca y cocida de ganado vacuno sacrificado con cuatro pesos corporales

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Abstract

The fatty acid composition of beef can be altered by factors related to the animal, management, processing and preparation. The effect of body weight and cooking of meat on the composition of long chain fatty acids was evaluated. Forty 10-month old crossbred young bulls (½ Brown Swiss x ½ Nellore) of initial body weight 219 kg finished in feedlot with high grain diet and slaughtered with 450, 469, 491 and 513 kg of body weight. The *Longissimus dorsi* muscle was collected after slaughter and carcass chilling. The individual composition of the fatty acids of the meat was not altered ($P < 0.05$) by different body weights and by cooking (until reaching 72° C). Likewise, the sum of the percentages of saturated, monounsaturated, polyunsaturated, omega 3 and 6 fatty acids; as well as the ratios between monounsaturated/polyunsaturated fatty acids and omega 3 and 6 were not altered. Therefore, the different body weights and heating used in this study were insufficient to cause significant alterations in the fat molecules and the meat can be consumed without damaging the health of the consumer.

Keywords: Adipose; Cooked meat; Fatty acids; Feedlot; Young bulls.

Resumo

A composição de ácidos graxos da carne bovina pode ser alterada por fatores relacionados ao animal, manejo, processamento e preparo. Foi avaliado o efeito do peso corporal e do cozimento da carne na composição de ácidos graxos de cadeia longa. Quarenta novilhos mestiços (½ Pardo suíço x ½ Nelore) de idade e pesos iniciais de 10 meses e 219 kg terminados em confinamento com dieta alto grão e abatidos com 450, 469, 491 e 513 kg de peso corporal. O músculo *Longissimus dorsi* foi coletado após o abate e resfriamento da carcaça. A composição individual dos ácidos graxos da carne não foi alterada ($P < 0,05$) pelos diferentes pesos corporais e pelo cozimento (até atingir 72° C). Da mesma forma, a soma das porcentagens dos ácidos graxos saturados, monoinsaturados, poliinsaturados, ômega 3 e 6; assim como as relações entre ácidos

graxos monoinsaturados/poliinsaturados e ômega 3 e 6 não foram alteradas. Portanto, os diferentes pesos corporais e aquecimento utilizados neste estudo foram insuficientes para causar alterações significativas nas moléculas de gordura e a carne pode ser consumida sem prejudicar a saúde do consumidor.

Palavras-chave: Gordura; Carne cozida; Ácidos graxos; Confinamento; Novilhos.

Resumen

La composición en ácidos grasos de la carne de vacuno se puede ver alterada por distintos factores, relacionados con el animal, manejo, procesamiento y la preparación. Se evaluó el efecto del peso corporal del animal y la cocción de la carne sobre la composición de ácidos grasos de cadena larga. Cuarenta vacunos (½ Pardo Suizo x ½ Nellore) de 10 meses de edad y con un peso corporal inicial 219 kg fueron terminados en intensivo con dieta alta en granos y sacrificados con 450, 469, 491 y 513 kg de peso vivo. Tras el sacrificio y el enfriamiento de la canal se muestreó el músculo *Longissimus dorsi*. La composición individual de los ácidos grasos de la carne no se vio alterada ($P < 0.050$) por los diferentes pesos corporales ni por el cocinado de la misma (hasta alcanzar los 72° C). Asimismo, tampoco se modificó significativamente la suma de los porcentajes de ácidos grasos saturados, monoinsaturados, poliinsaturados, omega 3 y 6; así como tampoco se alteraron las relaciones entre ácidos grasos monoinsaturados/poliinsaturados y omega 3 y 6. Por tanto, los diferentes pesos corporales y el tratamiento térmico utilizado en este estudio fueron insuficientes para provocar alteraciones significativas en las moléculas de grasa, pudiéndose consumir la carne sin dañar la salud del consumidor.

Palabras clave: Grasa; Carne cocinada; Ácidos grasos; Cebo intensivo; Novillos.

1. Introduction

Meat is an important source of nutrients and contribute considerable amounts in the intake of various nutrients that are essential for optimal growth and development of the body. The essential fatty acids for the human body are the linoleic (ω -6, omega-6) and the alpha-linolenic (ω -3, omega-3), necessitating therefore to be consumed through diet. These fat acids are synthesized in plant species and through of ruminal biohydrogenation, since the rumen microorganisms are able to insert carbon double bonds from the hydroxyl and form these compounds (Kaur, Chugh & Gupta, 2014).

It is desirable for the carcass to have minimal amounts of fat in the subcutaneous tissue

without a detrimental decrease of intramuscular fat. Lipids contribute significantly to the qualitative factors of the meat, as they are responsible for the smell and palatability of the meat, besides influencing the tenderness and nutritional value. However, it has been the subject of great concern regarding health related aspects associated with an increased risk of chronic diseases (Pickworth et al., 2011).

In general, the physicochemical composition of bovine meat is determined, mainly in the muscle *Longissimus dorsi* raw. Variations in the fatty acid profile in the meat are mainly related to the genetic group, slaughter weight, diet composition, finishing system, genders, use of additives or natural substances addition in the diet, methodology analysis, anatomical location of the evaluated cut, fat thickness, among others (Ornaghi et al., 2017; Rivaroli et al., 2016; Ito et al., 2012).

