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# Quality of retail beef from two grass-based production systems in comparison with conventional beef

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**Abstract**

Seventy beef strip loins (*Longissimus dorsi*) were sampled, originating from labels prescribing pasturing (PS, suckler beef; PF, finished steers or heifers), from conventional production (CH, heifers; CB, young bulls), and from a label producing intensively fattened young bulls (LB) and prescribing specific husbandry conditions but not grazing. Samples were purchased in autumn and spring (1:1) from 33 retail stores in northeastern Switzerland. Colour was lightest in LB beef, while PS displayed the least intensive red. Shear force was low in pasture beef, with PF showing the lowest variability. Pasture beef was richer in *n*−3 fatty acids than beef of all other origins. The *n*−6/*n*−3 ratio was consistently below 2 in pasture beef, while it ranged above 5 in LB, and also in CH and CB when purchased in spring. Prescribing year-round feeding of grass products and the use of steers or heifers therefore guarantees *n*−3 enriched beef, which can be at least as tender as conventional beef.


*Keywords:* Omega−3 fatty acids; Pasture; Meat colour; Tenderness; Beef

## 1. Introduction

Grass-based beef production systems are low-input systems that are particularly suitable to meet the demand of meat retailers and consumers for naturally and animal-friendly produced beef. Beside such idealistic aspects, the perceived healthiness of food is becoming a key quality issue for consumers. In the case of meat, this is largely related to its fat content and its fatty acid composition (Fisher et al., 2000). Concerning the health aspect of beef, there might be an advantage of grass-based systems since lipids of green forage are known to contain high proportions of α-linolenic acid (ALA). This basic *n*−3 (omega−3) fatty acid can be endogenously desaturated and elongated to long-chain *n*−3 fatty acids (*n*−3 LC-PUFA) (Sprecher, 2000), i.e., eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA), and docosahexaenoic acid (DHA). *n*−3 Fatty acids, particularly the *n*−3 LC-PUFA, were shown to exert various beneficial health effects (Simopoulos, Leaf, & Salem, 1999). While nearly all lipid containing foods in Western diets contribute to the intakes of *n*−6 PUFA and ALA, according to Meyer et al. (2003) only three main groups of foods contribute to the supply with *n*−3 LC-PUFA, namely seafood, meat, and eggs.

Conjugated linoleic acids (CLA) are another group of fatty acids, which naturally occur in ruminant-derived food and to which various beneficial health effects are ascribed (Belury, 2002). There is clear evidence for an enhanced proportion of *n*−3 fatty acids and CLA in beef from grass (and linseed) fed bulls compared with beef from bulls fed maize silage and concentrate (Dannenberger et al., 2004; Nürnberg et al., 2002). However, it is still unclear whether beef from pasture-based production systems compared to intensive production may provide a measurable and relevant dietetic advantage to consumers, when produced under commercial and not experimental conditions. In Switzerland and regions with similar climatic conditions it is especially unknown whether or not such an advantage is still found at

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the end of the winter period when typically several months without consumption of fresh grass have passed. Provided beef from grass-based fattening systems could be reliably distinguished from conventional beef at the point of sale by its fatty acid profile, this would facilitate authentication of meat (Franke, Gremaud, Hadorn, & Kreuzer, 2005), although other plant biomarkers would also be available (Prache, Cornu, Berdagué, & Priolo, 2005). Additionally, from the consumer's point of view, visual appearance and tenderness of beef are still very important traits influencing purchase decisions (Maltin, Balcerzak, Tilley, & Delay, 2003). As grass-based fattening is typically less intensive, animals are often older at slaughter, which could result in less tender meat (Mitchell, Reed, & Rogers, 1991) and darker meat colour (Priolo, Micol, & Agabriel, 2001).

The objective of the present investigation was, therefore, to purchase and analyse retail beef with stated origin from pasture-based systems both at the end of the vegetative season and at the end of the winter period, and to compare its composition, colour and texture with beef from conventional production or a label with other provisions than grazing.

