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Selected Nutrient Contents, Fatty Acid Composition, Including Conjugated Linoleic Acid, and Retention Values in Separable Lean from Lamb Rib Loins As Affected by External Fat and Cooking Method

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Proximate composition and fatty acid profile, conjugated linoleic acid (CLA) isomers included, were determined in separable lean of raw and cooked lamb rib loins. The cooking methods compared, which were also investigated for cooking yields and true nutrient retention values, were dry heating of fat-on cuts and moist heating of fat-off cuts; the latter method was tested as a sort of dietetic approach against the more traditional former type. With significantly ($P < 0.05$) lower cooking losses, dry heating of fat-on rib-loins produced slightly (although only rarely significantly) higher retention values for all of the nutrients considered, including CLA isomers. On the basis of the retention values obtained, both techniques led to a minimum migration of lipids into the separable lean, which was higher ($P < 0.05$) in dry heating than in moist heating, and was characterized by the prevalence of saturated and monounsaturated fatty acids. On the whole, the response to cooking of the class of CLA isomers (including that of the nutritionally most important isomer *cis*-9,*trans*-11) was more similar to that of the monounsaturated than the polyunsaturated fatty acids.

KEYWORDS: Lamb; fatty acid profile; cooking methods; true retention values; conjugated linoleic acid

INTRODUCTION

Reliable scientific evidence (*1*−*4*) supports that the inclusion of reasonable amounts of lean meat from domesticated, and even more so from wild, ruminants in the diet is favorable to human health thanks to the lipid composition of these animals' muscle tissue, a distinctive fatty acid of which is conjugated linoleic acid (CLA).

The acronym CLA refers to a mixture of positional and geometric conjugated dienoic isomers of linoleic acid formed both as intermediates in the reticulorumen biohydrogenation of linoleic acid and through the endogenous desaturation of *trans*-11-octadecenoic acid. In animal models, CLA has been shown to exhibit anticarcinogenic, antithrombotic, antiatherogenic, and immune modulator properties as well as alter body and bone metabolism—in short, pleiotropic effects that not surprisingly have been studied for quite some time now with special attention to human health (*5*). The *cis*-9,*trans*-11 (*c*9,*t*11) isomer (aptly named rumenic acid) is the main CLA occurring naturally in foodstuffs. This isomer, together with *trans*-10,*cis*-12 (*t*10,*c*12), is considered to be biologically active, although research has recently been extended to include the minor isomers *trans*-9,*trans*-11 (*t*9,*t*11) and *cis*-9,*cis*-11 (*c*9,*c*11) (*6*). Although humans also seem to be capable of partially converting dietary *trans*-11-octadecenoic acid to CLA, its main origin is thought to be dietary (*7*). Dairy products and ruminant animal fat are the richest natural sources of CLA (*8*−*11*), to the extent that they have been included in the list of functional foods by the American Dietetic Association (*12*). Among muscle foods, lamb is commonly considered to be the richest in CLA (*8*−*10*). Moreover, it has been established that lamb's subcutaneous and intermuscular adipose tissues provide a higher concentration of CLA than intramuscular fat (*13*, *14*).

Information is lacking, however, on the response to cooking of CLA in lamb, both as a whole and as selected isomers. Furthermore, very few works have considered whether and how

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the fatty acid composition of this meat's intramuscular fat is affected by cooking (*15*, *16*). Finally, no direct scientific evidence is available concerning the true retention values of fatty acids in general, and selected CLA isomers specifically, contained in lamb. Indeed, a knowledge of these coefficients combined with an awareness of the cooking yields may prove to be extremely useful in the frequent, cost-effective updating of food composition tables and databases, especially with regard to nutrients of more complex determination (*17*). Consequently, this study was conducted to determine the effect on the content and retention values of fatty acids and other nutrients produced in lamb by two markedly different cooking techniques (dry versus moist heat) as applied to paired multiple-muscled cuts with fat cover (dry heat) or without (moist heat). Because it was felt that in areas such as the Mediterranean where lamb is traditionally popular, its image may be tarnished (resulting in reduced consumption) by the perception that it is fatty and wasteful rather than because of objections about its flavor, it was attempted here to verify whether the removal of the fat cover as an intuitively more "dietetic" approach might in some way modify its nutritional characteristics. The study was conducted only on lamb carcasses issuing from the integrated production system "Qualità Controllata" (QC). QC is a quality assurance scheme, founded on voluntary participation, which was set up in 1992 by the Emilia-Romagna region (northeastern Italy) for several animal and plant foods and extended in 1997 to include the meat from heavy lambs (slaughter weight = 25−50 kg) and wethers (slaughter weight = 40−100 kg).

MATERIALS AND METHODS

Animals and Cuts. Eight QC heavy lamb carcasses (sex ratio 1:1) were obtained from an exclusive retailer during the summer months. The lambs came from four farms and were intentionally selected to equally represent both the major meat breeds and/or crosses (Appenninica, Biellese, Biellese × Suffolk, and Ile de France × Suffolk), and the most common diets adopted under the QC scheme, based on fodder (mainly lucerne hay) and concentrates (either commercial concentrates, or a mixture of corn, barley, and faba bean seeds in various proportions), to attain a growth rate between 200 and 250 g/day. The animals ranged from 4 to 5 months of age; their average slaughter weight, dressing percentage, and hot carcass weight [± standard error (SE)] were 38.2 ± 0.65 kg, 52.1 ± 1.33%, and 19.9 ± 0.70 kg, respectively. The carcasses, mostly classified as R3 for conformation and fat cover according to the European SEUROP classification scale (*18*, *19*), were conditioned at ambient temperature for ∼4 h prior to chilling at 4 °C. At 48 h post-mortem, the chilled carcasses were split into halves along the midline and fabricated into retail cuts. The rib loin, that is, *costolette* + *lombata* according to the Italian pattern of lamb cutting as illustrated by Swatland (*20*), was retained from both sides. Ultimate pH measurements of M. longissimus thoracis et lumborum were taken in duplicate at both ends of each rib loin using a benchtop pH-meter (model 420A, Orion Europe, Cambridge, U.K.) fitted with a spear-type gel electrode (model 52-32, Crison Instruments S.A., Barcelona, Spain) and an ATC temperature probe. The range of pH values obtained (5.33−5.77) ruled out any effects of dark, firm, and dry (DFD) meat on muscle composition. All rib loins were deboned. Two 2-cm-thick cross-sectional slices were taken from both the cranial and caudal ends of each cut (combined weight ± SE = 382 ± 32 g) and were retained as its composite raw reference. The cuts to be cooked by dry heat (DH) or moist heat (MH) came alternately from the left and right sides. Each roast intended for DH was left untrimmed of surface adipose tissue (average weight ± SE = 1129 ± 102 g). The anatomically matched roast (i.e., from the opposite side of the same carcass) intended for MH was carefully trimmed of surface adipose tissue (average weight ± SE = 829 ± 66 g). Both types of roasts were rolled and wrapped in an elastic netting. Bilateral symmetry was assumed.

