New data on the total lipid, cholesterol and fatty acid composition of raw and grilled beef *longissimus dorsi*

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SUMMARY. Simultaneous analyses of total lipids, cholesterol and fatty acids were carried out on raw and grilled beef *longissimus dorsi* trimmed of external fat. Cholesterol was determined by high performance liquid chromatography and the fatty acids by gas chromatography. Mean total lipid (g/100 g) ranged from 2.1 to 2.6 for raw beef and 3.5 to 4.0 for grilled beef steaks. Cholesterol levels (mg/100 g) ranged from 40 to 43 for raw beef and 67 to 70 for grilled beef steaks. The main intramuscular fatty acids of the raw and grilled meat were 14:0, 16:0, 16:1n7, 18:0, 18:1n9, 18:1n7 and 18:2n6. Grilled lean beef steaks had significantly higher contents of the principal fatty acids and most of the minor fatty acids. The higher values for the three components in the grilled meat were due to loss of moisture during grilling. There was no significant difference between the apparent and true retentions values, both indicating no significant loss or degradation of total lipids, cholesterol and fatty acids during grilling.

Key words: beef, grilling, retention value, cholesterol, fatty acids, lipids.

RESUMO. Novos dados de lipídios totais, colesterol e ácidos graxos em carne bovina (*longissimus dorsi)* crua e grelhada. Análise integrada de colesterol, lipídios totais e composição de ácidos graxos foi realizada em *Longissimus dorsi*de carne bovina crua e grelhada. O colesterol foi quantificado por cromatografia líquida de alta eficiência e os ácidos graxos por cromatografia gasosa. A média de lipídios totais (g/100g) variou de 2,1 a 2,6 na carne crua e de 3,5 a 4,0 na carne grelhada. O teor de colesterol (mg/100g) variou de 40 a 43 na carne crua e de 67 a 70 na carne grelhada. Os principais ácidos graxos intramusculares foram C14:0, C16:0, C16:1n7, C18:0, C18:1n9, C18:1n7 e C18:2n6. A carne grelhada apresentou valores significativamente maiores de ácidos graxos principais e da maioria dos ácidos graxos minoritários. Os maiores valores obtidos nos três componentes na carne grelhada foram devidos a perda da umidade durante o cozimento. Os valores de retenção aparente e verdadeira não apresentaram diferença significativa, ambos indicando que não houve perda ou degradação significativa no conteúdo total de lipídios, colesterol e ácidos graxos durante o cozimento.

Palavras chave: carne bovina, carne grelhada, valores de retenção, colesterol, ácidos graxos, lipídios

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INTRODUCTION

Cardiovascular disease is the principal cause of death in Brazil, as in many other countries. This disease has been linked to high cholesterol levels in the blood. Human serum cholesterol depends not only on dietary cholesterol but also on the fatty acid composition of foods. To maintain serum cholesterol at a low level, the diet should be

low in cholesterol and fat, especially saturated fat (1). Moreover, there is concern that the Western diet may have an excessively high ratio of n6/n3 polyunsaturated fatty acids (PUFA). This is believed to cause an imbalance in the ratio of n6/n3 PUFA in the tissue membranes (2).

The numerous studies showing the relation between diet and diseases have encouraged consumers to improve their eating habits during the past two decades, but fat consumption, particularly of saturated fat, is still considered excessive. The contibuition of meat and meat products to the supply of total fat and saturated fatty acids in the diet, approximately 25% for each in the UK (3), is well known, but their supply of 16% of dietary polyunsaturated fatty acids is less widely recognized.

Undoubtedly, there is ample data on the fatty acid composition and cholesterol content of raw and cooked beef cuts, coming from both research papers and food composition tables. However, there is some divergence in reported results and great improvements in analytical methodology and instrumentation have been achieved in recent years, which should be taken advantage of in generating new data. In addition, more information is needed on the effects of the cooking methods used.

Given the above considerations, simultaneous analyses of the total lipid, cholesterol and fatty acid composition of raw and grilled beef *longissimus dorsi* from three breed types were carried out in the present work. In addition, the apparent and true retention of these food components were calculated to verify the influence of grilling.

MATERIALS AND METHODS

Materials

Raw and grilled *longissimus dorsi* muscles trimmed of surface adipose fat were analyzed. Three cattle breed types were utilized: Nelore (*Bos indicus*), Canchim (crossbreed 3/8 Nelore x 5/8 Charolais) and Beefalo (crossbreed 3/8 hybrid Bison x 5/8 Nelore). Samples from five animals were analyzed individually for each breed. Fifteen male animals were taken at random from an initial lot of 49 animals. The animals were obtained from the same ranch, were of the same age (22 months) and received the same type of feed.