## 2. Material and methods

### 2.1. Sample origin

This investigation was conducted with 70 strip loins (*Longissimus dorsi*, LD) obtained from five different origins, and purchased in 33 different retail stores in north-eastern Switzerland. Two of these origins were beef labels, which prescribe grazing during the vegetative season: one provides suckler beef, i.e., calves staying with their mother from birth until being slaughtered at an age of approximately 10 months (PS, $n = 10$). At that age, carcass weights range from 150 to 220 kg. The other pasture-based label (PF, $n = 20$) represents a recently launched organic production system, additionally prescribing a diet consisting of hay and grass silage in winter time. Feeding low amounts of organically produced concentrate is allowed in the finishing phase. The animals have to be steers or heifers, slaughtered at ages of 18–24 months and providing carcasses weighing from 250–320 kg. The compliance of the producers with the rules is regularly controlled in both labels. The other three origins were based on intensive fattening regimes and comprised: young bulls also kept under label conditions which prescribe, among others, animal-friendly husbandry systems (i.e., access to an outdoor area, unrestricted movement and social contact, fresh air and sufficient daylight in the barn), and recommend the feeding of grass, hay, maize, silage, cereals, beet and milk products (LB, $n = 20$), conventionally fattened heifers (CH, $n = 10$) and conventionally fattened young bulls (CB, $n = 10$). In Switzerland, young bulls (as fattened in LB and CB) are commonly slaughtered at about 13 months of age, providing carcasses weighing between 270 and 310 kg. Heifers are typically fattened less intensively than bulls in order to avoid excessive fat accretion. They are commonly slaughtered at an age of 18–20 months, with carcasses of about 250 kg. The CH samples were purchased from butcher shops, the ones from PS, PF, LB and CB in supermarkets. Beef from PF and LB had been processed in the same slaughter and cutting plant and was sold by the same supermarket chain (although in different shops). From these two origins 20 samples each (instead of ten as for the other origins) were purchased to more thoroughly validate the potential differences between extensive, grass-based and intensive beef production as well as the potential interactions with season.

Half of the samples were purchased in October and November, following several months of grazing in the case of PS and PF, the other half in February and March, i.e., just before the next grazing season started. In all cases, the retailers had assured that the beef had been aged and was ready for consumption.

### 2.2. Sample analysis

The samples were transported in a refrigerated box to the laboratory. Directly after transport, pH was measured using an IP67 electrode (model SenTix 21) attached to a WTW-340 pH meter (Wissenschaftliche Technische Werkstätten, Weilheim, Germany). Subsequently, the samples were stored at 4 °C over night and then cut to obtain 2.5 cm thick slices for further analyses. Colour traits were determined at three defined areas of the fresh cut surface, bloomed for 1 h at 4 °C and using a Chroma Meter (model 300-CR, Minolta, Dietikon, Switzerland), applying the $L^*a^*b^*$ system with D65 as light source.

For texture measurements the beef slices were grilled to a final core temperature of 72 °C in an electrical double contact grill (model TURMIX 246, Beer Grill, Zurich, Switzerland) heated to 240 °C. The core temperatures were controlled by two thermocouples (Thermo ZA9020-FS, NiCr-Ni Type K) inserted into the centre of the slices and attached to a datalogger (ALMEMO model 3290-8, Ahlborn, Holzkirchen, Germany). Cooking loss was determined after cooling the grilled slices on a grid for 30 min at room temperature. Subsequently, six cores (cylinders of 1.27 cm diameter) and six stripes ($1 \times 1$ cm cross-section) were prepared from each grilled slice by drilling/cutting parallel to the muscle fibre direction. The cores were sheared by a modified Warner–Bratzler–Shear blade and the stripes by a Volodkevich bite tendrometer, both mounted on a TA-XT2 Textur Analyser (Stable Micro System, Surrey, UK).

Adhering connective and adipose tissue was carefully removed from one slice which then was homogenized in a Moulinette (Moulinex, type 643, Ecully Cedex, France) for subsequent chemical analyses. For lipid analysis, 1.8 g of the homogenate was subjected to extraction with 20 ml hexane-isopropanol (3:2), containing tritridecanoin and phosphatidylcholin 11:0 (Fluka Chemie, Buchs, Switzerland) as internal standard. The fatty acids in the extracted lipids were then converted to methyl esters according to IUPAC (1987) with slight modifications. Apart from analysing the