Performance may also interfere in an indirect way, where animals with greater weight gain tend to consume larger amounts of food and deposit more fat in the carcass. Animals with higher weight have a higher percentage of subcutaneous and intramuscular fat in the meat and can alter the profile of fatty acids. The percentage of unsaturated fatty acids, mainly monounsaturated is directly associated with total carcass fat (Pereira et al., 2012).

In addition to diet, breed, gender, age and weight at slaughter are important characteristics of beef production. While all of these factors can influence deposition of fat in the carcass, less is known about their effects on the fatty acid concentrations. In developing management that maximise the concentration in beef of fatty acids beneficial to human health, mainly concentrations of unsaturated fatty acids in beef, most research effort has been directed towards the effects of nutrition and there are relatively few reports on the effects of slaughter weight (Park et al., 2018).

In the same context, meat is eaten baked, boiled or fried. These preparation processes can denature the protein matrix of the meat and cause significant changes in its structure and composition. Loss of liquids initially occurs, promoting the concentration of nutrients and the incorporation of substances from the cooking medium. The heat can generate several modifications in the chemical components of the product as alteration in composition of fatty acids, contents of vitamins, content of cholesterol, contents and form of the proteins. The process of roasting, cooking or frying is essential to determine the flavor and juiciness of the meat. However, studies that report the effect of cooking on the fatty acids stability of meat are controversial (Kaur, Chugh & Gupta, 2014; Chávez et al., 2012)

We hypothesised that pre-slaughter growth rate and consequently increased deposition of fat in the carcass therefore would also alter the composition of fatty acids in muscle. The

precocity will determine the amount of fat in the carcass. Animals with diets with high energy density, which allow greater gains, will reach the appropriate body composition more quickly. Less precocious animals, with smaller gains, in turn, have physiologically younger carcasses, that is, leaner carcasses. The objectives of the present study were to determine the fatty acid composition of muscle from young bulls slaughtered at four target weights, as well as to evaluate the possible alterations in this profile by the cooking process.

2. Methodology

2.1. Local, animals and diets

Forty 10 ± 2.2 -month old crossbred young bulls ($\frac{1}{2}$ Brown Swiss + $\frac{1}{2}$ Nellore) of initial body weight 219 ± 11.7 kg were used. The experiment lasted 187 days and the animals were slaughtered at approximately 17 months of age and had a mean BW of 475 ± 51.3 kg in a commercial slaughterhouse following the slaughtering standards of the State Inspection Service (SIE) of Brazilian Legislation.

The basal diet was the same for all animals, and consisted on 90% concentrate and 10% of pellets cane sugar (103.1 g/kg DM), formulated to be isonitrogenous and isoenergetics (Table 1).

Table 1. Chemical composition of basal diet (g/kg DM).

Chemical composition	Diet
Dry matter	895
Crude protein	131
Organic matter	977
Ash	22.5
Ether extract	39.8
Neutral detergent fibre	233
Acid detergent fibre	123
Total digestible nutrients	826
Metabolisable energy (MJ/kg DM)	12.5
Calcium	5.80
Phosphorus	3.44

Source: Authors.

The concentrate was composed of craked corn (793.1 g/kg DM), soybean meal (52.8 g/kg DM), premix (42.2 g/kg DM), limestone (4.19 g/kg DM), salt (2.2 g/kg DM), yeast (0.40

g/kg DM) and dicalcium phosphate (2.20 g/kg DM). The premix was composed of magnesium (57 g/kg), sodium (81 g/kg), sulphur (3.75 g/kg), cobalt (20 mg/kg), copper (500 mg/kg), iodine (25 mg/kg), manganese (1 500 mg/kg), selenium (10 mg/kg), zinc (2 000 mg/kg), vitamin A (400 000 UI/kg), vitamin D3 (50 000 UI/kg), vitamin E (750 UI/kg), ether extract (168 g/kg) and urea (200 g/kg).

The animals were slaughtered all on the same day and separated into four groups according to body weight (BW). Group 1 (T450): young bulls averaging 450 kg BW; group 2 (T469): young bulls averaging 469 kg BW; group 3 (T491): young bulls averaging 491 kg BW and group 4 (T513): young bulls averaging 513 kg BW.

After slaughter, the carcass was cooled (24 hours) in a chilling chamber at 4 ± 1 °C. The *Longissimus dorsi et thoracis* (LT) muscle samples from the 6th rib (about 150 g) were collected. The samples were packed in a vacuum and stored frozen (-26 °C) until analysis.

This experiment was approved by the Department of Animal Production and Research Ethic Committee at the State University of Maringá, and it followed the guiding principles of biomedical research with animals n° 081/2014. It was carried out at Experimental Farm of Iguatemi, belonging to the State University of Maringá, Maringá, Paraná, Brazil.

2.2. Cooking and preparation of samples

Samples were thawed in a chilling chamber (4 ± 2 °C) trimmed with connective and adipose tissues and cut into a 10 x 5 cm rectangular section measuring 2.5 cm thick. To perform thermal processing, the samples were packed in aluminum foil and baked in an electric grill (Philco Jumbo Inox Grill, Philco SA, Brazil) preheated at 200 °C until reaching the internal temperature of 72 °C, this temperature was monitored with thermometer (Incoterm, 145 mm, Incoterm LTDA, Brazil) at five different points.

2.3. Determination of fatty acid composition

For the analysis of total lipids, the extraction with chloroform-methanol (1:2, v/v) was used according to the methodology described by Bligh and Dyer (1959). For the feed samples moisture correction was performed and hypersaturated NaCl solution was added to assist in the phase separation, as described in the methodology proposed by the same author.