For each carcass, approximately three kg of *longissimus dorsi* muscle were taken from the sixth to the ninth rib from the left and right side and cut into steaks of approximately 1.5 cm thickness. Fourteen paired steaks (7 analysed raw and the other 7 after grilling) from each animal were taken. The steaks were grilled over a hot plate at 165^{o}C to an internal temperature of 75^{o}C. Both raw and grilled samples were trimmed of external fat, ground in a meat grinder and mixed thoroughly. Duplicate samples were taken for analysis.

Extraction of lipids

The analytical scheme is shown in Figure 1.

Lipids were extracted with chloroform-methanol (2:1) according to Folch et al. (4). Aliquots were taken and the total lipid content was determined gravimetrically. Other

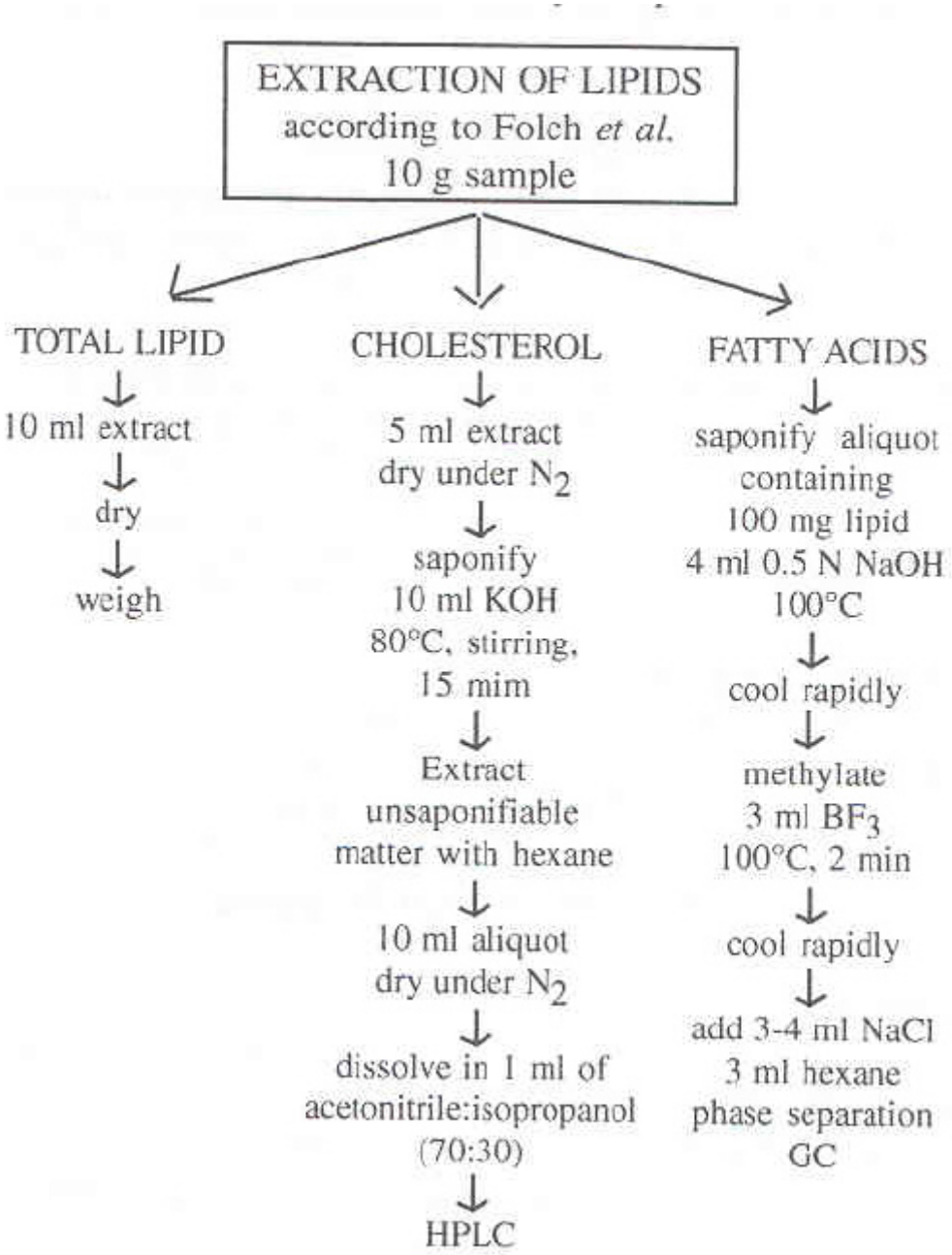
aliquots were saponified, the unsaponifiable material extracted by the procedure of Bohac et al. (5), and cholesterol was quantified by high performance liquid chromatography (HPLC). Aliquots of the lipid extract were also saponified, the fatty acids esterified with BF_3-methanol (6) and the fatty acid composition determined by gas chromatography (GC).