fatty acid composition of total lipids, fatty acids were also determined after separation into phospholipids and neutral lipids being accomplished by solid phase extraction (Kaluzny, Duncan, Merritt, & Epps, 1985) using $NH_2$ Columns (Separtis AG, Grellingen, Schweiz). The fatty acid analyses were done with a gas chromatograph (HP 6890, Hewlett-Packard, Wilmington, DE, USA) equipped with a split injector, an FID detector and a 100 m CP-Sil88 column. Analysis was performed using an initial isothermic period (175 °C, 20 min). Thereafter the temperature was increased at a rate of 2 °C/min to 225 °C. Finally, an isothermic period of 235 °C followed. Chromatograms were recorded and integrated with a ChemStation (Hewlett-Packard, USA). Identification of different fatty acid methyl esters was performed by comparing the retention times with those of known standards. Response factors were determined by injecting samples containing a known amount of FAME in order to calculate the fatty acid content in the beef. The proportion of fatty acids were expressed as percentages of the total area of injected methyl esters. The intramuscular fat content (IMF) was determined according to AOAC Method 954.02 (1977) with slight modification and using the extraction system B-811 (Büchi Labortechnik AG, Flawil, Switzerland).

### 2.3. Statistical analyses

Data were statistically analysed with the SAS program (version 8.0, SAS Institute Inc., Cary, NC). The model for analyses of variance included origin and season as well as their interaction as fixed effects. The Scheffé test was applied for the multiple comparisons among means, considering $P < 0.05$ as significant. Where appropriate for further interpretation, LS-means of the different origins or seasonal effects within beef origins were compared using a *t*-test. For colour, pH, texture and cooking loss analyses, samples with pH $\geqslant$ 5.8 ($n = 3$) were excluded since an undesirably high pH is rather the result of inappropriate handling and treatment of the animals right before slaughter than a potential characteristic of the underlying production systems. The tables give the least square means of beef origin (seasons combined) and season (origins combined), the maximum standard error of the mean and the levels of significance for the main effects and the interaction.

## 3. Results

### 3.1. Physico-chemical meat quality traits

Beef from the young bulls intensively fattened under label conditions (LB) was lightest in colour (significantly different from PF, CH, and CB in a direct comparison, *t*-test $P < 0.05$), followed by pasture beef from sucklers (PS, Table 1). Conventionally fattened heifers (CH) provided the numerically darkest beef (significantly different from LB, *t*-test $P < 0.01$ and borderline significant from PS, *t*-test $P = 0.06$). Pasture beef from steers or heifers (PF) presented the most intensive red colour (versus CB and PS $P < 0.05$, *t*-test), while PS was least intensively red (*t*-test versus PF and LB $P < 0.05$, versus CH $P = 0.08$), followed by conventionally fattened young bulls (CB). No significant differences between origins were recorded for yellowness ($b^*$ value) in the multiple comparison of means.

Three samples from different origin groups showed a pH $\geqslant$ 5.8, indicating a tendency to dark-firm-dry meat. The ultimate pH of all other beef samples ranged around 5.5 and did not differ significantly between groups. Cooking loss accounted for 30% on average and was not influenced

Table 1
Physico-chemical traits of retail beef from different categories and production systems (LS-means)

| | Origin | | | | | Season | | SEM | *P* level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pasture-derived label beef | | Other label beef | Conventional beef | | Autumn | Spring | | Origin (O) | Season (S) | O × S |
| Category | Suckler beef | Steers/heifers | Young bulls | Heifers | Young bulls | | | | | | |
| Acronym | PS | PF | LB | CH | CB | | | | | | |
| *n* | 10 | 19 | 20 | 9 | 9 | 34 | 33 | | | | |
| *Colour* | | | | | | | | | | | |
| $L^*$ (lightness) | 39.8ab | 38.8ab | 41.0b | 37.5a | 38.7ab | 39.0 | 38.9 | 0.88 | 0.012 | 0.90 | 0.38 |
| $a^*$ (redness) | 20.3b | 23.6a | 22.6ab | 22.2ab | 21.4ab | 22.0 | 21.5 | 0.78 | 0.009 | 0.78 | 0.74 |
| $b^*$ (yellowness) | 10.7 | 11.8 | 11.7 | 10.8 | 10.8 | 11.3 | 10.7 | 0.35 | 0.011 | 0.16 | 0.92 |
| $pH_{ultimate}$ | 5.55 | 5.52 | 5.53 | 5.54 | 5.50 | 5.53 | 5.55 | 0.026 | 0.71 | 0.72 | 0.85 |
| *Cooking loss (%)* | 30.9 | 30.4 | 31.4 | 30.6 | 29.4 | 30.1 | 30.8 | 0.66 | 0.16 | 0.35 | 0.023 |
| *Texture* | | | | | | | | | | | |
| Maximal shear force (Warner–Bratzler) | | | | | | | | | | | |
| Force (N) | 40.3ab | 34.7a | 39.7ab | 51.0b | 52.5b | 42.7 | 45.0 | 4.02 | 0.002 | 0.41 | 0.54 |
| CV (%) | 24.9 | 16.2 | 24.7 | 23.5 | 24.0 | 24.1 | 21.3 | 3.19 | 0.028 | 0.24 | 0.85 |
| Total shear energy (Volodkevich) | | | | | | | | | | | |
| Energy (J) | 1101ab | 1038a | 1222ab | 1571b | 1469b | 1316 | 1262 | 107.8 | 0.001 | 0.51 | 0.54 |
| CV (%) | 23.2 | 17.3 | 23.9 | 16.8 | 20.4 | 20.2 | 20.5 | 3.37 | 0.31 | 0.64 | 0.21 |