Cooking and Preparation of Samples. DH cooking was performed in a Teflon-coated baking pan placed in a preheated (30 min) forced-air convection oven (model Compact VE 104 M, Lainox-Ali, S.p.A., Vittorio Veneto, Italy) set at 160 °C. For MH cooking, each roast was placed in an oven film bag that was bound with a piece of string and then in a Teflon-coated baking pan. Several small holes were made in the bag to allow steam to escape and to prevent bag eruption. MH cooking was performed using the same preheated (30 min) forced-air convection oven set at 150 °C. For both DH and MH cooking, meat and oven temperatures were monitored by iron−constantan (type J) wire thermocouples respectively inserted in the geometric center of the roast and positioned adjacently. Both thermocouples were connected to a digital potentiometer (model Microtemp2, Eurotron Italiana, S.r.l., Sesto S. Giovanni, Italy). Cooking was discontinued when a core temperature of 75 °C [medium, according to Matthews and Garrison (*21*)] was reached, at which time the MH rib loin was immediately freed from the bag. The total cooking time (min/kg) and postcooking rise (°C) were recorded, and the heating rate (°C/min) was calculated for each cooking method. Evaporative loss, drip, and total cooking losses (% initial raw mass) were determined according to AMSA (*22*) as modified by Badiani et al. (*23*). Weights of cuts were recorded to the nearest 1 g on a Bel Engineering electronic balance (model Mark 4520, Monza, Italy). Each cooked cut and its raw reference were trimmed of fat cover and/or surface browning, if any, intermuscular (seam) fat, and heavy epimysial connective tissue in order to obtain the lean plus intramuscular fat (marbling), that is, the separable lean, intended to approximate the edible portion of the cut freed of as much fat as possible. The separable lean, made up of M. longissimus thoracis et lumborum, the adjacent small muscles, and part of the abdominal muscles, was diced, finely ground in three 10-s bursts with an Ovatio 2 food processor (Moulinex, S.p.A., Milano, Italy), and thoroughly mixed between grindings.

Proximate Composition and Energy Value. The moisture, Kjeldahl nitrogen, and ash contents of the homogenized meat samples were determined using AOAC methods 950.46 B, 981.10, and 920.153, respectively (*24*). Total protein was calculated from Kjeldahl nitrogen using a 6.25 conversion factor. Total lipids were extracted from 10 g of each sample by means of the chloroform/methanol (2:1, v/v) method of Folch et al. (*25*), as modified by Michaelsen et al. (*26*), and measured gravimetrically. Energy value (kcal) was derived by multiplying the amount of protein and fat by conversion factors 4 and 9, respectively (*27*).

Fatty Acid Analysis. *Preparation of Methyl Esters.* An aliquot of the fat extract was transferred to a screw-cap test tube and stored at −80 °C until all samples could be analyzed for fatty acid and CLA profiles. To determine the fatty acid composition, 100 mg of the extracted lipid was dissolved in 2 mL of hexane, and then 50 μg of methyl heneicosanoate (21:0, catalog no. H3265, Sigma-Aldrich, Corp., St. Louis, MO) was added as an internal standard. An alkaline transesterification was performed using sodium methoxide in anhydrous methanol (15 min at 55 °C), as suggested by Shantha et al. (*28*), to avoid isomerization of CLA isomers. Both gas chromatography (GC) and silver-ion impregnated high-performance liquid chromatography (Ag^+-HPLC) were carried out on the same methyl ester solution.

GC Analysis. An HRGC 8560 series Mega 2 gas chromatograph (Fisons Instruments, Milano, Italy) equipped with a flame ionization detector and an automatic injection system (S 800, Fisons Instruments) was used. The column was an SP-2380 fused-silica capillary column (60 m × 0.32 mm i.d., phase thickness = 0.20 μm; catalog no. 24117, Supelco, Inc., Bellefonte, PA), injected in the split mode with a split ratio of 1:50. Helium was selected as carrier gas at a flow rate of 1.5 mL/min. Both injector and detector temperatures were set at 250 °C. The initial oven temperature was 140 °C, immediately raised by 4 °C/min to 170 °C, followed by a gradient of 1 °C/min to 185 °C, further raised by 4 °C/min to 230 °C, and held for 10 min, for a total run time of 44 min. Chrom-Card software for Windows (version 1.21, 1998, CE Instruments, Milano, Italy) was used for data analysis. Identification was accomplished by comparing the retention time of unknown fatty acid methyl esters (FAMEs) with those of known FAME standard mixtures (Alltech Associates, Inc., Deerfield, IL; Sigma-Aldrich Corp.) to which a mixture of CLA methyl esters (*t*9,*t*11, *c*9,*t*11, *c*9,*c*11, and *t*10,*c*12, catalog no. 1257, 1258, 1256, and 1254, respectively; Matreya, Inc., Pleasant Gap, PA) had been added. Quantification of methyl esters

was based on methyl heneicosanoate as an internal standard and on relative peak areas of the fatty acids. The CLA region of the GC chromatogram, which was free of other fatty acids, contained a single peak, occurring between linolenic acid [18:3 (*n*−3)] and heneicosanoic acid. Because this was most probably the sum of several unresolved CLA isomers (*29*), it was designated "total CLA".

Ag^+-HPLC Analysis. The CLA isomeric distribution was determined by Ag^+-HPLC with UV detection. The HPLC equipment consisted of a Beckman solvent delivery module 126, coupled to an autosampler model 507 with a Rheodyne injector fitted with a 20 μL loop, and a UV detector model 166 set at 233 nm (Beckman, San Ramon, CA). The separation was obtained using a ChromSpher 5 lipids analytical column (250 × 4.6 mm i.d., 5 μm particle size; Chrompack, Bridgewater, NJ) protected by a ChromGuard guard column (50 × 3 mm i.d., 5 μm particle size; Chrompack), and the mobile phase was 0.1% acetonitrile in hexane maintained at a flow rate of 1 mL/min, following the approach outlined by Sehat et al. (*30*). The identification of CLA isomers was based on the retention time of the same mixture of CLA methyl esters used in GC analysis and on its co-injection with the sample, as suggested by Yurawecz and Morehouse (*31*). HPLC chromatograms contained nine peaks. Three of these were identified as *t*9,*t*11, *c*9,*t*11 (although the coeluting presence of the minor *t*9,*c*11 could not be ruled out), and *c*9,*c*11. The isomer *t*10,*c*12 was not detected. The concentration of each Δ9,Δ11 isomer in lipid extracts was calculated on the basis of its area relative to the area of all peaks, as follows:

concentration of the Δ9,Δ11 isomer =
(total CLA concentration determined by GC × area %)/100

Nutrient Retention Values. True retention values (RVs) for all nutrients were calculated using the following formula (*17*):

RV (%) = [(nutrient content per g of cooked food ×
g of food after cooking)/(nutrient content per g of raw food ×
g of food before cooking)] × 100

Analytical Quality Assurance. Analyses were carried out in duplicate, and the reagents were of analytical or HPLC grade. The quality of the analytical results was controlled by analyzing the standard reference material "Meat Homogenate" (SRM 1546; National Institute of Standards and Technology, Gaithersburg, MD) for relevant nutrients. For each nutrient, double determinations were carried out five times during the project, following the analytical procedures used in this work. The mean values observed were always within the certified (or reference) intervals (*32*).