Liquid chromatography

For HPLC, a Varian chromatograph was used, equipped with a ternary solvent delivery system (Model 9010), rheodyne injector with a 10 μl loop, Waters diode array detector (Model 990) and a Hewlett-Packard recorder (Model 2225 D). The analytical column was 4.6 x 150 mm Spherisorb ODS-2 (5 μm), preceeded with a 4.6 x 10 mm Spherisorb ODS-2 (5 μm) guard column. The mobile phase (flow rate, 1 ml/min) consisted of acetonitrile:isopropanol (70:30, v/v). Each run took 15 min. Absorption spectra were taken at 190 to 300 nm and the chromatograms at 210 nm. All solvents were reagent-grade for extraction and HPLC grade for chromatography. Quantification was carried out by external standardization. The standard curves passed though the origin, were linear and bracketted the samples' concentrations. Calibration was done on each day of analysis. Aside from spiking, the peak's identity and also its purity were verified by means of the spectra obtained with the photodiode array detector, taken at the maximum and at the ascending and descending slopes of the peak.

FIGURA 1

Flow diagram of the analytical procedure



Capillary gas chromatography

For GC, a Varian 3300 chromatograph equipped with a split/splitless injector (split ratio, 100:1), a flame ionization detector and a fused silica capillary DB-WAX columm (30 m x 0.30 mm, 0.25 μm film thickness, J & W Scientific, U.S.A.) was used. The columm temperature was held at 150°C for 11 min and programmed at 3°C/min to 210°C. Other operating conditions were: carrier gas, hydrogen at 1.26 ml/min; make-up gas, nitrogen at 30 ml/min; detector temperature, 280°C; injector temperature, 250°C. Retention times and peak area percentages were computed automatically by a Varian 4290 computing integrator. A CP-Sil 88 column (50 m x 0.25 mm, 0.2 μm film thickness, Chrompack WCOT, Holland) was also utilized to verify the presence of *trans* fatty acids. Fatty acids were identified by the adjusted retention times compared with those of standards, spiking and equivalent chain length (7). A total of 36 saturated,

monounsaturated and polyunsaturated fatty acid standards (Sigma and Polyscience, U.S.A.) were used, along with PUFA-1 and PUFA-2 of Supelco (U.S.A.). In addition, the equivalent chain length results were found to correlate well with mass spectrometric data in our laboratory (8). Quantification was carried out by normalization and transformation of the area percentage to mg per 100 g of edible portion, using the lipid conversion factor of Holland et al. (9).

Calculation of retention during grilling

Apparent (AR) and true retention (TR) factors for the lipids, cholesterol and principal fatty acids were calculated according to Murphy et al. (10), as follows:

$$AR = \frac{100 \times \text{nutrient content per g of cooked food (dry basis)}}{\text{nutrient content per g of raw food (dry basis)}}$$

$$TR = \frac{100 \times \text{nutrient content per g of cooked food} \times \text{g of food after cooking}}{\text{nutrient content per g of raw food} \times \text{g of food before cooking}}$$

Statistical analysis

To verify significant, the results were submitted to analysis of variance (ANOVA). The Tukey□s test was utilized to compare means at a 5% significance level.

RESULTS AND DISCUSSION

Total lipid content

The total intramuscular lipid contents of the raw and grilled *longissimus dorsi* steaks are presented in Table 1. Total lipids of the grilled samples (means of 3.5 to 4.0 g/100 g) were higher than those of the raw samples (means of 2.1 to 2.6 g/100 g). This is due to loss of moisture during cooking, as shown by the yield factor, with consequent concentration of the sample's components. Surprisingly, Morris et al. (11) found higher total intramuscular lipid in raw meat (4.0 g/100 g) than cooked meat (2.4 g/100 g) in *longissimus lumborum* muscle.

In general, the results of the present work are in agreement with those reported in the literature for trimmed beef, raw as well as grilled. The values are within the range obtained for five cuts of beef by Sahasrabudhe & Stewart (12) (range of 2.1 to 7.5 g/100 g, raw meat and 3.9 to 11 g/100 g, grilled meat) and for eight cuts by Araujo de Vizcarrondo et al. (13) (1.62 to 5.15 g/100, raw). Especifically for *longissimus dorsi*, the present results agree well with those of Hood (14) (2.4 to 7.7 g/100 g, raw), and Sweeten et al. (15) (1.9 to 6.2 g/100 g, raw), but lower than those encountered by Hoelscher et al. (16) (5.7, raw and 7.4 g/100 g, grilled) and Swize et al. (17) (7.1, raw and 12 g/100 g, grilled). Badiani et al. (18) reported values of 2.4 to 7.1 and 3.9 to 11.1 g/100g for raw and cooked beef cuts, respectively for broiled *longissimus lumborum* and *infraspinatus*,oven-roasted and microwaved *semitendinosus*. The values

presented in the USDA Nutrient Database (19) are much higher both for raw and cooked samples.