a and b, LS-means of beef origins lacking a common letter are significantly different (Scheffé test; $P < 0.05$); CV, coefficients of variation (standard deviation/mean) within each slice; SEM, standard error of the mean.

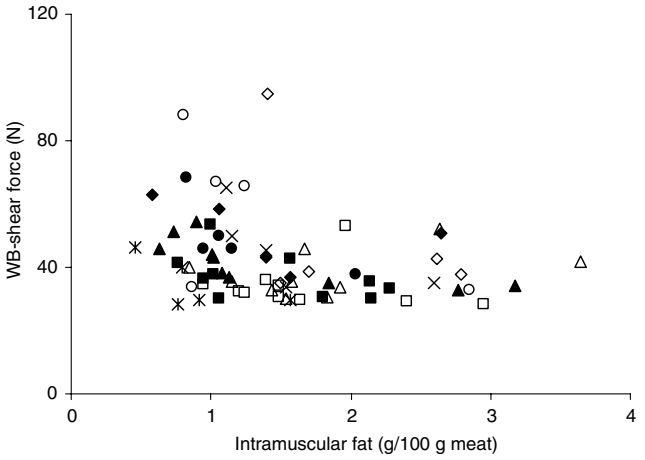


Fig. 1. Intramuscular fat content plotted against the corresponding Warner–Bratzler shear force in beef of different origin grilled to a core temperature of 72 °C. PS, pasture beef from sucklers (×, spring; ✳, autumn); PF, pasture beef from finished steers/heifers (□, spring; ■, autumn); LB, other label beef from intensively fattened young bulls (△, spring; ▲, autumn); CH, conventional beef from heifers (◇, spring; ◆, autumn); CB, conventional beef from young bulls (○, spring, ●, autumn).

by origin. The intramuscular fat content did not differ significantly between the groups, but varied overall from <1% to about 3.5% (Fig. 1).

Both mechanical methods used to measure meat texture traits, the Warner–Bratzler and the Volodkevich device, indicated a superior tenderness for the mature pasture beef, while both conventional origins showed significantly higher shear force and energy values. Furthermore, the variation of texture within the same slice, here given as coefficient of variance (CV), was lowest for PF, being significantly different from PS, LB, and CB in preplaned comparisons (*t*-test). The variation among samples of the same origin was also highest in both conventional origins with standard deviations in WB-shear force of 18.3 and 18.1 N for CH and CB, respectively, while the variation within PF and LB was considerably lower (both 7.2 N) and intermediate for PS (11.7). This indicates a more consistent texture and uniform tenderness in the beef from label origin.

Season had no effects on the physico-chemical traits with the exception of intramuscular fat content, which was higher in spring than in autumn. Interactions of origin and season only occurred with cooking loss but were not systematic concerning pasture beef versus non-pasture beef in that respect and were likely to have been a statistical artefact.

### 3.2. Fatty acid composition

Beef from both grass-based systems was richer in total *n*−3 and lower in total *n*−6 fatty acids than beef from the intensive production systems (Table 2). In detail, pasture beef expressed the highest concentration of all investigated *n*−3 fatty acids, i.e., ALA, EPA and DHA, compared to the