Statistical Analysis. Arcsin transformation was used for proportion data before statistical analysis. Summary statistics (mean and standard error of the mean) were computed for each dependent variable. Nutrient contents and retention values were evaluated by analysis of variance (repeated measures design) to test the significance of the effect of the cooking method on the nutrient composition of the separable lean. Mean values were separated at, or below, the 5% probability level using the Scheffé post hoc test. All statistical computation was performed using the Statistica software package (release 5, 1997; StatSoft, Inc., Tulsa, OK).

RESULTS AND DISCUSSION

Heat-Processing Parameters and Cooking Losses. The cooking methods adopted differed significantly in terms of both processing parameters (cooking time, postcooking rise, heating rate) and percent total losses, but not in the incidence of evaporative and drip losses. Overall, the ratios of evaporative to drip losses were approximately 74:26 for dry-heat (DH) cooking and 72:28 for moist-heat (MH) cooking (**Table 1**). The total losses observed for DH and MH cooked cuts were roughly centered within the wide ranges assembled from the work of Hoke et al. (*16*), Matthews and Garrison (*21*), Chan et al. (*27*), Griffin et al. (*33*), and Greenfield et al. (*34*) for lamb cuts brought to a core temperature of 75−79 °C, either roasted or braised (combined literature ranges of 13−57 and 12−46%, respectively). The ratio of evaporative to drip losses obtained for DH cooking were in line with the figures calculated for roasted lamb cuts based on the data provided by Matthews and Garrison (*21*) and equal to 74−75:26−25, whereas no comparison was possible for braised cuts.

Table 1. Heat-Processing Parameters and Cooking Losses for Lamb Rib Loins Cooked by Dry- or Moist-Heat Methods[a]

trait	dry-heat cooking	moist-heat cooking	*P* value
cooking time (min/kg)	74 ± 5	54 ± 1	0.0028
postcooking rise (°C)	7.1 ± 0.5	4.9 ± 0.8	0.0431
heating rate (°C/min)	0.99 ± 0.07	1.31 ± 0.03	0.0007
total losses[b] (%)	25.2 ± 1.14	28.4 ± 1.37	0.0295
evaporative loss (%)	18.6 ± 0.88	20.5 ± 1.24	0.1049
drip loss (%)	6.62 ± 0.59	7.91 ± 0.58	0.0667

[a] Values represent means ± standard error ($n = 8$). [b] All cooking losses are expressed as a percentage of the initial raw mass.

The use of DH cooking for fat-on rib loins, as opposed to MH cooking of fat-off rib loins, resulted in a lower heating rate of the cut and therefore higher cooking time, higher postcooking rise, and lower total losses (i.e., higher cooking yield, percent). Similar observations on the effect of fat cover on cooking time were made in relation to roasted or braised beef cuts by Coleman et al. (*35*), who also observed greater yields on the whole in fat-on cooked cuts. The prediction equations for cooking yields of several beef cuts developed by Jones et al. (*36*) led to the same conclusions.

Proximate Composition and Energy Value. The separable lean of the cuts analyzed in the raw state (**Table 2**) indicated protein and ash contents well within the range of values taken for raw lamb rib loin (or, whenever unavailable, "generic" lamb lean) from food composition tables, databases, and compositional surveys published in several European countries (*27*, *37*−*39*), in the United States (*40*, *41*), and in Australia (*16*, *34*), namely, 15.0−22.6% for protein and 0.90−1.20% for ash. In any case, the mean values obtained for lipids and moisture in this study were almost at the far end of the ranges derived from the sources above (2.70−16.5% and 67.5−76.5, respectively), whereas the mean energy value was actually just below the range concerned (106−209 kcal). Even though the samples used in this study also included the accessory muscles of M. longissimus thoracis et lumborum, the basic definition of "extra lean meat" as used in both the United Kingdom (*27*) and the United States (*42*) applied.

Both DH and MH cooking produced a comparable and statistically significant decrease in moisture in the edible part of the cuts (**Table 2**). This was matched by both a significant increase in the protein and lipid content and a consequent rise in energy value, without significant differences between the cooking techniques used. Compared to raw meat, there are fewer food composition tables and databases available for comparisons with cooked meat, and they are limited only to roasted rib loins (*16*, *27*, *39*−*41*). Compared with the ranges assembled from these sources for moisture, protein, lipids, ash, and energy value (52.1−66.5%, 24.4−34.4%, 4.20−13.3%, 0.97−1.35%, and 153−257 kcal, respectively), the mean values obtained here for DH and MH cooked roasts confirmed that this meat was very lean, with only ∼25% of the total energy derived from lipids against 75% contributed by protein.

On the basis of the results obtained and in relation solely to proximate composition and energy value, it can be argued that

Table 2. Proximate Composition and Energy Value for Raw and Cooked Rib Loins[a]

nutrient	raw state	dry-heat cooking	moist-heat cooking	*P* value
moisture (g/100 g of lean)	76.4 ± 0.29 a	65.0 ± 0.88 b	65.6 ± 0.78 b	0.00006
protein (g/100 g of lean)	19.5 ± 0.34 b	29.5 ± 0.42 a	29.2 ± 0.62 a	0.00002
lipids (g/100 g of lean)	2.98 ± 0.29 b	4.56 ± 0.58 a	4.36 ± 0.41 a	0.00005
ash (g/100 g of lean)	1.05 ± 0.01 ab	1.03 ± 0.02 b	1.07 ± 0.02 a	0.03300
energy value (kcal)	105 ± 2 b	159 ± 6 a	156 ± 5 a	0.00007

[a] Values represent means ± standard error ($n = 8$). Mean values in the same row followed by different letters differ significantly ($P \leq 0.05$).

Table 3. Fatty Acid Composition (Percent Fatty Acid Methyl Esters) and Health-Related Ratios for Raw and Cooked Lamb Rib Loins[a]