TABLE 1

Total lipid of raw and grilled beef *longissimus dorsi*, with true and apparent retention values[a]

Cattle	Total lipid (g/100g) Wet basis[b]		Yield factor	Retention on grilling (%)[b]	
breed	Raw	Grilled		Apparent retention	True retention
Nelore	2.5 ± 0.4 a	3.9 ± 0.9 a	0.66 ±0.04	105 ± 1 a	107 ± 1 a
Beefalo	2.1 ± 0.5 a	3.5 ± 0.4 a	0.65 ±0.05	103 ± 20 a	102 ± 17 a
Canchim	2.6 ± 0.6 a	4.0 ± 1.0 a	0.64 ±0.04	98 ± 6 a	98 ± 6 a

aValues are means and standard deviations of five samples analyzed individually in duplicate.

bMeans in the same column with the same letter were not significantly different (p> 0.05)

TR = true retention, AR = apparent retention

The concentrations of food components can increase or decrease in the cooked food simply by loss of moisture, which concentrates the components in the cooked food, or by absorption of moisture, which dilutes the components in the cooked food. In order to evaluate true increase or loss/degradation of a food component during cooking, the removal or addition of water should be accounted for. Thus, calculation of the apparent retention (AR) (calculation based on the food component□s content of moisture-free raw and cooked foods, i.e. dry basis) and of the true retention (TR) (calculation based on the food component□s content of known weights of food before and after cooking) was introduced. Murphy et al. (10) applied both calculations on several food components and observed that AR overestimated the true retention in nealy all cases. Thus, TR was recommended.

In this study, AR varied from 98 to 105% (Table 1) and TR from 98 to 107% for total lipids during grilling. There was no significant difference between results obtained by the two procedures for calculating retention.

Badiani et al. (18) consistently found higher values for AR (102 to 109%) than TR (94 to 101%) for the total lipids in broiled*longissimus lumborum*, boiled *infraspinatus* and oven-roasted or microwaved *semitendinosus*, but the difference was not significant in broiled *longissimus lumborum*.

Literature data for TR of beef lipids vary remarkable, from 90 to 122% for braising, 91 to 160% for broiling, 71 to 125% for roasting (20-25). This variability has been attributed to the presence of variable levels of subcutaneos and intermuscular fat, whose rendering and subsequent infiltration into the lean tissue during cooking lead to TR

values higher than 100%. When only intramuscular fat is present, a 100% TR is expected, unless fat is partially lost to drip or cooking medium (23, 25).

Cholesterol content

As with total lipids, the cholesterol concentrations in the *longissimus dorsi* analyzed are higher in cooked meat (67-70 mg/100 g) than in raw samples (40-43 mg/100 g) (Table 2). Rhee et al. (26) observed that cooking did not increase the quantity of cholesterol, but merely reduced the weight of the samples, consequently turning the amount of cholesterol per gram of cooked sample higher than in an equivalent weight of raw sample. On the other hand, Kritchevsky & Tepper (27) concluded that cooking lowered the cholesterol content, lower values being obtained with cooked beef (mean of 62 mg/100 g) than with raw meat (114 mg/100 g).

TABLE 2

Cholesterol of raw and grilled beef *longissimus dorsi*, with true and apparent retention values[a]

Cattle breed	Cholesterol (mg/100g) Wet basis[b]		Retention on grilling (%)[b]	
	Raw	Grilled	Apparent retention	True retention
Nelore	40 ± 4 a	67 ± 11 a	102 ± 10 a	100 ± 7 a
Beefalo	40 ± 2 a	68 ± 8 a	100 ± 7 a	103 ± 5 a
Canchim	43 ± 3 a	70 ± 7 a	99 ± 14 a	100 ± 5 a

aValues are means and standard deviations of five samples analyzed individually in duplicate.

bMeans in the same column with the same letter were not significantly different (p> 0.05).

TR = true retention, AR = apparent retention

The values in the literature for cholesterol in beef vary substantially, those obtained in the present study for raw meat being slightly lower than majority of the data. These results are also lower than those of a previous work (50 to 56 mg/100 g) (28) referring to *longissimus dorsi* acquired from the market, thus of unknown breed, origin, rearing system and diet, and determined by the colorimetric method of Bohac et al. (5). Ranges or means of 36-46 mg/100 g (29), 48-55 mg/100g (18), 52-58 mg/100 g (14), 61 mg/100 g (16), 68 mg/100g (17) and 64-69 mg/100g (30) had been reported for raw *longissimus dorsi* muscle.