The fatty acid methyl esters (FAME) were obtained by saponification (transesterification) of the total lipids described by Hartman and Lago (1973).. The methyl

esters were analyzed by gas chromatography using 3300 Thermo gas, a flame-ionization detector (FID) equipped with a CP-7420 fused silica capillary column (100 m x 0.25 mm id x 0.25 mM of cyanopropyl).

For identification, the retention times of fatty acids were compared with those of the standard methyl esters (Sigma, St. Louis, MO). Retention times and percentages of peak areas were automatically calculated with Chronquest 5.0 software. The fatty acid compositions were expressed as a percentage. Each sample was analyzed in triplicate.

The operating parameters were as follows: Detector at 240 °C, injection point 230 °C, column at 165 °C for 18 min, programmed to increase at 4 °C min⁻¹ up to 235 °C, with a duration of 14.5 minutes, the carrier gas was the hydrogen, flow rate of 1.2 mL min⁻¹ and the gas make-up was the nitrogen at 30 mL min⁻¹, and injection divided at a ratio of 1:80.

2.4. Statistical analyzes

All variables under study were tested for normality, those with normal distribution were submitted to a variance analysis (ANOVA). The means were compared using the Tukey test at the 5% level of significance or 5% T-test (two treatments). The statistical program used was IBM SPSS Statistic® version 21.0.

3. Results and discussion

3.1. Fatty acid composition in the diets

Diet composition directly affects intake, BW and fat deposition in the carcass. The fat contents of the grains, although low, have high proportions of unsaturated fatty acids such as oleic acid (18:1n-9c), linolenic acid (18:3n-3 and 18:3n-6) and linoleic acid (18:2n-6) (Hall, Schönfeldt, & Pretorius, 2016), being 33.8, 0.3, 2.5 and 33.2%, respectively (Table 2). These fatty acids are precursors of polyunsaturated fatty acids (PUFA) in the meat and can not be biosynthesized by mammals, being consumed through vegetable oils, and are necessary for health (Gogus & Smith, 2010). In the case of human, he can still consume through the meat.

A large amount of saturated palmitic acid (20.4%) was found. This acid is commonly found in corn kernels and soybean meal. This fatty acid can be used as a substrate for subsequent synthesis of other monounsaturated fatty acids through the action of enzymes by stretching and desaturation in the rumen (Lalotitis, Bizelis, & Rogdakis, 2010).

Table 2. Percentage of fatty acids in the diet of bovines finished in different BW.

Fatty acid, %	Nomenclature	Diet
Saturated		
14:0	Myristic	0.99
15:0	Pentadecyl	0.31
16:0	Palmitic	20.44
17:0	Margaric	0.26
18:0	Stearic	4.54
20:0	Eicosanoic	0.26
24:0	Tetracosanoic	1.74
Monounsaturated		
14:1n-5	Myristoleic	0.15
14:1n-9	Tetradecenoic	0.23
15:1n-5	Pentadecenoic	0.53
16:1n-7	Palmitoleic	0.71
17:1n-7	Heptadecenoic	0.37
18:1n-9t	Trans-octadecenoic	0.57
18:1n-9c	Oleic	33.8
18:1n-7	Octadecenoic	0.96
20:1n-9	9 – eicosenoic	0.25
24:1n-9	15-Tetracosenoic	0.16
Polyunsaturated		
16:2n-6	Hexadecadienoic	0.32
18:2n-6	Linoleic	33.18
18:3n-3	Alpha-linolenic	0.31
18:3n-6	Gamma-linolenic	2.52
20:4n-6 (AA)	Arachidonic	0.72
20:5n-3 (EPA)	Eicosapentaenoic	0.17
22:6n-3 (DHA)	Docosahexaenoic	0.08

Fonte: Elaborado pelo autor.

Note that 4.54% stearic acid is very important for the synthesis of unsaturated fatty acids by the introduction of a double bond between carbon atoms 9 and 10 and is catalyzed by the enzyme delta-9-desaturase. This enzyme is present in plants and animals, and converts stearic acid to oleic acid (Lee et al., 2016).

The supplying linolenic acid and its derivatives, adding a total of 36.0% in this diet, increases concentration of CLA in ruminant muscle fat (Kramer et al., 2013).

The composition of total lipids and fatty acids of the diet was determined, where the percentage of total lipids was of the order of 0.61% (Table 3). In general, the diet of cattle finished in feedlot presents between 2 and 3% of total lipids.

Table 3. Total lipids and sum of fatty acids present in the diet.

Fatty acid,%	Nomenclature	Diet
TL	Total lipids	0.61
SFA ^a	Saturated	27.08
MUFA ^b	Monounsaturated	36.4
PUFA ^c	Polyunsaturated	36.53
ω -6 ^d	Omega 6	30.62
ω -3 ^e	Omega 3	0.51

^aSum of saturated fatty acids: 14:0, 15:0, 16:0, 17:0, 18:0, 20:0 and 24:0. ^bSum of monounsaturated fatty acids: 14:1n-5, 14:1n-9, 15:1n-5, 16:1n-7, 17:1n-7, 18:1n-9t, 18:1n-9c, 18:1n-7, 20:1n-9 and 24:1n-9. ^cSum of polyunsaturated fatty acids: 16:2n-6, 18:2n-6, 18:3n-3, 18:3n-6, 20:4n-6, 20:5n-3 and 22:6n-3. ^dSum of 16:2n-6, 18:2n-6, 18:3n-6 and 20:4n-6. ^eSum of 18:3n-6, 20:4n-6 and 22:6n-3. Fonte: Elaborado pelo autor.