fatty acid	raw state	dry-heat cooking	moist-heat cooking	*P* value
14:0	3.63 ± 0.29	4.01 ± 0.45	3.91 ± 0.36	0.0750
15:0	0.46 ± 0.02 b	0.53 ± 0.03 a	0.52 ± 0.03 a	0.0018
16:0	25.0 ± 0.68	25.6 ± 0.90	25.2 ± 0.52	0.4092
16:1 (*n*–7)	2.44 ± 0.27	2.55 ± 0.29	2.65 ± 0.29	0.7584
17:0	0.71 ± 0.06	0.64 ± 0.07	0.70 ± 0.08	0.2758
18:0	15.0 ± 0.52	15.6 ± 0.58	15.1 ± 0.62	0.2899
∑ 18:1 *trans*	2.87 ± 0.36	3.11 ± 0.41	3.04 ± 0.42	0.1882
18:1 (*n*–9)	33.8 ± 1.16	33.0 ± 1.29	33.6 ± 1.21	0.2217
18:1 (*n*–11)	1.04 ± 0.09	1.04 ± 0.12	1.08 ± 0.11	0.5829
18:2 (*n*–6)	6.68 ± 0.87	5.99 ± 0.72	6.18 ± 0.60	0.0717
18:3 (*n*–3)	0.59 ± 0.14	0.54 ± 0.10	0.57 ± 0.13	0.2613
total CLA[b]	0.47 ± 0.05	0.48 ± 0.04	0.49 ± 0.05	0.6696
20:4 (*n*–6)	2.11 ± 0.44	1.91 ± 0.35	1.95 ± 0.29	0.4587
22:4 (*n*–6)	0.16 ± 0.03	0.15 ± 0.03	0.15 ± 0.03	0.9153
22:6 (*n*–3)	0.40 ± 0.07	0.35 ± 0.04	0.38 ± 0.05	0.2628
unidentified sum	4.59 ± 0.30	4.51 ± 0.37	4.54 ± 0.37	0.9808
∑ SFA[c]	44.8 ± 0.63	46.4 ± 1.32	45.4 ± 0.49	0.1412
∑ MUFA[c]	40.2 ± 1.08	39.7 ± 1.26	40.3 ± 1.11	0.4458
∑ PUFA[c]	10.4 ± 1.36	9.43 ± 1.06	9.73 ± 0.87	0.1568
∑ (*n*–6) PUFA[d]	8.94 ± 1.33	8.06 ± 1.09	8.29 ± 0.89	0.1562
∑ (*n*–3) PUFA[e]	0.99 ± 0.20	0.89 ± 0.13	0.96 ± 0.17	0.2040
(*n*–6)/(*n*–3)	10.2 ± 1.55	10.0 ± 1.48	10.0 ± 1.49	0.4592
PUFA/SFA	0.23 ± 0.03	0.21 ± 0.03	0.21 ± 0.02	0.1576

[a] Values represent means ± standard error ($n = 8$). Mean values in the same row followed by different letters differ significantly ($P \leq 0.05$). [b] Total CLA, sum of the conjugated linoleic acid isomers determined by GC. [c] SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids (total CLA excluded). [e] Sum of 18:2, 20:4, and 22:4. [e] Sum of 18:3 and 22:6.

fat cover trimming before cooking does not produce any noteworthy nutritional variation in the lean part of the multiple-muscled cut examined here after cooking; that is, the result is largely in line with that obtained by leaving the fat cover in place during cooking and broadly in accordance with the findings for roasted or braised beef cuts in the works of Smith et al. (*43*) and Wahrmund-Wyle et al. (*44*). Together with Jones et al. (*36*), it may be argued that external fat probably affects the lipid content of cooked meat in single-muscled cuts, whereas in multiple-muscled cuts a considerable role in this sense might be played by seam fat, which is always present.

Fatty Acid Profile and Nutritional Implications. In normalized terms (i.e., each fatty acid as a percentage of total FAME), the most represented fatty acids in the lipids extracted from the raw lean, in descending order of concentration, were oleic, palmitic, and stearic acids [18:1 (*n*−9), 16:0, and 18:0, respectively] followed at a considerable distance by linoleic and myristic acids [18:2 (*n*−6), or LA, and 14:0, respectively] for a total of ∼84.2% FAME (**Table 3**). The order of importance and levels of the main fatty acids, as well as the total CLA concentration in intramuscular fat of the raw lean observed in this study, were similar to those reported by others in lambs of different breeds and slaughter weights fed either forage and concentrates or concentrates alone (*13*, *15*, *45*, *46*).

Generally speaking, DH cooking and MH cooking hardly modified the fatty acid composition of the intramuscular fat of the rib loins at all compared to the uncooked samples (**Table 3**). The only statistically significant variation was observed in pentadecanoic acid (15:0). Other slight and only marginally significant variations ($P < 0.10$) were recorded for myristic and linoleic acids with differences from the raw state that were more evident in DH than in MH cooking. These findings suggested that there were no "selective" variations (i.e., of different magnitude for different fatty acids) caused by subcutaneous and/or seam fat migration into the lean or, on the other hand, by the rendering and subsequent loss of intramuscular fat from the lean or, with specific reference to polyunsaturated fatty acids (PUFA), by oxidative degradation.

The quantitative fatty acid composition (i.e., fatty acid content, expressed in mg/100 g of edible portion) was determined in both raw and cooked meat for the dual purpose of permitting observations of nutritional interest and calculating the true nutrient retention values of the fatty acids according to the cooking method applied. Cooking produced significant increases in the contents of all fatty acids, but without any statistically significant differences between DH and MH cooked meat (data not shown). After the results of the two methods had been pooled, the proportion of total energy derived from saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and PUFA amounted to mean values of 10.6, 9.28, and 2.10%, respectively; moreover, within MUFA, the energy fraction contributed by oleic acid was clearly predominant (∼83%). These aspects, combined with the modest lipid content of the meats (and therefore the modest contribution supplied by the lipids to total energy), confirmed the possibility of easy introduction into a diet formulated to combine healthful nutrition with practical preparation despite the drawback of the limited contribution made by PUFA in general, and by (*n*−3) PUFA in particular (*47*). Regardless of the cooking method employed, one serving (100 g) of this cooked meat was found to be capable of contributing an average value of 311 mg of (*n*−6) PUFA, 235 mg of which derived from LA and 71 mg from arachidonic acid [20:4 (*n*−6) or AA]. The mean levels of contribution of (*n*−3) PUFA amounted to only 37 mg/100 g of cooked meat, of which 23 mg was supplied by α-linolenic acid [18:3 (*n*−3) or ALA] and 14 mg by docosahexaenoic acid [22:6 (*n*−3) or DHA]. These latter values were a negligible contribution compared to the daily human requirements of (*n*−3) PUFA, recently set at 2000 mg of ALA + 200 mg very long chain (*n*−3) fatty acids (*47*).

The mean total CLA content provided by the raw lean examined in this study amounted to 12.78 mg/100 g of edible portion. After cooking, the CLA content increased significantly but without a difference between the two cooking methods, rising to a mean total value of 19.62 mg/100 g. Comparison with the limited literature available is possible only by expressing CLA in mg/g of fat, so that the lipid content of the meat under examination has no bearing on the data. The mean values