Results obtained in the present work for grilled meat are similar to those obtained previously (28) (66 mg/100 g) and by Hutchison et al. (31) (62 to 72 mg/100 g). Higher levels were reported by Sahasrabudhe & Stewart (12) (64.9 to 87.0 mg/100 g), Rhee et al. (26) (76.7 to 92.2 mg/100 g), Swize et al. (17) (92 mg/100 g) and in the USDA Nutrient Database (19) (81 mg/100 g), and an even higher value was found by Rhee et al. (32) (101.9 mg/100 g).

An AR of 99 to 102% and TR of 100 to 103% during grilling were found for cholesterol in the samples analyzed, no significant difference occurring between the results of the two calculation procedures. These retention values of about 100% showed that no loss with fat drip or degradation of cholesterol occurred during grilling.

Data for cholesterol retention during cooking is scanty in the literature. Badiani et al. (18) reported AR of 100 to 117% and TR of 95 to 107% for boiled *infraspinatus*, broiled *longissimus lumborum*, oven-roasted or microwaved *semitendinosus*, the difference

between the two values being insignificant only in broiled *longissimus lumborum*. Slover et al. (24) obtained TR values of 106, 105 and 105% for braised, broiled and roasted beef, respectively.

In a previous study (28) a 14% loss was observed, this discrepancy with the current results being probably due to the thinner steaks and uncontrolled cooking temperature in the previous work.

Various investigations (33, 34) demonstrated that the method of cooking (broiling, grill frying, braising, pan-frying, roasting, conventional, convection and microwave cooking) did not affect the cholesterol level. However, Morgan et al. (33) and Prusa & Hughes (34) noted that microwave cooking resulted in slightly higher values than those of the other methods, attributed to a smaller loss of colesterol during the short cooking period. On the other hand, Badiani et al. (18) found lower cholesterol levels in microwaved than in oven-roasted *semitendinosus*.

Fatty acid composition

Sixty peaks were detected in the GC chromatograms, of which 42 were identified (Table 3). Seven fatty acids predominated in raw and grilled meat, accounting, on the average, for 87% of the total fatty acids. These were: 18:1n9, 16:0, 18:0, 18:2n6, 14:0, 16:1n7 and 18:1n7.

Literature data on fatty acids in meat are limited in terms of the number of fatty acids identified and quantified, even whem a capillary column is used, the number varying from 6 to 20 fatty acids. (11, 13, 15, 30, 35).

The principal fatty acids identified and quantified in the present work are the same as those encountered by Sweeten et al. (15), Harris et al. (36), Morris et al. (11), Enser et al. (37), Araujo de V0izcarrondo et al. (13) and Huerta-Leidenz et al. (30) in different beef cuts.

The principal fatty acids were significantly higher in the grilled than in the raw samples, with the exception of 14:0 in Beefalo and 18:2n6 in Nelore and Beefalo which had higher but statistically insignificant values in the grilled samples. The minor fatty acids, in general, were also higher in the cooked samples, but the differences were not significant for some fatty acids. In a few cases, though insignificant, lower values were obtained for the grilled meat.

TABLE 3

Fatty acid composition (mg/100g of edible portion) of raw and grilled beef *longissimus dorsi* a

Fatty Acid	Nelore	Beefalo	Canchim			
	raw	grilled	raw	grilled	Raw	grilled
10:0	2.2 ± 0.8 b	2.9 ± 0.7 b	1.9 ± 0.4 b	2.7 ± 0.7 b	5.1 ± 1.9 a	5.3 ± 0.3 a
12:0	4.3 ± 1.5 ab	4.2 ± 0.9 ab	3.4 ± 0.8 b	4.4 ± 0.9 ab	5.7 ± 1.1 a	5.9 ± 1.0 a
i-14:0	2.4 ± 0.8 c	3.7 ± 0.5 b	3.1 ± 0.5 bc	4.3 ± 0.3 b	3.3 ± 0.6 bc	6.2 ± 0.9 a
14:0	80.2 ± 14.8 c	119.4 ± 13.7 ab	73.8 ± 10.9 c	96.1 ± 10.3 bc	101.1 ± 27.7 bc	145.3 ± 18.9 a
14:1n5	13.4 ± 1.7 b	20.9 ± 4.8 a	18.0 ± 1.6 ab	17.5 ± 1.9 ab	18 .1 ± 1.4 ab	16.3 ± 2.0 ab
i-15:0	6.9 ± 1.7 d	10.9 ± 0.9 bc	6.7 ± 1.3 d	11.4 ± 0.6 ab	8.7 ± 0.7 cd	13.8 ± 1.4 a
ai-15:0	8.1 ± 1.9 d	12.4 ± 0.7 bc	8.1 ± 0.9 d	14.4 ± 2.6 ab	9.4 ± 1.3 cd	17.0 ±