The percentages of the sums of SFA, MUFA and PUFA were 27.8, 36.4 and 36.5%, respectively. In this way, the sum of the unsaturated was 72.9%, this high percentage can be explained by the large amount of corn present in the diet (79.3%). Omega 6 values were elevated (30.62%), while the percentage of omega 3 was intermediate (0.51%). Lipids are intensely metabolized in the rumen and this has a high correlation with the fatty acid profile available for absorption and use of tissues, especially in adipose tissue. The fatty acid composition of the meat is the result of the synthesis of fatty acids of the tissue and the composition of fatty acids of the lipids ingested in the diet (Kouba & Mourot, 2011).

3.2. Fatty acid composition in the raw meat

The fat of the cattle meat presents great variation and the deposited amounts result from the energetic balance of the diet and metabolic requirements of the animal (Hocquette et al., 2010). The fatty acid composition of the meat is of great importance, especially the ω -3 and ω -

6 families, because they have numerous benefits to the health (Simopoulos, 2016). The table 4 shows the distribution of the main fatty acid classifications found in meat in this study.

There were no differences in the fatty acid profile between treatments with different termination BW (Table 4). Similar work was found in the literature (Dias et al., 2016). However, also report decreasing linear variation of saturated fatty acids as the animals gained weight (Broncano et al., 2009; Serrano et al., 2007; Tejeda et al., 2008).

Table 4. Percentage of fatty acids in raw meat of cattle finished in different BW.

Fatty acid,%	Nomenclature	Treatments ¹				SEM ²	P ³
		T450	T469	T491	T513		
Saturated							
14:0	Myristic	3.40	3.14	3.41	3.41	0.069	ns
15:0	Pentadecyl	0.43	0.41	0.50	0.46	0.012	ns
16:0	Palmitic	27.63	28.83	27.52	28.06	0.430	ns
17:0	Margaric	0.80	0.80	0.83	0.97	0.030	ns
18:0	Stearic	17.11	17.05	17.17	16.84	0.267	ns
20:0	Eicosanoic	0.22	0.20	0.24	0.21	0.007	ns
24:0	Tetracosanoic	0.12	0.08	0.08	0.08	0.012	ns
Monounsaturated							
14:1n-5	Myristoleic	0.24	0.22	0.23	0.20	0.010	ns
14:1n-9	Tetradecenoic	0.76	0.66	0.75	0.76	0.026	ns
15:1n-5	Pentadecenoic	1.66	1.47	1.41	1.24	0.091	ns
16:1n-7	Palmitoleic	2.63	2.64	2.76	2.86	0.080	ns
17:1n-7	Heptadecenoic	0.81	0.74	0.62	0.70	0.068	ns
18:1n-9t	Trans-octadecenoic	0.35	0.34	0.54	0.67	0.056	ns
18:1n-9c	Oleic	33.24	34.50	33.92	34.50	0.938	ns
18:1n-7	Octadecenoic	1.07	1.09	0.93	1.17	0.038	ns
20:1n-9	9 – eicosenoic	0.08	0.09	0.07	0.09	0.006	ns
24:1n-9	15-Tetracosenoic	0.16	0.13	0.15	0.14	0.008	ns
Polyunsaturated							
16:2n-6	Hexadecadienoic	0.45	0.46	0.46	0.41	0.013	ns
18:2n-6	Linoleic	6.63	5.44	6.51	5.60	0.308	ns
18:3n-3	Alpha-linolenic	0.18	0.16	0.15	0.15	0.007	ns
18:3n-6	Gamma-linolenic	0.07	0.06	0.08	0.07	0.002	ns
20:4n-6 (AA)	Arachidonic	0.28	0.19	0.24	0.21	0.015	ns
20:5n-3 (EPA)	Eicosapentaenoic	1.28	0.96	1.10	0.87	0.078	ns
22:6n-3 (DHA)	Docosahexaenoic	0.30	0.22	0.22	0.22	0.021	ns

¹Treatments: T450: young bulls averaging 450 kg BW; T469: young bulls averaging 469 kg BW; T491: young bulls averaging 491 kg BW and T513: young bulls averaging 513 kg BW. ²SEM: standard error of mean. ³Statistical probability of treatment: ns: P > 0.05. Fonte: Elaborado pelo autor.

The meat of cattle is rich in saturated fatty acids derived from the peculiar process of lipid digestion in ruminants. However, it is not all saturated fatty acids that are considered hypercholesterolemic. The most undesirable fatty acid would be myristic acid, which found an

average value of 3.34% in the meat of these animals, values considered within the standards for meat (Kaur, Chugh & Gupta, 2014). Palmitic acid has the lowest hypercholesterolemic effect, with an average value of 28.01%. And finally, stearic acid, with an average of 17.04% of the total saturated fatty acids in the meat, but is considered to be null, since it is a precursor of oleic acid in the body, not influencing blood cholesterol levels (Sokoła-Wysoczańska et al., 2018).

The most common MUFA is oleic acid, also observed in this work with an average value of 34.0%, followed by palmitic acid with 3.72%. The higher levels of these fatty acids are found in animals with high dietary energy and fast fat deposition (Pickworth et al., 2011), according to this study.