Table 2
Concentration of fat and selected fatty acids as well as fatty acid ratios in retail beef of different categories and production systems (LS-means)

| | Origin | | | | | Season | | SEM | *P* level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pasture-derived label beef | | Other label beef | Conventional beef | | Autumn | Spring | | Origin (O) | Season (S) | O × S |
| Category | Suckler beef | Steers/heifers | Young bulls | Heifers | Young bulls | | | | | | |
| *n* | 10 | 20 | 20 | 10 | 10 | 35 | 35 | | | | |
| *Fat (g/100 g beef)* | 1.22 | 1.57 | 1.61 | 1.73 | 1.31 | 1.28 | 1.68 | 0.221 | 0.37 | 0.029 | 0.89 |
| *Fatty acid content (mg/100 g beef)* | | | | | | | | | | | |
| 18:1*trans* | 25.4 | 42.0 | 47.6 | 53.5 | 37.1 | 32.8 | 49.5 | 7.48 | 0.079 | 0.007 | 0.16 |
| 18:2*c*9*t*11 (CLA) | 6.6 | 6.7 | 5.8 | 5.6 | 4.3 | 5.2 | 6.4 | 1.36 | 0.68 | 0.29 | 0.54 |
| 18:2*n*−6 (LA) | 52.9a | 53.9a | 84.3b | 66.6ab | 81.3ab | 56.5 | 79.1 | 7.32 | <0.001 | <0.001 | 0.09 |
| 18:3*n*−3 (ALA) | 19.7ab | 22.9a | 12.5b | 16.1ab | 12.2ab | 14.6 | 18.7 | 2.86 | 0.004 | 0.08 | 0.62 |
| 20:4*n*−6 (AA) | 22ab | 18a | 26b | 19ab | 25ab | 19.2 | 24.4 | 1.71 | 0.001 | <0.001 | 0.066 |
| 20:5*n*−3 (EPA) | 12.3c | 9.6ac | 4.3b | 7.1ab | 4.2b | 7.3 | 7.6 | 1.11 | <0.001 | 0.69 | 0.64 |
| 22:5*n*−3 (DPA) | 12.6ab | 14.3a | 9.3b | 11.4ab | 8.8b | 10.4 | 12.1 | 1.31 | 0.002 | 0.101 | 0.198 |
| 22:6*n*−3 (DHA) | 1.8a | 1.7a | 1.1b | 1.5ab | 1.1ab | 1.3 | 1.6 | 0.20 | 0.008 | 0.17 | 0.076 |
| SFA | 448 | 581 | 768 | 621 | 549 | 481 | 706 | 93.1 | 0.064 | 0.004 | 0.31 |
| MUFA | 380 | 549 | 716 | 585 | 510 | 442 | 655 | 92.4 | 0.056 | 0.006 | 0.35 |
| PUFA | 147 | 151 | 170 | 149 | 159 | 134 | 177 | 13.5 | 0.54 | <0.001 | 0.17 |
| *n*−3 | 47ab | 49a | 28b | 37ab | 27b | 34 | 41 | 5.2 | <0.001 | 0.12 | 0.50 |
| *n*−6 | 82ab | 80b | 121b | 94 ab | 116b | 84 | 114 | 9.3 | <0.001 | <0.001 | 0.061 |
| *Fatty acid ratios* | | | | | | | | | | | |
| PUFA/SFA | 0.45b | 0.28a | 0.26a | 0.26a | 0.32ab | 0.35 | 0.28 | 0.032 | <0.001 | 0.011 | 0.002 |
| LA/ALA | 2.5a | 2.5a | 9.2b | 8.1ab | 7.7ab | 4.8 | 7.4 | 1.47 | <0.001 | 0.036 | 0.054 |
| *n*−6/*n*−3 | 1.9a | 1.7a | 5.6b | 3.5ab | 5.0b | 3.0 | 4.1 | 0.61 | <0.001 | 0.026 | 0.11 |
| AA/EPA | 2.0a | 2.0a | 8.4b | 3.5a | 7.6b | 3.8 | 5.6 | 0.84 | <0.001 | 0.008 | 0.056 |

a–c, LS-means of beef origins lacking a common letter are significantly different (Scheffé test; $P < 0.05$); AA, arachidonic acid; ALA, α-linolenic acid; CLA, conjugated linoleic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; LA, linoleic acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SEM, standard error of the mean; SFA, saturated fatty acids.

origins from intensive fattening (CB and LB), while CH mostly showed intermediate values (Table 2). A low content of arachidonic acid was observed for PF and CH beef while LB and CB beef showed higher values and PS beef intermediate concentrations. The overriding effect, though, was that on the ratios of AA to EPA, LA to ALA and, generally, *n*−6 to *n*−3. The PUFA/SFA ratio was highest for PS (significant against PF, LB and CH), mainly due to the rather low content of SFA. Contents of *cis*-9, *trans*-11 CLA were not significantly different between origins, although values were numerically higher in pasture beef.