						2.8 a
15:0	11.0 ± 2.1 b	17.8 ± 1.5 a	10.8 ± 1.4 b	18.3 ± 2.6 a	11.9 ± 2.0 b	21.3 ± 4.4 a
15:1n9	5.7 ± 0.6 b	10.1 ± 1.1 ab	9.7 ± 2.0 ab	9.0 ± 2.4 ab	8.7 ± 1.2 ab	14.8 ± 5.1 a
15:1n5	1.3 ± 0.1 c	9.3 ± 1.0 ab	6.6 ± 0.0 b	9.5 ± 0.9 ab	3.0 ± 0.7 c	10.6 ± 1.2 a
16:0	567.7 ± 32.1 c	852.4 ± 45.4 a	485.6 ± 38.2 d	770.5 ± 36.0 b	589.4 ± 46.6 c	891.4 ± 32.8 a
16:1n9	7.0 ± 1.1 d	9.9 ± 0.6 bc	7.5 ± 1.3 cd	10.7 ± 0.8 b	8.5 ± 0.8 bcd	13.4 ± 2.6 a
16:1n7	54.0 ± 3.1 d	84.9 ± 6.0 bc	68.0 ± 11.4 dc	85.4 ± 3.5 b	76.3 ± 6.2 bc	125.0 ± 12.8 a
16:1n5	2.0 ± 0.3 a	3.4 ± 1.1 a	2.8 ± 0.9 a	3.5 ± 0.5 a	1.6 ± 0.2 a	2.6 ± 0.1 a
16:2n5	9.0 ± 0.2 b	15.1 ± 0.4 a	8.0 ± 0.8 b	14.7 ± 1.6 a	9.0 ± 1.2 b	16.7 ± 3.5 a
16:2n4	13.7 ± 1.4 b	22.7 ± 2.3 a	11.5 ± 1.0 b	22.0 ± 2.1 a	13.8 ± 1.7 b	23.1 ± 0.4 a
17:0	20.7 ± 1.5 b	35.3 ± 2.7 a	15.8 ± 1.3 b	30.7 ± 4.3 a	18.8 ± 1.8 b	34.6 ± 6.9 a
17:1n9	16.7 ± 0.3 c	30.3 ± 4.4 ab	15.7 ± 3.6 c	26.8 ± 3.7 b	22.0 ± 2.7 bc	36.8 ± 7.6 a
17:2n7	15.3 ± 3.3 a	14.6 ± 3.8 a	2.2 ± 0.5 b	4.8 ± 0.3 b	2.8 ± 0.2 b	4.6 ± 0.7 b
18:0	387.6 ± 26.2 b	658.5 ± 82.8 a	288.3 ± 57.7 b	582.9 ± 48.0 a	352.1 ± 6.7 b	594.8 ± 90.5 a
18:1n9	713.1 ± 88.7 c	1186.2 ± 50.6 a	600.7 ± 39.6 c	1009.3 ± 74.1 b	711.3 ± 63.6 c	1125.3 ± 77.3 ab
18:1n7	49.6 ± 2.0 b	84.7 ± 6.5 a	47.4 ± 7.1 b	91.0 ± 6.5 a	51.4 ± 7.7 b	82.2 ± 11.0 a
18:1n6	6.6 ± 0.8 b	10.6 ± 1.2 a	5.3 ± 0.6 b	10.0 ± 1.7 a	6.1 ± 1.8 b	10.5 ± 1.8 a
18:1n5	3.8 ± 0.4 bc	6.3 ± 2.0 a	3.2 ± 0.2 c	5.3 ± 0.7 ab	3.7 ± 0.6 bc	6.0 ± 0.6 a
18:1n4	1.9 ± 0.2 b	2.9 ± 0.2 a	1.6 ± 0.3 b	3.0 ± 0.3 a	2.0 ± 0.7 b	3.1 ± 0.6 a
18:2n6	114.6 ± 34.0 ab	127.8 ± 31.5 ab	101.2 ± 1.5 b	133.1 ± 18.6 ab	97.9 ± 23.3 b	179.3 ± 58.7 a
18:2n3	3.3 ± 0.6 bc	4.9 ± 1.0 ab	2.8 ± 0.6 c	5.6 ± 0.9 a	2.9 ± 0.9 c	5.9 ± 0.9 a
19:1n11	1.9 ± 0.4 bc	3.8 ± 0.9 a	1.5 ± 0.3 c	3.3 ± 0.8 a	1.7 ± 0.3 bc	3.0 ± 0.4 ab
19:1n9	2.1 ± 0.5 bc	3.7 ± 0.7 a	1.6 ± 0.2 c	3.0 ± 0.2 ab	1.6 ± 0.7 c	2.9 ± 0.7 ab
18:3n3	15.2 ± 3.3 b	16.3 ± 2.2 b	12.6 ± 2.7 b	15.9 ± 1.7 b	16.1 ± 2.5 b	26.3 ± 5.6 a
18:4n3	6.7 ± 0.6 b	11.5 ± 1.4 a	6.0 ± 1.3 b	11.1 ± 1.1 a	7.0 ± 1.7 b	12.2 ± 2.7 a
20:0	3.1 ± 0.6 bc	5.9 ± 0.4 a	2.7 ± 0.6 c	4.5 ± 0.7 ab	3.0 ± 0.8 c	4.8 ± 1.1 a