The most representative PUFA in meat are linoleic, arachidonic, eicosapentaenoic and docosahexaenoic acids (Sokoła-Wysoczańska et al., 2018), together they were found in an average amount of 7.56% in meat. Higher values usually found are around 5% of polyunsaturated acids. However, lipolysis and biohydrogenation rates are lower in situations of high grain concentration in the diet, resulting in a greater escape of unsaturated fatty acids. As for polyunsaturated fatty acids, meat and fish oil are the only food sources of arachidonic acid and eicosapentaenoic acid, and values were found within normal standards for meat (Shingfield, Bonnet & Scollan, 2013).

The percentage of total lipids observed in the LT muscle was influenced ($P < 0.05$) by the finishing BW of the animals (Table 5), since the increase of the weight of slaughter causes an increase in the BW of several tissues, among them the adipose. The observed values are considered low for this animal category, finished in feedlot and high grain diet. These values are explained by the precocity of slaughtering of these animals (17 months of age) and the physiological condition of the animals (young bulls) (Ito et al., 2012).

Table 5. Percentage of total lipids and sum of the percentages of SFA, MUFA and PUFA of the meat of young bulls finished in different BW.

Fatty acid,%	Nomenclature	Treatments ¹				SEM ²	P ³
		T450	T469	T491	T513		
TL	Total lipids	0.71a	0.90a	1.38b	2.69c	0.227	**
SFA ^a	Saturated	49.73	50.53	49.78	50.06	0.667	ns
MUFA ^b	Monounsaturated	41.04	41.94	41.43	42.37	0.845	ns
PUFA ^c	Polyunsaturated	9.21	7.52	8.79	7.55	0.422	ns
ω -6 ^d	Omega 6	7.44	6.16	7.30	6.30	0.325	ns
ω -3 ^e	Omega 3	1.77	1.35	1.48	1.25	0.104	ns
Ratio ^f	ω -6: ω -3	4.42	5.40	4.97	5.48	0.217	ns
Ratio ^g	PUFA:MUFA	0.22	0.18	0.21	0.18	0.024	ns

¹Treatments: T450: young bulls averaging 450 kg BW; T469: young bulls averaging 469 kg BW; T491: young bulls averaging 491 kg BW and T513: young bulls averaging 513 kg BW. ²SEM: standard error of mean. ³Statistical probability of treatment: ns: P > 0.05; **: P < 0.001; means in the same row with different letters are significantly different (P < 0.05). ^aSum of saturated fatty acids: 14:0, 15:0, 16:0, 17:0, 18:0, 20:0 and 24:0. ^bSum of monounsaturated fatty acids: 14:1n-5, 14:1n-9, 15:1n-5, 16:1n-7, 17:1n-7, 18:1n-9t, 18:1n-9c, 18:1n-7, 20:1n-9 and 24:1n-9. ^cSum of polyunsaturated fatty acids: 16:2n-6, 18:2n-6, 18:3n-3, 18:3n-6, 20:4n-6, 20:5n-3 and 22:6n-3. ^dSum of 16:2n-6, 18:2n-6, 18:3n-6 and 20:4n-6. ^eSum of 18:3n-6, 20:4n-6 and 22:6n-3. ^f ω -6: ω -3 ratio = $\Sigma \omega$ -6/ $\Sigma \omega$ -3. ^gPUFA:MUFA ratio = Σ polyunsaturated/ Σ monounsaturated. Fonte: Elaborado pelo autor.

There was no effect (P > 0.05) of the treatments on the percentages of MUFA and PUFA in the muscle *LT* with a mean of 41.7 and 8.3%, respectively, of the total quantified fatty acids. The results obtained in this experiment demonstrated that the meat fat of these cattle was constituted in half by unsaturated fatty acids, being these beneficial to human health. The other half is composed of saturated fatty acids, in which a large part refers to the stearic fatty acid, which is considered neutral with respect to blood cholesterol levels (Lee et al., 2016).

The PUFA:MUFA ratio was not altered (P > 0.05) by treatments (Table 5), presenting an average value of 0.2. This reason, according to the Health Department of England is recommended to be above 0.4, so that food brings benefits to human health. The low quantified ratio can be explained in parts by the increase of stearic acid, this being the result of the final product of ruminal biohydrogenation of unsaturated fatty acids.

Likewise, the ratio ω -6: ω -3 did not present a difference (P > 0.05) between the treatments, with a mean ratio of 5.0. This ratio must be less than four parts of ω -6, for a part of

ω-3. According Corpet (2011) this reason is important because of the risks of cancer and coronary diseases that an unbalanced diet provides.

3.3. Fatty acid composition in cooked meat

Brazilians, for the most part, consume fairly well meat, so the meat was still evaluated for the fatty acid profile after cooking and presented in Table 6.

Table 6. Percentage of fatty acids in young bulls meat raw or cooked at 72 °C.