Beef purchased in spring was lower in *n*−3 and higher in *n*−6 fatty acid contents on average which, however, was mainly the result of seasonal differences in conventional beef, while ratios were consistently low in pasture beef and high in LB (Fig. 2), indicating a season × origin interaction. In detail, *n*−6/*n*−3 ratios in autumn and spring for PS, PF, LB, CH and CB, respectively, were: 1.9 and 1.8, 1.8 and 1.5, 5.4 and 5.8, 2.2 and 4.9, and 3.5 and 6.4.

In Tables 3 and 4, presenting the fatty acid profiles of phospholipids and neutral lipids, only those fatty acids are displayed which made up >0.1% of total fatty acid methyl esters. Total *n*−3 and *n*−6 fatty acids and their ratio differed similarly between the origin of beef in both fractions, phospholipids and neutral lipids, although the PUFA concentrations were much lower in neutral lipids than in phospholipids. The elevated *n*−3 proportion in phospholipids and neutral lipids of pasture-derived beef comprised all major *n*−3 fatty acids (ALA, EPA, DPA and DHA), with suckler beef being superior in total *n*−3 LC-PUFA. In phospholipids of pasture beef, the high *n*−3 proportions were compensated by lower proportions of 18:1*cis* and 18:2*n*−6, while this was not obvious for 20:4*n*−6 (arachidonic acid; AA). The proportion of CLA was significantly higher in beef from sucklers than in LB and conventional beef, with pasture beef from mature cattle showing intermediate proportions in both lipid fractions. The proportion of 18:1*trans* was similar across groups, except for the conventionally fattened heifers where proportions were higher. Generally, the proportion of *trans* fatty acids, including CLA, were smaller in phospholipids than in neutral lipids. There were some origin differences in uneven-chain fatty

Table 3
Fatty acid profile of phospholipids in retail beef samples from different categories and production systems (LS-means)