Table 4. True Nutrient Retention Values (Percent) for Cooked Lamb Rib Loins[a]

nutrient	dry-heat cooking	moist-heat cooking	*P* value
moisture	63.8 ± 1.46	60.9 ± 1.74	0.1136
protein	113 ± 1.0 a	106 ± 1.0 b	0.0002
lipids	108 ± 3.3	104 ± 3.0	0.1307
ash	73.3 ± 1.09	72.2 ± 1.90	0.4889
energy	115 ± 2.3 a	105 ± 0.8 b	0.0064
14:0	124 ± 8.1	112 ± 6.7	0.1691
15:0	130 ± 8.3	116 ± 6.7	0.0889
16:0	115 ± 6.1	105 ± 3.9	0.0843
16:1 (*n*–7)	126 ± 19	124 ± 23	0.8062
17:0	101 ± 7.8	101 ± 6.9	0.9507
18:0	119 ± 7.7 a	105 ± 3.7 b	0.0388
∑ 18:1 *trans*	123 ± 8.5	111 ± 7.4	0.1882
18:1 (*n*–9)	110 ± 5.8	103 ± 2.9	0.2208
18:1 (*n*–11)	110 ± 6.9	107 ± 4.8	0.4109
18:2 (*n*–6)	102 ± 5.8	98.5 ± 3.59	0.3811
18:3 (*n*–3)	108 ± 6.3	102 ± 4.2	0.2495
total CLA[b]	118 ± 9.1	110 ± 6.0	0.2490
20:4 (*n*–6)	104 ± 6.9	102 ± 5.9	0.6352
22:4 (*n*–6)	112 ± 6.9	106 ± 8.7	0.3207
22:6 (*n*–3)	103 ± 6.6	103 ± 7.3	0.9954
∑ SFA[c]	117 ± 6.5	106 ± 3.5	0.0709
∑ MUFA[c]	111 ± 5.6	105 ± 3.4	0.2315
∑ PUFA[c]	104 ± 5.9	100 ± 3.9	0.3784
∑ (*n*–6) PUFA[d]	103 ± 6.0	99.4 ± 4.11	0.4082
∑ (*n*–3) PUFA[e]	106 ± 6.0	102 ± 5.0	0.4753

[a–e] See footnotes in **Table 3**.

obtained in this study did not show any significant variation produced by the cooking method (4.32 mg/g of fat for raw meat versus 4.44 mg/g of fat for cooked meat), being subject to a certain degree of variability (raw meat range = 3.01−6.96; cooked meat range = 2.93−7.07). The mean value provided above for raw meat was within the range of 3.13−5.60 mg/g of fat assembled from the work of Mir et al. (*48*) for the rib muscle of control group lambs in feeding trials and of Chin et al. (*9*) for retail lamb.

True Nutrient Retention Values. As far as the proximate composition and energy value are concerned, DH cooking provided higher retention values (RVs) than MH cooking (**Table 4**), which was expected given the former's superior cooking yield. However, the differences observed were statistically significant only for proteins, a phenomenon for which there is no ready explanation, and therefore for energy value. The RVs obtained for moisture and ash in DH and MH cooking and for protein in MH cooking were comparable with those reported by Ono et al. (*49*) for lambs of two age groups and with the figures calculated from the mean composition values provided by Hoke et al. (*16*) for exported Australian lambs, both comparisons referring to multiple-muscled cuts either roasted or braised fat-on. On the basis of the data obtained, lipid retention did not vary significantly between the dry-heat cooking of a multiple-muscled fat-on cut and the moist-heat cooking of the same cut after fat cover trimming. The same conclusions were drawn by Wahrmund-Wyle et al. (*44*), although other researchers studying roasted or braised beef cuts have reported a significantly lower lipid retention for fat-off cooking (*35*, *36*, *43*). The RVs for lipids obtained here were just over 100%, which is typical of a mere concentration effect to which a nutrient is subject as a consequence of moisture loss from the cut during cooking. The mean lipid RVs obtained through calculation from the data presented by Hoke et al. (*16*) were higher (118% for roasting and 109% for braising), whereas the RVs provided by Ono et al. (*49*) were even higher, in the ranges of 137−156% for roasting and 130−136% for braising.

As was the case with proximate composition and energy value, individual fatty acids seemed to be retained better in DH cooked lean than in MH cooked lean (**Table 4**), even though the difference was statistically significant only for stearic acid and only marginally so ($P < 0.10$) for pentadecanoic and palmitic acids as well as for Σ SFA. RVs tended to exceed 100% in individual SFA and MUFA, and in particular for palmitoleic [16:1 (*n*−7)] and *trans*-octadecenoic acids (Σ 18:1 *trans*), whereas it was around the 100% mark for individual PUFA. It is also noted that total CLA revealed RVs closer to the values obtained for MUFA than for PUFA. A similar pattern of results was obtained by elaborating the data produced by Hoke et al. (*16*) for raw and cooked fat-on lamb cuts, with mean RVs for Σ SFA, Σ MUFA, and Σ PUFA, respectively, of 120, 116, and 112% for roasted cuts and 108, 106, and 101% for braised cuts.

Because lamb's subcutaneous and intermuscular adipose tissues are not only richer in total CLA than intramuscular fat but also contain more *trans*-octadecenoic acids (*13*, *46*, *50*), both total CLA and these fatty acids may be considered nutrient "indicators" of the fact that some migration of "external" fat into the lean had indeed occurred; this was more perceptible where, in addition to seam fat, cover fat was also present, although not to such an extent as to bring about changes in the fatty acid composition of intramuscular fat. A contribution to the interpretation may be provided by calculating the quantity of lipids, in particular the amounts of individual fatty acids that the lean would actually have gained through the effect of cooking, as opposed to the hypothesis of a mere phenomenon of concentration caused by moisture loss (i.e., RV = 100%). Comparing the "nutrient contents per gram of cooked food" effectively observed with those calculated by adopting a value of RV = 100 in the formula expressed above for the calculation of retention values, the mean quantity of fat migrating into the DH cooked meat amounted to 550 mg/100 g of lean, against 138 mg/100 g for MH cooked meat ($P < 0.05$). For 100 g of DH cooked lean, the mean contributions of SFA, MUFA, and PUFA were, respectively, estimated at 298 mg (mainly palmitic and stearic acids), 183 mg (mainly oleic acid, followed by *trans*-octadecenoic acids), and 7 mg (almost half of which was CLA). The average contributions estimated for 100 g of MH cooked lean were of course lower: 81 mg for SFA (once again mainly palmitic and stearic acids) and 50 mg for MUFA (mainly oleic and palmitoleic acids); as for PUFA, there was a minimal migration of α-linolenic acid and CLA into the lean and a certain loss of (*n*−6) fatty acids (especially linoleic acid), with total loss averaging 8 mg/100 g of lean.

Conjugated Linoleic Acid Isomers. The qualitative and quantitative picture of the CLA isomers determined in the lamb (**Table 5**) showed the clear predominance of *c*9,*t*11 (perhaps coeluting with the minor *t*9,*c*11). The relative proportion of *c*9,*t*11 to the total CLA in raw meat was much lower than the only value available for lamb, namely, the 92% provided by Chin et al. (*9*), whereas it was in line with the values more recently found in beef (*51*−*53*). In light of such a high incidence for this isomer, the values of the other Δ9,Δ11 isomers identified were decidedly low but, in any case, comparable to the only figure available, namely, *t*9,*t*11 for beef (*53*).