Fatty acid, %	Nomenclature	Treatments ¹		SEM ²	P ³
		Raw	Cooked		
Saturated					
14:0	Myristic	3.20	3.20	0.066	ns
15:0	Pentadecyl	0.44	0.48	0.012	ns
16:0	Palmitic	28.0	28.7	0.408	ns
17:0	Margaric	0.83	0.88	0.029	ns
18:0	Stearic	16.9	17.6	0.254	ns
20:0	Eicosanoic	0.22	0.24	0.007	ns
24:0	Tetracosanoic	0.12	0.12	0.011	ns
Monounsaturated					
14:1n-5	Myristoleic	0.22	0.27	0.010	*
14:1n-9	Tetradecenoic	0.75	0.81	0.025	ns
15:1n-5	Pentadecenoic	1.47	1.36	0.086	ns
16:1n-7	Palmitoleic	2.69	2.83	0.076	ns
17:1n-7	Heptadecenoic	0.69	0.70	0.027	ns
18:1n-9t	Trans-octadecenoic	0.41	0.52	0.054	ns
18:1n-9c	Oleic	34.1	32.2	0.895	ns
18:1n-7	Octadecenoic	1.08	1.07	0.036	ns
20:1n-9	9 – eicosenoic	0.09	0.06	0.006	*
24:1n-9	15-Tetracosenoic	0.14	0.14	0.007	ns
Polyunsaturated					
16:2n-6	Hexadecadienoic	0.45	0.45	0.017	ns
18:2n-6	Linoleic	6.06	6.06	0.290	ns
18:3n-3	Alpha-linolenic	0.07	0.07	0.002	ns
18:3n-6	Gamma-linolenic	0.17	0.18	0.007	ns
20:4n-6 (AA)	Arachidonic	0.24	0.23	0.015	ns
20:5n-3 (EPA)	Eicosapentaenoic	1.13	1.06	0.075	ns
22:6n-3 (DHA)	Docosahexaenoic	0.27	0.27	0.020	ns

¹Treatments: Raw: raw product evaluated; Cooked: product evaluated after cooking at 72 °C. ²SEM: standard error of mean. ³Statistical probability of treatment: ns: P > 0.05; *: P < 0.05; means in the same row with different letters are significantly different (P < 0.05). Fonte: Elaborado pelo autor.

The treatments had no differences (P > 0.05), therefore the results were presented with the means of all the treatments.

The cooking in general, did not alter the composition of fatty acids when compared to raw meat (P > 0.05). Similar result to that found by Sarriés et al. (2009) in meat cooking (grilled at 140° C for 30 min) of crossbred heifers. Suggesting that the cooking causes minimal changes

on the fatty acids of the meat, being beneficial for the conservation of the product, retarding the oxidation and development of unpleasant odors.

When the samples were analyzed cooked, it was observed that there was an increase in the amount of lipids ($P > 0.05$) (from 1.37 to 3.83%) due to the loss of water with the consequent concentration of the constituents (Table 7).

Table 7. Percentage of total lipids and sum of percentages of SFA, MUFA and PUFA of raw and cooked meat at 72 °C.

Fatty acid, %	Nomenclature	Treatments ¹		SEM ²	P ³
		Raw	Cooked		
TL	Total lipids	1.37	3.83	0.247	**
SFA ^a	Saturated	49.7	51.5	0.633	ns
MUFA ^b	Monounsaturated	41.8	40.1	0.806	ns
PUFA ^c	Polyunsaturated	8.42	8.35	0.404	ns
ω -6 ^d	Omega 6	6.83	6.82	0.311	ns
ω -3 ^e	Omega 3	1.58	1.52	0.099	ns
Ratio ^f	ω -6: ω -3	4.65	4.73	0.206	ns
Ratio ^g	PUFA:MUFA	0.20	0.23	0.023	ns

¹Treatments: Raw: raw product evaluated; Cooked: product evaluated after cooking at 72 °C. ²SEM: standard error of mean. ³Statistical probability of treatment: ns: $P > 0.05$; ** $P < 0.001$. ^aSum of saturated fatty acids: 14:0, 15:0, 16:0, 17:0, 18:0, 20:0 and 24:0. ^bSum of monounsaturated fatty acids: 14:1n-5, 14:1n-9, 15:1n-5, 16:1n-7, 17:1n-7, 18:1n-9t, 18:1n-9c, 18:1n-7, 20:1n-9 and 24:1n-9. ^cSum of polyunsaturated fatty acids: 16:2n-6, 18:2n-6, 18:3n-3, 18:3n-6, 20:4n-6, 20:5n-3 and 22:6n-3. ^dSum of 16:2n-6, 18:2n-6, 18:3n-6 and 20:4n-6. ^eSum of 18:3n-6, 20:4n-6 and 22:6n-3. ^f ω -6: ω -3 ratio = $\Sigma \omega$ -6/ $\Sigma \omega$ -3. ^gPUFA:MUFA ratio = Σ polyunsaturated/ Σ monounsaturated. Fonte: Elaborado pelo autor.

Saturated fats solidify after cooking positively affecting the sensory characteristics of the meat. In addition to improving digestibility, reducing or eliminating pathogenic microorganisms, bringing to the food better sanitary conditions (Frank, Joo & Warner, 2016). The loss of water during the process that can vary from 20 to 30% (Monteschio et al., 2017; Rivaroli et al., 2016). In this way, the fat concentration increases (Alfaia et al., 2010).

The percentage of saturated fatty acids was similar ($P < 0.05$) in raw and cooked meat. The percentages of palmitic (28.4%) and stearic (17.3%) fatty acids in meat were the highest, as observed by other authors (Eiras et al., 2016; Prado et al., 2016). The percentage of 18: 1n-9c (oleic) fatty acid was the highest among the monounsaturated fatty acids present in meat as observed by several authors (Guerrero et al., 2016).

The percentage of PUFA was similar ($P > 0.05$) in raw or cooked meat. The fatty acid 18:2n-6 (linoleic) presented the highest percentage (6.2%), 18:3n-3 (alpha-linolenic) being the lowest percentage (0.17%). Crossbred cattle (*Bos taurus taurus* vs. *Bos taurus indicus*) for meat

production and finishing in feedlot have values between 2 and 6% for linoleic fatty acid and between 0.1 and 0.8% for alpha-linolenic fatty acid (Valero et al., 2014).