| | Origin | | | | | Season | | SEM | *P* level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pasture-derived label beef | | Other label beef | Conventional beef | | Autumn | Spring | | Origin (O) | Season (S) | O × S |
| Category | Suckler beef | Steers/heifers | Young bulls | Heifers | Young bulls | | | | | | |
| *Fatty acid (g/100 g total fatty acids methyl esters)* | | | | | | | | | | | |
| 10:0 | 0.15 | 0.13 | 0.12 | 0.16 | 0.14 | 0.16 | 0.11 | 0.028 | 0.80 | 0.009 | 0.21 |
| 12:0 | 0.14 | 0.17 | 0.13 | 0.18 | 0.15 | 0.15 | 0.15 | 0.022 | 0.36 | 0.84 | 0.034 |
| 16:0 | 20.5 | 20.2 | 20.0 | 18.6 | 18.8 | 19.4 | 19.8 | 0.43 | 0.003 | 0.32 | 0.24 |
| 17:0 | 0.47ab | 0.65a | 0.38b | 0.63a | 0.38b | 0.49 | 0.51 | 0.051 | <0.001 | 0.63 | 0.006 |
| 18:0 | 8.71a | 8.80a | 9.10ab | 9.32ab | 9.88b | 8.98 | 9.34 | 0.229 | 0.002 | 0.051 | 0.84 |
| 19:0 | 0.11 | 0.09 | 0.11 | 0.12 | 0.09 | 0.30 | 0.10 | 0.008 | 0.026 | 0.27 | 0.033 |
| 16:1 | 1.03 | 1.04 | 1.17 | 1.17 | 0.86 | 1.03 | 0.86 | 0.092 | 0.065 | 0.73 | 0.048 |
| 17:1 | 0.95 | 1.32 | 1.21 | 0.99 | 1.47 | 1.07 | 1.29 | 0.212 | 0.33 | 0.18 | 0.98 |
| 18:1*cis* | 18.4a | 21.2a | 25.5b | 23.5ab | 21.7ab | 22.2 | 21.9 | 1.28 | <0.001 | 0.73 | 0.030 |
| 18:1*trans* | 1.61ab | 1.73ab | 1.60b | 2.25a | 1.43b | 1.61 | 1.84 | 0.151 | 0.003 | 0.059 | 0.18 |
| 18:2*c*9*t*11 (CLA) | 0.30a | 0.21ab | 0.17b | 0.19ab | 0.14b | 0.24 | 0.15 | 0.025 | <0.001 | <0.001 | 0.009 |
| 18:2*n*−6 (LA) | 15.8ab | 14.8a | 18.2ab | 16.7ab | 21.1b | 17.6 | 17.0 | 1.36 | 0.005 | 0.55 | 0.054 |
| 18:3*n*−6 | 0.14 | 0.19 | 0.17 | 0.20 | 0.19 | 0.20 | 0.15 | 0.025 | 0.42 | 0.033 | 0.45 |
| 20:2*n*−6 | 0.15 | 0.16 | 0.14 | 0.15 | 0.15 | 0.17 | 0.15 | 0.014 | 0.77 | 0.89 | 0.29 |
| 20:3*n*−6 | 1.88 | 1.82 | 1.65 | 1.79 | 1.75 | 1.85 | 1.69 | 0.103 | 0.35 | 0.053 | 0.24 |
| 20:4*n*−6 (AA) | 8.58b | 6.85a | 7.69ab | 6.72a | 8.00ab | 7.73 | 7.41 | 0.375 | <0.001 | 0.29 | 0.017 |
| 22:4*n*−6 | 0.28a | 0.36a | 0.84b | 0.52a | 0.82b | 0.50 | 0.62 | 0.062 | <0.001 | 0.021 | 0.057 |
| 22:5*n*−6 | 0.08c | 0.13ac | 0.21b | 0.14abc | 0.18ab | 0.09 | 0.20 | 0.017 | <0.001 | <0.001 | 0.45 |
| 18:3*n*−3 (ALA) | 4.99a | 5.15a | 1.95c | 3.97ab | 2.62bc | 4.06 | 3.40 | 0.418 | <0.001 | 0.054 | 0.32 |
| 20:5*n*−3 (EPA) | 4.99d | 3.82ad | 1.36c | 2.76ab | 1.57bc | 3.09 | 2.69 | 0.334 | <0.001 | 0.14 | 0.49 |
| 22:5*n*−3 (DPA) | 4.33a | 4.86a | 2.53c | 3.90ab | 2.83bc | 3.89 | 3.48 | 0.286 | <0.001 | 0.082 | 0.14 |
| 22:6*n*−3 (DHA) | 0.64a | 0.58a | 0.28c | 0.53ab | 0.35bc | 0.50 | 0.44 | 0.049 | <0.001 | 0.15 | 0.085 |
| SFA | 32.1 | 32.3 | 31.7 | 31.2 | 31.4 | 30.8 | 32.7 | 0.44 | 0.19 | <0.001 | 0.71 |
| MUFA | 24.7b | 27.7ab | 31.9a | 30.3ab | 27.8ab | 28.3 | 28.7 | 1.34 | <0.001 | 0.69 | 0.042 |
| PUFA | 43.1b | 39.9ab | 36.4a | 38.5ab | 40.9ab | 40.9 | 38.6 | 1.38 | 0.002 | 0.040 | 0.022 |
| *n*−3 | 14.9a | 14.4a | 6.1c | 11.1ab | 7.4bc | 11.6 | 10.0 | 0.93 | <0.001 | 0.047 | 0.25 |
| *n*−6 | 26.9ab | 24.3a | 28.9ab | 26.2ab | 32.2b | 28.2 | 27.2 | 1.54 | 0.001 | 0.44 | 0.018 |
| *Fatty acid ratios* | | | | | | | | | | | |
| *n*−6/*n*−3 | 1.9a | 1.7a | 5.6b | 3.3ab | 5.3b | 3.0 | 4.1 | 0.60 | <0.001 | 0.025 | 0.044 |
| AA/EPA | 1.9a | 1.9a | 7.7c | 3.4ab | 6.7bc | 3.6 | 5.0 | 0.76 | <0.001 | 0.025 | 0.028 |

a–d, LS-means of beef origins lacking a common letter are significantly different (Scheffé test; $P < 0.05$); AA, arachidonic acid; ALA, α-linolenic acid; CLA, conjugated linoleic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid; EPA, eicosapentaenoic acid; LA, linoleic acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SEM, standard error of the mean; SFA, saturated fatty acids.