20:1n11	2.7 ± 0.7 bc	4.3 ± 0.6 a	2.1 ± 0.7 c	3.4 ± 0.3 ab	3.1 ± 0.8 abc	3.9 ± 0.7 ab
20:1n9	2.6 ± 0.7 bc	4.0 ± 0.5 a	1.8 ± 0.3 c	3.1 ± 0.7 ab	2.5 ± 0.4 bc	3.6 ±0.5 a
20:2n6	1.6 ± 0.2 c	3.0 ± 0.7 ab	1.4 ± 0.1 c	1.9 ± 0.4 bc	1.9 ± 0.3 bc	3.8 ± 0.8 a
20:3n6	4.3 ± 1.5 bc	5.2 ± 1.4 ab	3.3 ± 0.9 bc	4.8 ± 1.1 ab	2.4 ± 0.4 c	6.8 ± 0.6 a
20:4n6	11.2 ± 2.3 bc	13.7 ± 2.8 b	8.9 ± 1.2 c	12.6 ± 1.6 bc	9.3 ± 0.2 bc	26.4 ± 2.7 a
20:5n3	2.7 ± 0.5 b	3.6 ± 0.5 b	3.7 ± 1.1 b	3.4 ± 0.5 b	3.4 ± 1.2 b	9.4 ± 1.9 a
22:3n3	37.3 ± 6.4 b	39.9 ± 4.6 b	15.8 ± 2.4 c	17.0 ± 4.2 c	41.0 ± 7.4 b	63.7 ± 7.8 a
22:4n6	1.9 ± 0.2 a	3.0 ± 0.5 a	1.7 ± 0.3 a	2.9 ± 0.7 a	2.2 ± 0.8 a	2.9 ± 0.6 a
22:5n3	8.9 ± 2.3 b	8.6 ± 0.5 b	4.7 ± 0.3 c	8.1 ± 0.5 bc	6.0 ± 0.5 bc	13.6 ± 2.9 a
22:6n3	1.7 ± 0.2 b	2.4 ± 0.8 b	1.8 ± 0.1 b	2.4 ± 0.3 b	2.3 ± 0.6 b	3.9 ± 0.8 a
Saturated (%)	49.2	49.3	47.9	49.8	49.3	48.5
Monounsat. (%)	39.6	42.3	42.2	41.8	41.0	40.4
Polyunsat. (%)	11.2	8.4	9.9	8.4	9.7	11.1
Polyunsat. / Sat.	0.23	0.17	0.38	0.38	0.20	0.23
Total n3 (%)	3.4	2.5	2.5	2.0	3.5	3.8
Total n6 (%)	6.3	4.7	6.5	5.3	5.3	6.4
n6/n3	1.9	1.9	2.6	2.7	1.5	1.7

[a]Values are means and standard derivations of five samples analyzed individually in duplicate.
i = iso, ai =anteiso, sat. = saturated, monounsat. = monounsaturated, polyunsat. = polyunsaturated
**Means in the same row with different letters were significantly different ($p > 0.05$).

Badiani et al. (18) also observed that regardless of the cooking method, all fatty acids were significantly higher in the cooked meat, with the exception of C20:2n6 in broiled *longissimus* and microwaved *semitendinosus*. Sinclair et al. (38), however, found significantly lower contents of all the 20 and 22 carbon PUFA in the grilled beef compared with the raw samples, although there was no consistent loss of a specific PUFA as the length of cooking increased. Janicki & Appledorf (39) encountered significant changes in 16:0, 18:1 and 18:2 during various cooking methods (broiling, grill frying and microwave cooking) of ground beef. The fatty acid 16:0 suffered the greatest loss during cooking while 18:1 and 18:2 increased. On the other hand, Morris et al. (11) reported that there was no preferential loss of specific fatty acids during cooking, since there was no significant difference in their composition in *longissimus lumborum* of raw and cooked.