The highest percentage was for SFA, followed by MUFA and PUFA. Likewise, the percentages of omega 3 and omega 6 fatty acids were not altered by the cooking of the meat.

The ratio between the percentages of PUFA:MUFA was not altered ($P > 0.05$) by the meat cooking process. The ratio of PUFA:MUFA was 0.20. Thus, the ratio observed in this experiment is low (HMSO, 1994). However, this ratio in the meat of finished feedlot animals is always between 0.10 and 0.20 (Eiras et al., 2016).

The results of this experiment show that meat fat consists of 51% SFA, 41% MUFA and only 8% PUFA. For most saturated fatty acids it was stearic acid which is considered neutral for blood cholesterol levels (Shingfield, Bonnet & Scollan, 2013).

The ratio of the percentages between omega 6 and omega 3 was not altered ($P > 0.05$) by the meat cooking process. The ratio of omega-6 to omega-3 was 4.7. Therefore, the reason observed in this experiment is adequate (HMSO, 1994). The ratio in the meat of finished cattle in feedlot is always between 4 to 10 (Eiras et al., 2016). In general, the ratio of omega-6 fatty acids to omega-3 fatty acids in pasture finishing cattle is more adequate because of the higher contribution of omega-3 fatty acids in these animals (Eiras et al., 2016).

4. Final Considerations

In view of the above, the individual composition of the fatty acids was not altered by the difference in the BW of the animals and by the meat cooking process. The BW of the animals and cooking influenced the amount of total lipids, but the composition of fatty acids remained unchanged, concluding that the different BW and the heating used in this study were insufficient to cause important changes in the fat molecules and the meat can be consumed without damaging the health of the consumer.

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References

- Alfaia, C. M. M., Alves, S. P., Lopes, A. F., Fernandes, M. J. E., Costa, A. S. H., Fontes, C. M. G. A., Prates, J. A. M. (2010). Effect of cooking methods on fatty acids, conjugated isomers of linoleic acid and nutritional quality of beef intramuscular fat. *Meat Science*, 84(4), 769-777.
- Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, 37(8), 911-917.
- Broncano, J. M., Petró, M. J., Parra, V., & Timón, M. L. (2009). Effect of different cooking methods on lipid oxidation and formation of free cholesterol oxidation products (COPs) in Latissimus dorsi muscle of Iberian pigs. *Meat Science*, 83(3), 431-437.
- Chávez, A., Pérez, E., Rubio, M. S., Méndez, R. D., Delgado, E. J., & Díaz, D. (2012). Chemical composition and cooking properties of beef forequarter muscles of Mexican cattle from different genotypes. *Meat Science*, 91(2), 160-164.
- Corpet, D. E. (2011). Red meat and colon cancer: Should we become vegetarians, or can we make meat safer? *Meat Science*, 89(3), 310-316.
- Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal*, 9(1), 1-12.
- Dias, A. M. O., Menezes, L. F. G., Silveira, M. F., Paris, W., Santos, P. V., & Lazzarotto, E. F. C. O. (2016). Organs and carcass non-integrant components of Holstein calves, slaughtered at different weights, held in different finishing systems. *Semina: Ciências Agrárias*, 37(2), 1045-1056.
- Eiras, C. E., Ornaghi, M. G., Valero, M. V., Rivaroli, D. C., Guerrero, A., & Prado, I. N. (2016). How does the dietary cottonseed hull affect the carcass characteristics and meat quality of young bulls finished in a high-concentrate diet? *Acta Scientiarum. Animal Sciences*, 38(3), 301-310.

Frank, D., Joo, S. T., & Warner, R. (2016). Consumer Acceptability of Intramuscular Fat. *Korean journal for food science of animal resources*, 36(6), 699–708.

Gogus, U., & Smith, C. (2010). n-3 Omega fatty acids: a review of current knowledge. *International Journal of Food Science & Technology*, 45(3), 417-436.

lar lipids of Dutch steers. *Annals of Chemical Brazilian Association*, 52(1), 46-50.

Guerrero, A., Muela, E., Valero, M. V., Prado, I. N., Campo, M. M., Olleta, J. L., Sañudo, C. (2016). Effect of the type of dietary fat when added as an energy source on animal performance, carcass characteristics and meat quality of intensively reared Friesian steers. *animal*, 56(1144-1151).

Hall, N., Schönfeldt, H. C., & Pretorius, B. (2016). Fatty acids in beef from grain-and grass-fed cattle: the unique South African scenario. *South African Journal of Clinical Nutrition*, 29(2), 55-62.

Hartman, L., & Lago, R. C. (1973). Rapid preparation of fatty acid methyl esters from lipids. *Laboratory practice*, 22(6), 475-476.

Hocquette, J., Gondret, F., Baéza, E., Médale, F., Jurie, C., & Pethick, D. (2010). Intramuscular fat content in meat-producing animals: Development, genetic and nutritional control, and identification of putative markers. *Animal*, 4(2), 303-319.

Ito, R. H., Prado, I. N., Rotta, P. P., Oliveira, M. G. , Prado, R. M., & Moletta, J. L. (2012). Carcass characteristics, chemical composition and fatty acid profile of longissimus muscle of young bulls from four genetic groups finished in feedlot. *Revista Brasileira de Zootecnia*, 41(2), 384-391.