In qualitative terms (i.e., with values expressed in mg of isomer/g of fat), the average content of *c*9,*t*11 found in raw meat was much lower than available literature data for lamb: the 11 mg/g of fat reported by Dufey (*54*) for grazing lambs and the range of 7.00−13.87 mg/g of fat obtainable on the basis of the data provided by Nürnberg et al. (*55*) for lambs of two breeds also kept on pasture. Far greater similarity appeared in

Table 5. Concentration, Content, and True Retention Value (RV) of Δ9,Δ11 CLA Isomers for Raw and Cooked Lamb Rib Loins[a]

isomer[b]	raw state	dry-heat cooking	moist-heat cooking	*P* value
trans-9,*trans*-11				
% total CLA	1.48 ± 0.08 b	1.83 ± 0.14 a	1.76 ± 0.10 ab	0.0107
mg/g of fat	0.064 ± 0.008 b	0.080 ± 0.008a	0.077 ± 0.006 a	0.0045
mg/100 g of lean	0.19 ± 0.03 b	0.36 ± 0.06a	0.34 ± 0.04 a	0.0004
RV (%)		145 ± 13	132 ± 11	0.3060
cis/*trans*-9,11				
% total CLA	78.3 ± 1.97	76.4 ± 2.64	72.4 ± 2.71	0.2996
mg/g of fat	3.40 ± 0.40	3.40 ± 0.37	3.26 ± 0.35	0.6161
mg/100 g of lean	10.13 ± 1.33 b	15.19 ± 2.18 a	14.12 ± 1.87 a	0.0013
RV (%)		115 ± 9.0	103 ± 9.4	0.1050
cis-9,*cis*-11				
% total CLA	0.79 ± 0.13	0.69 ± 0.11	0.68 ± 0.10	0.5709
mg/g of fat	0.031 ± 0.004	0.030 ± 0.004	0.029 ± 0.004	0.8807
mg/100 g of lean	0.09 ± 0.01	0.14 ± 0.03	0.12 ± 0.01	0.2051
RV (%)		111 ± 16	104 ± 13	0.7452

[a] Values represent means ± standard error ($n = 8$). Mean values in the same row followed by different letters differ significantly ($P \leq 0.05$). [b] *cis*/*trans* refers to the Δ9,Δ11 isomers with either a *cis*,*trans* or a *trans*,*cis* configuration.

the comparison of the data range (1.20−7.40 mg/g of fat) established on the basis of numerous studies conducted on raw beef, either retail samples or meat derived from animals subjected to various trials, obviously limited to the control group (*11*, *51*, *52*, *54*, *56*−*58*). The observation of greatest importance from the nutritional point of view, however, regards the content of *c*9,*t*11 expressed in mg/100 g of lean. The average value for the raw meat analyzed here had only one possible comparison in the range of 8.4−20.8 mg/100 g of lean provided by Nürnberg et al. (*55*) and into which it fell, contrary to the qualitative observation mentioned above, thanks to the higher average lipid content in the meat from the lambs used in this study. In any event, and as was the case with total CLA mentioned previously, the *c*9,*t*11 content in raw meat observed here varied considerably, from 4.98 to 15.75 mg/100 g of edible portion.

After cooking, the relative proportion of the various isomers to total CLA and their incidence in each gram of fat varied significantly only for *t*9,*t*11, with the highest increases in DH cooking (**Table 5**). Moreover, regardless of the cooking method employed, the contents of *t*9,*t*11 and *c*9,*t*11 provided by 100 g of lean increased significantly with cooking, whereas a nonsignificant increase was produced for *c*9,*c*11. The RVs calculated for the three isomers were always higher with DH cooking than with MH cooking, although the considerable dispersion of data probably prevented the emergence of any significant difference. The *t*9,*t*11 RV was higher than those obtained for *c*9,*c*11 and *c*9,*t*11, these two values being similar to each other and—always within the same cooking method—of the same order as that found for total CLA.

The average *c*9,*t*11 contribution obtainable from 100 g of cooked meat, regardless of cooking method adopted, was 14.65 mg (range of 8.12−25.84 mg/100 g); no comparative data for lamb exist in the literature. The only figures that may be compared to those obtained here were provided by Ma et al. (*11*) for beef sirloin roast tip and for rib roast, with mean values equal to 28.7 and 77.6 mg/100 g, respectively, both characterized by considerable variability and linked to high lipid contents (9.2 and 27.8%, respectively). At this point it would be sensible to ask how much one serving (100 g) of this DH or MH cooked lamb contributes to the coverage of the human daily requirements of *c*9,*t*11—a value that is still not official. Taking as reference the values recently suggested by Ritzenthaler et al. (*59*), equal to 620 mg/day of *c*9,*t*11 for adult males and 441 mg/day for adult females, the levels of coverage of such requirements provided by this meat were decidedly low for both men (mean = 2.36%, range = 1.31−4.17%) and women (mean = 3.32%, range = 1.84−5.86%). These considerations might suggest the implementation of feeding practices aimed at standardizing upward the average content of *c*9,*t*11 in meat from intensively reared lambs. Nevertheless, in the authors' opinion, muscle foods, such as ruminant meats, naturally having comparatively high amounts of *c*9,*t*11 and low energy values, can usefully complement the consumption of this nutrient without necessarily requiring enrichment, perhaps as a partial substitute for dairy products (especially cheese and ewe cheese in particular), which are certainly the preferred source (*60*, *61*), but which also have the disadvantage of a higher calorie content.

In conclusion, a dry-heat method applied to fat-on lamb rib loins produced nutritional changes in the cooked lean not dissimilar to those produced by a moist-heat method applied to fat-off rib loins. In terms of true retention, the quantitatively and nutritionally most important isomer of conjugated linoleic acid, that is, *cis*-9,*trans*-11, responded to cooking more like the monounsaturated than the polyunsaturated fatty acids.

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LITERATURE CITED

(1) Sinclair, A. J.; Johnson, L.; O'Dea, K.; Holman, R. T. Diets rich in lean beef increase arachidonic acid and long-chain ω3 polyunsaturated fatty acid levels in plasma phospholipids. *Lipids* **1994**, *29*, 337−343.

(2) Enser, M.; Hallett, K. G.; Hewitt, B.; Fursey, G. A. J.; Wood, J. D.; Harrington, G. Fatty acid content and composition of UK beef and lamb muscle in relation to production system and implications for human nutrition. *Meat Sci.* **1998**, *49*, 329−341.

(3) Rule, D. C.; Broughton, K. S.; Shellito, S. M.; Maiorano, G. Comparison of muscle fatty acid profiles and cholesterol concentrations of bison, beef cattle, elk, and chicken. *J. Anim. Sci.* **2002**, *80*, 1202−1211.

(4) Cordain, L.; Watkins, B. A.; Florant, G. L.; Kelher, M.; Rogers, L.; Li, Y. Fatty acid analysis of wild ruminant tissues: evolutionary implications for reducing diet-related chronic disease. *Eur. J. Clin. Nutr.* **2002**, *56*, 181−191.

(5) Belury, M. A. Dietary conjugated linoleic acid in health: physiological effects and mechanisms of action. *Annu. Rev. Nutr.* **2002**, *22*, 505−531.