The AR during grilling varied from 92 to 104% and the TR from 95 to 108% for the principal fatty acids (Table 4). As with total lipid and cholesterol contents, there was no significant difference between the AR and TR values. The values indicate little or no significant loss of fatty acids by degradation during grilling. This appears surprising because lipid oxidation is one of the major routes for flavor development in cooked meat (40). It is probable that the amount of fatty acids needed for this purpose is small, that the quantity lost do not reach significant levels.

Badiani et al. (18) did not encounter significant difference between the AR and the TR values for the principal fatty acids in broiled *longissimus lumbrorum*, but found significant differences between these two values in boiled *infraspinatus* and in roasted and microwaved *semitendinosus*.

Enser et al. (37) and Uzcátegui B et al. (41) encountered high levels of *trans* fatty acids for 18:1 in fresh beef meat. In the present study *trans* fatty acids were not found even in the grilled samples, although the column used, CP-Sil 88 Chrompack Ltd, could separate these fatty acids.

Results of the present work show that the total saturated fatty acids (SFA) varied from 48% to 49% in raw meat and 49 to 50% in grilled meat. The sum of monounsaturates (MUFA) ranged from 40% to 42% in both raw and grilled meat. The total polyunsaturated fatty acids (PUFA) were lower, ranging from 10 to 11% in raw meat and 8 to 11% in grilled meat. The percentage of total n3 PUFA ranged from 2.5 to 3.5% and from 2.0 to 3.8% for raw and grilled *longissimus* muscle, respectively.

Beef had been thought to contain more than 50% total saturated fatty acids. Campbell & Turkki (42), for example, reported values of up to 62% saturated fatty acids. Recent work have indicated, however, that beef contained less than 50% saturated fatty acids. Sinclair et al. (43) encountered 35%; Sweeten et al. (15), 41%; Eichhorn et al. (44), 45%; Andrae et al. (45), 46% of these acids. Exceptions are the studies of Araujo de Vizcarrondo et al. (13) and Morris et al. (11) in which saturated fatty acids accounted for about 51% and 55%, respectively. However, Morris et al. (11) quantified only six fatty acids.

TABLE 4

True and apparent retention values of principal fatty acids in cooked beef *longissimus dorsi*

	Cattle bree		
Fatty acid*	Nelore	Beefalo	Canchin
C14**			
TR	100 ± 12 a	98 ± 1 a	95 ± 15 a
AR	102 ± 3 a	93 ± 2 a	100 ± 16 a
C16**			
TR	98 ± 7 a	102 ± 3 a	96 ± 2 a
AR	93 ± 2 a	97 ± 4 a	93 ± 1 a

C16:1n7**			
TR	96 ± 14 a	99 ± 10 a	95 ± 17 a
AR	99 ± 6 a	92 ± 10 a	101 ± 16 a
C18**			
TR	96 ± 5 a	108 ± 19 a	97 ± 15 a
AR	99 ± 6 a	102 ± 5 a	96 ± 6 a
C18:1n7**			
TR	103 ± 7 a	106 ± 11 a	97 ± 13 a
AR	102 ± 2 a	101 ± 5 a	100 ± 15 a
C18:1n9**			
TR	95 ± 14 a	101 ± 8a	97 ± 6 a
AR	98 ± 10 a	104 ± 3a	100 ± 7 a
C18:2n6**			
TR	101 ± 4 a	101 ± 11 a	102 ± 2 a
AR	102 ± 18 a	103 ± 8 a	96 ± 2 a

*Values are means and standard deviations of five samples analyzed individually in duplicate.

**Means within a colunm by same letter were not significantly different ($p>0.05$).

TR = true retention, AR = apparent retention

Lower values for the total polyunsaturated fatty acids were reported by Araujo de Vizcarrondo et al. (13) (3.51 to 5.67%), Duckett & Wagner (46) (5.46%), Andrae et al. (45) (4.69%) and Morris et al. (11) (3.0%) compared to results in our work.

Considering the nutritional implications of the results, grilled meat (trimmed of external fat) had less than 5 g of fat per 100g and could be considered as low in fat (47).

The PUFA/SFA ratio of 0.17 to 0.38 for these *longissimus* samples falls short of the recommended minimum value of 0.45 (48) for the whole diet. This implies a need for offsetting this deficiency with other components of the whole diet. On the other hand, the n6:n3 ratio of 1.5 to 2.7 is advantageous, being below the maximun ratio of 4.0 recommended for the whole diet.

CONCLUSIONS

The total lipid, cholesterol and fatty acid contents of grilled samples were higher than those of the raw samples because of loss of moisture during grilling. There was no significant difference in the apparent and true retention values obtained for the three food components, both indicating no significant loss or degradation of these components.

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