Kaur, N., Chugh, V., & Gupta, A. K. (2014). Essential fatty acids as functional components of foods- a review. *Journal of food science and technology*, 51(10), 2289–2303.

Kouba, M., & Mourot, J. (2011). A review of nutritional effects on fat composition of animal products with special emphasis on n-3 polyunsaturated fatty acids. *Biochimie*, 93(1), 13-17.

Kramer, R., Wolf, S., Petri, T., von Soosten, D., Dänicke, S., Weber, E. M., Zimmer, R., Rehage, J., & Jahreis, G. (2013). A commonly used rumen-protected conjugated linoleic acid supplement marginally affects fatty acid distribution of body tissues and gene expression of mammary gland in heifers during early lactation. *Lipids in health and disease*, 12, 96.

Laliotis, G. P., Bizelis, I., & Rogdakis, E. (2010). Comparative approach of the de novo fatty acid synthesis (Lipogenesis) between ruminant and non ruminant mammalian species: from biochemical level to the main regulatory lipogenic genes. *Current genomics*, 11(3), 168-183.

Lee, J. M., Lee, H., Kang, S., & Park, W. J. (2016). Fatty Acid Desaturases, Polyunsaturated Fatty Acid Regulation, and Biotechnological Advances. *Nutrients*, 8(1), 23.

Monteschio, J. O., Souza, K. A., Vital, A. C. P., Guerrero, A., Valero, M. V., Kempinski, E. M. B. C., . . . Prado, I. N. (2017). Clove and rosemary essential oils and encapsuled active principles (eugenol, thymol and vanillin blend) on meat quality of feedlot-finished heifers. *Meat Science*, 130, 50-57.

Ornaghi, M. G., Passetti, R. A. C., Torrecilhas, J. A., Mottin, C., Vital, A. C. P., Gurerrero, A., Prado, I. N. (2017). Essential oils in the diet of young bulls: Effect on animal performance, digestibility, temperament, feeding behaviour and carcass characteristics. *Animal Feed Science and Technology*, 234, 274-283.

Park, S. J., Beak, S. H., Jung, D., Kim, S. Y., Jeong, I. H., Piao, M. Y., Kang, H. J., Fassah, D. M., Na, S. W., Yoo, S. P., & Baik, M. (2018). Genetic, management, and nutritional factors affecting intramuscular fat deposition in beef cattle - A review. *Asian-Australasian journal of animal sciences*, 31(7), 1043–1061.

Pereira, A. S. C., Santos, M. V., Aferri, G., Corte, R. R. P. S., Silva, S. L., Freitas Júnior, J. E., Leme, P. R., & Rennó, F. P. (2012). Lipid and selenium sources on fatty acid composition of intramuscular fat and muscle selenium concentration of Nellore steers. *Revista Brasileira de Zootecnia*, 41(11), 2357-2363.

Pickworth, C. L., Loerch, S. C., Velleman, S. G., Pate, J. L., Poole, D. H., & Fluharty, F. L. (2011). Adipogenic differentiation state-specific gene expression as related to bovine carcass adiposity. *Journal of Animal Science*, 89(2), 355-366.

ture systems. *Asian-Australasian journal of animal sciences*, 21(10), 1449-1457.

Prado, I. N., Cruz, O. T. B., Valero, M. V., Zawadzki, F., Eiras, C. E., Rivaroli, D. C., Visentainer, J. V. (2016). Effects of glycerin and essential oils (*Anacardium occidentale* and *Ricinus communis*) on the meat quality of crossbred bulls finished in a feedlot. *Animal Production Science*, 56(12), 2105-2114.

Rivaroli, D. C., Guerrero, A., Valero, M. M., Zawadzki, F., Eiras, C. E., Campo, M. M., Prado, I. N. (2016). Effect of essential oils on meat and fat qualities of crossbred young bulls finished in feedlots. *Meat Science*, 121, 278-284.

Sarriés, M. V., Murray, B. E., Moloney, A. P., Troy, D., & Beriain, M. J. (2009). The effect of cooking on the fatty acid composition of longissimus muscle from beef heifers fed rations designed to increase the concentration of conjugated linoleic acid in tissue. *Meat Science*, 81(2), 307-312.

Simopoulos A. P. (2016). An Increase in the Omega-6/Omega-3 Fatty Acid Ratio Increases the Risk for Obesity. *Nutrients*, 8(3), 128.

Shingfield, K., Bonnet, M., & Scollan, N. (2013). Recent developments in altering the fatty acid composition of ruminant-derived foods. *Animal*, 7(S1), 132-162.

Sokoła-Wysoczańska, E., Wysoczański, T., Wagner, J., Czyż, K., Bodkowski, R., Lochyński, S., & Patkowska-Sokoła, B. (2018). Polyunsaturated Fatty Acids and Their Potential Therapeutic Role in Cardiovascular System Disorders-A Review. *Nutrients*, 10(10), 1561.

Tejeda, J. F., Peña, R. E., & Andrés, A. I. (2008). Effect of live weight and sex on physico-chemical and sensorial characteristics of Merino lamb meat. *Meat Science*, 80(4), 1061-1067.

Valero, M. V., Torrecilhas, J. A., Zawadzki, F., Bonafé, E. G., Madrona, G. S., Prado, R. M., Prado, I. N. (2014). Propolis or cashew and castor oils effects on composition of *Longissimus* muscle of crossbred bulls finished in feedlot. *Chilean Journal of Agricultural and Research*, 74(4), 445-451.

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