(6) Martin, J.-C.; Valeille, K. Conjugated linoleic acids: all the same or to everyone its own function? *Reprod. Nutr. Dev.* **2002**, *42*, 525−536.
(7) Adlof, R. O.; Duval, S.; Emken, E. A. Biosynthesis of conjugated linoleic acid in humans. *Lipids* **2000**, *35*, 131−135.
(8) Fogerty, A. C.; Ford, G. L.; Svoronos, D. Octadeca-9,11-dienoic acid in foodstuffs and in the lipids of human blood and breast milk. *Nutr. Rep. Int.* **1988**, *38*, 937−944.
(9) Chin, S. F.; Liu, W.; Storkson, J. M.; Ha, Y. L.; Pariza, M. W. Dietary sources of conjugated dienoic isomers of linoleic acid, a newly recognized class of anticarcinogens. *J. Food Compos. Anal.* **1992**, *5*, 185−197.
(10) Fritsche, J.; Steinhart, H. Analysis, occurrence, and physiological properties of trans fatty acids (TFA) with particular emphasis on conjugated linoleic acid isomers (CLA)—a review. *Fett/Lipid* **1998**, *100* (6), 190−210.
(11) Ma, D. W. L.; Wierzbicki, A. A.; Field, C. J.; Clandinin, M. T. Conjugated linoleic acid in Canadian dairy and beef products. *J. Agric. Food Chem.* **1999**, *47*, 1956−1960.
(12) ADA. Position of the American Dietetic Association: functional foods. *J. Am. Diet. Assoc.* **1999**, *99*, 1278−1285.
(13) Bolte, M. R.; Hess, B. W.; Means, W. J.; Moss, G. E.; Rule, D. C. Feeding lambs high-oleate or high-linoleate safflower seeds differentially influences carcass fatty acid composition. *J. Anim. Sci.* **2002**, *80*, 609−616.
(14) Paterson, L. J.; Weselake, R. J.; Mir, P. S.; Mir, Z. Positional distribution of CLA in TAG of lamb tissues. *Lipids* **2002**, *37*, 605−611.
(15) Badiani, A.; Nanni, N.; Gatta, P. P.; Bitossi, F.; Tolomelli, B.; Manfredini, M. Nutrient content and retention in selected roasted cuts from 3-month-old ram lambs. *Food Chem.* **1998**, *61*, 89−100.
(16) Hoke, I. M.; Buege, D. R.; Ellefson, W.; Maly, E. Nutrient and related food composition of exported Australian lamb cuts. *J. Food Compos. Anal.* **1999**, *12*, 97−109.
(17) USDA. *Composition of Foods—Raw, Processed, Prepared*, release 15; U.S. Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory: Washington, DC, 2002; p 37, available at: http://www.nal.usda.gov/fnic/foodcomp/Data/SR15/sr15_doc.htm, accessed March 29, 2003.
(18) EEC. Council Regulation 137/92 of July 23, 1992, concerning the Community scale for the classification of carcasses of ovine animals and the determination of the Community standard quality for fresh or chilled ovine carcasses, which extends the EEC regulation No. 338/91. *Off. J. Eur. Communities* **1992**, *No. L 214*, 1−5.
(19) EEC. Commission Regulation 461/93 of Feb 26, 1993, laying down the conditions of enforcement of the Community scale for the classification of ovine carcasses. *Off. J. Eur. Communities* **1993**, *No. L 049*, 70−74.
(20) Swatland, H. J. *Meat Cuts and Muscle Foods*; Nottingham University Press: Nottingham, U.K., 2000; pp 100−101.
(21) Matthews, R. H.; Garrison, Y. J. *Food Yields Summarized by Different Stages of Preparation*; Agriculture Handbook 102; U.S. Department of Agriculture: Washington, DC, 1975; pp 64−65, available at http://www.nal.usda.gov/fnic/foodcomp/Data/Classics, accessed March 7, 2003.
(22) AMSA. *Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness of Fresh Meat*; American Meat Science Association and National Live Stock and Meat Board: Chicago, IL, 1995; pp 1−11, 39−40.
(23) Badiani, A.; Stipa, S.; Bitossi, F.; Gatta, P. P.; Vignola, G.; Chizzolini, R. Lipid composition, retention and oxidation in fresh and completely trimmed beef muscles as affected by common culinary practices. *Meat Sci.* **2002**, *60*, 169−186.
(24) AOAC. *Official Methods of Analysis*, 17th ed.; AOAC International: Gaithersburg, MD, 2000; methods 920.153, 950.46 B, 981.10.
(25) Folch, J.; Lees, M.; Sloane-Stanley, G. H. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.* **1957**, *226*, 497−509.
(26) Michaelsen, S. A.; Johnson, D. D.; West, R. L.; Leak, F. W. *Determination of Cooking Characteristics for Lean Retail Beef Cuts*; Meat Science Section, Department of Animal Science, University of Florida: Gainesville, FL, 1991; pp 42−43.
(27) Chan, W.; Brown, J.; Lee, S. M.; Buss, D. H. Meat, poultry and game. *McCance and Widdowson's The Composition of Foods*, 5th Suppl., 5th ed.; The Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food: Cambridge, U.K., 1995; pp 4, 30−53, 136, 144.
(28) Shantha, N. C.; Decker, E. A.; Hennig, B. Comparison of methylation methods for the quantitation of conjugated linoleic acid isomers. *J. Assoc. Off. Anal. Chem. Int.* **1993**, *76*, 644−649.
(29) Christie, W. W. *Analysis of Conjugated Linoleic Acid (CLA)*; The Scottish Crop Research Institute: Dundee, Scotland, 2002; p 6, available at http://www.lipid.co.uk/infores/topics/cla, accessed April 30, 2002.
(30) Sehat, N.; Yurawecz, M. P.; Roach, J. A. G.; Mossoba, M. M.; Kramer, J. K. G.; Ku, Y. Silver-ion high-performance liquid chromatographic separation and identification of conjugated linoleic acid isomers. *Lipids* **1998**, *33*, 217−221.
(31) Yurawecz, M. P.; Morehouse, K. M. Silver-ion HPLC of conjugated linoleic acid isomers. *Eur. J. Lipid Sci. Technol.* **2001**, *103*, 609−613.
(32) Welch, M. J.; Colbert, J. C.; Gill, L. M.; Phinney, C. S.; Sharpless, K. E.; Sniegoski L. T.; Wood, L. J. The certification of SRM 1546—Meat homogenate, a new reference material for nutrients in a high protein, high fat matrix. *Fresenius J. Anal. Chem.* **2001**, *370*, 42−47, plus Supporting Information available in electronic form at http://link.springer.de/journals/fjac, accessed July 29, 2002.
(33) Griffin, C. L.; Savell, J. W.; Smith, G. C.; Rhee, K. S.; Johnson, H. K. Cooking times, cooking losses and energy used for cooking lamb roasts. *J. Food Qual.* **1985**, *8*, 69−79.
(34) Greenfield, H.; Kuo, Y. L.; Hutchison, G. I.; Wills, R. B. H. Composition of Australian foods. 33. Lamb. *Food Technol. Aust.* **1987**, *39*, 202−207.
(35) Coleman, M. E.; Rhee, K. S.; Cross, H. R. Sensory and cooking properties of beef steaks and roasts cooked with and without external fat. *J. Food Sci.* **1988**, *53*, 34−36, 61.
(36) Jones, D. K.; Savell, J. W.; Cross, H. R. Effects of fat trim on the composition of beef retail cuts—3. Cooking yields and fat retention of the separable lean. *J. Muscle Foods* **1992**, *3*, 73−81.
(37) Souci, S. W.; Fachmann, W.; Kraut, H. *Food Composition and Nutrition Tables*, 6th ed.; Medpharm GmbH Scientific Publishers: Stuttgart, Germany, 2000; pp 220−221.
(38) Favier, J.-C.; Ireland-Ripert, J.; Toque, C.; Feinberg, M. *Répertoire Général des Aliments: Table de Composition*, 2nd ed.; Lavoisier: Paris, France, 1995; p 217.
(39) Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione (INRAN). *Tabelle di Composizione degli Alimenti, Aggiornamento 2000*; EDRA srl: Milano, Italy, 2000; p 30.
(40) National Live Stock and Meat Board. *Nutrient Values of Muscle Foods*, 1st ed.; National Live Stock and Meat Board: Chicago, IL, 1988; pp 42, 44.
(41) USDA. *U.S. Department of Agriculture Nutrient Database for Standard Reference*, release 15; Nutrient Data Laboratory, 2002; NDB 17026, 17028, 17032, 17034, 17078, 17082, 17083, available at http://www.nal.usda.gov/fnic/foodcomp/Data/SR15/sr15.html, accessed Aug 20, 2002.
(42) U.S. Food and Drug Administration. *The Food Label*; FDA Backgrounder, 1999; p 12, available at http://www.cfsan.fda.gov/~dms/fdnewlab.html, accessed May 3, 2003.
(43) Smith, D. R.; Savell, J. W.; Smith, S. B.; Cross, H. R. Fatty acid and proximate composition of raw and cooked retail cuts of beef trimmed to different external fat levels. *Meat Sci.* **1989**, *26*, 295−311.
(44) Wahrmund-Wyle, J. L.; Harris, K. B.; Savell, J. W. Beef retail cut composition: 2. Proximate analysis. *J. Food Compos. Anal.* **2000**, *13*, 243−251.

(45) Sañudo, C.; Enser, M. E.; Campo, M. M.; Nute, G. R.; María, G.; Sierra, I.; Wood, J. D. Fatty acid composition and sensory characteristics of lamb carcasses from Britain and Spain. *Meat Sci.* **2000**, *54*, 339−346.

(46) Wachira, A. M.; Sinclair, L. A.; Wilkinson, R. G.; Enser, M.; Wood, J. D.; Fisher, A. V. Effects of dietary fat source and breed on the carcass composition, *n*−3 polyunsaturated fatty acid and conjugated linoleic acid content of sheep meat and adipose tissue. *Br. J. Nutr.* **2002**, *88*, 697−709.

(47) EURODIET. *Nutrition and Diet for Healthy Lifestyles in Europe: Science and Policy Implications*; Core Report of the Eurodiet Project Steering Committee, 2000; p 20, available at: http://eurodiet.med.uoc.gr, accessed Sept 26, 2002.

(48) Mir, Z.; Rushfeldt, M. L.; Mir, P. S.; Paterson, L. J.; Weselake, R. J. Effect of dietary supplementation with either conjugated linoleic acid (CLA) or linoleic acid rich oil on the CLA content of lamb tissues. *Small Ruminant Res.* **2000**, *36*, 25−31.

(49) Ono, K.; Berry, B. W.; Johnson, H. K.; Russek, E.; Parker, C. F.; Cahill, V. R.; Althouse, P. G. Nutrient composition of lamb of two age groups. *J. Food Sci.* **1984**, *49*, 1233−1239, 1257.

(50) Enser, M.; Hallett, K. G.; Hewitt, B.; Fursey, G. A. J.; Wood, J. D. Fatty acid content and composition of English beef, lamb and pork at retail. *Meat Sci.* **1996**, *42*, 443−456.

(51) Fritsche, J.; Fritsche, S.; Solomon, M. B.; Mossoba, M. M.; Yurawecz, M. P.; Morehouse, K.; Ku, Y. Quantitative determination of conjugated linoleic acid isomers in beef fat. *Eur. J. Lipid Sci. Technol.* **2000**, *102*, 667−672.

(52) Fritsche, S.; Rumsey, T. S.; Yurawecz, M. P.; Ku, Y.; Fritsche, J. Influence of growth promoting implants on fatty acid composition including conjugated linoleic acid isomers in beef fat. *Eur. Food Res. Technol.* **2001**, *212*, 621−629.

(53) Nürnberg, K.; Nürnberg, G.; Ender, K.; Lorenz, S.; Winkler, K.; Rickert, R.; Steinhart, H. *N*-3 fatty acids and conjugated linoleic acids of *longissimus* muscle in beef cattle. *Eur. J. Lipid Sci. Technol.* **2002**, *104*, 463−471.

(54) Dufey, P.-A. La viande, source alimentaire d'acides linoléiques conjugués (CLA). *Rev. Suisse Agric.* **1999**, *31*, 173−176.

(55) Nürnberg, K.; Grumbach, S.; Zupp, W.; Hartung, M.; Nürnberg, G.; Ender K. Erhöhung der *n*−*3* Fettsäuren und der konjugierten Linolsäure im Lammfleisch durch Weidehaltung. *Fleischwirtschaft* **2001**, *81*, 120−122.

(56) Shantha, N. C.; Crum, A. D.; Decker, E. A. Evaluation of conjugated linoleic acid concentrations in cooked beef. *J. Agric. Food Chem.* **1994**, *42*, 1757−1760.

(57) Shantha, N. C.; Moody, W. G.; Tabeidi, Z. Conjugated linoleic acid concentration in *semimembranosus* muscle of grass-fed and grain-fed and zeranol-implanted beef cattle. *J. Muscle Foods* **1997**, *8*, 105−110.

(58) Madron, M. S.; Peterson, D. G.; Dwyer, D. A.; Corl, B. A.; Baumgard, L. H.; Beermann, D. H.; Bauman, D. E. Effect of extruded full-fat soybeans on conjugated linoleic acid content of intramuscular, intermuscular, and subcutaneous fat in beef steers. *J. Anim. Sci.* **2002**, *80*, 1135−1143.

(59) Ritzenthaler, K. L.; McGuire, M. K.; Falen, R.; Shultz, T. D.; Dasgupta, N.; McGuire, M. A. Estimation of conjugated linoleic acid intake by written dietary assessment methodologies underestimates actual intake evaluated by food duplicate methodology. *J. Nutr.* **2001**, *131*, 1548−1554.

(60) Prandini, A.; Geromin, D.; Conti, F.; Masoero, F.; Piva, A.; Piva, G. Survey on the level of conjugated linoleic acid in dairy products. *Ital. J. Food Sci.* **2001**, *13*, 243−253.

(61) Zlatanos, S.; Laskaridis, K.; Feist, C.; Sagredos, A. CLA content and fatty acid composition of Greek feta and hard cheeses. *Food Chem.* **2002**, *78*, 471−477.

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