Table 4
Fatty acid profile of neutral lipids in retail beef samples from different categories and production systems (LS-means)

| | Origin | | | | | Season | | SEM | *P* level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pasture-derived label beef | | Other label beef | Conventional beef | | Autumn | Spring | | Origin (O) | Season (S) | O × S |
| Category | Suckler beef | Steers/heifers | Young bulls | Heifers | Young bulls | | | | | | |
| *Fatty acid (g/100 g total fatty acid methyl esters)* | | | | | | | | | | | |
| 10:0 | 0.34b | 0.11a | 0.12a | 0.13a | 0.14a | 0.22 | 0.11 | 0.046 | 0.002 | 0.002 | 0.001 |
| 12:0 | 0.23b | 0.07a | 0.09a | 0.09a | 0.08a | 0.12 | 0.11 | 0.016 | <0.001 | 0.68 | 0.057 |
| 16:0 | 26.2ab | 25.0a | 26.7b | 25.8ab | 25.0a | 25.7 | 25.6 | 0.59 | 0.031 | 0.99 | 0.19 |
| 17:0 | 1.24a | 1.27a | 0.99c | 1.16ab | 1.01bc | 1.15 | 1.10 | 0.055 | <0.001 | 0.18 | 0.30 |
| 18:0 | 13.7c | 16.2a | 17.6b | 17.0ab | 18.4b | 16.5 | 16.6 | 0.71 | <0.001 | 0.91 | 0.93 |
| 19:0 | 0.23 | 0.22 | 0.22 | 0.19 | 0.20 | 0.19 | 0.23 | 0.015 | 0.30 | 0.001 | 0.88 |
| 16:1 | 3.81b | 3.06a | 2.95a | 2.71a | 2.57a | 3.00 | 3.01 | 0.186 | <0.001 | 0.92 | 0.55 |
| 17:1 | 0.73a | 0.71a | 0.51b | 0.58ab | 0.48b | 0.61 | 0.59 | 0.035 | <0.001 | 0.60 | 0.61 |
| 18:1*cis* | 33.4b | 36.8a | 35.2ab | 35.9ab | 36.0ab | 35.4 | 35.3 | 0.85 | 0.032 | 0.86 | 0.82 |
| 18:1*trans* | 3.47 | 3.44 | 3.24 | 4.05 | 3.40 | 3.53 | 3.50 | 0.329 | 0.40 | 0.93 | 0.64 |
| 18:2*c*9*t*11 (CLA) | 0.94c | 0.65a | 0.40b | 0.53ab | 0.41ab | 0.67 | 0.47 | 0.066 | <0.001 | <0.001 | 0.003 |
| 18:2*n*−6 (LA) | 1.66ab | 1.44a | 1.93ab | 1.53ab | 2.24b | 1.69 | 1.86 | 0.158 | 0.001 | 0.34 | 0.23 |
| 18:3*n*−3 (ALA) | 0.90ac | 0.95a | 0.42b | 0.64ab | 0.54bc | 0.73 | 0.85 | 0.089 | <0.001 | 0.28 | 0.098 |
| SFA | 49.3 | 48.1 | 51.0 | 49.6 | 49.5 | 49.6 | 49.3 | 0.65 | 0.056 | 0.72 | 0.57 |
| MUFA | 45.3 | 47.2 | 45.1 | 46.3 | 45.8 | 45.7 | 46.18 | 0.89 | 0.20 | 0.53 | 0.97 |
| PUFA | 5.35a | 4.75a | 3.93b | 4.10bc | 4.73ac | 4.66 | 4.48 | 0.262 | <0.001 | 0.36 | 0.003 |
| *n*−3 | 1.15a | 1.15a | 0.53c | 0.85b | 0.72bc | 0.93 | 0.82 | 0.099 | <0.001 | 0.18 | 0.045 |
| *n*−6 | 2.00ab | 1.73a | 2.11ab | 1.78ab | 2.56b | 1.95 | 2.12 | 0.175 | 0.004 | 0.23 | 0.064 |
| Fatty acid ratios | | | | | | | | | | | |
| *n*−6/*n*−3 | 2.5ac | 1.6a | 4.5b | 3.5bc | 3.9bc | 2.5 | 3.8 | 0.66 | <0.001 | 0.015 | 0.22 |
| AA/EPA | 1.8 | 2.9 | 1.9 | 1.7 | 1.9 | 2.0 | 2.1 | 0.97 | 0.81 | 0.83 | 0.71 |

a–c, LS-means of beef origins lacking a common letter are significantly different (Scheffé test; $P < 0.05$); AA, arachidonic acid; ALA, α-linolenic acid; CLA, conjugated linoleic acid; LA, linoleic acid; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SEM, standard error of the mean; SFA, saturated fatty acids.

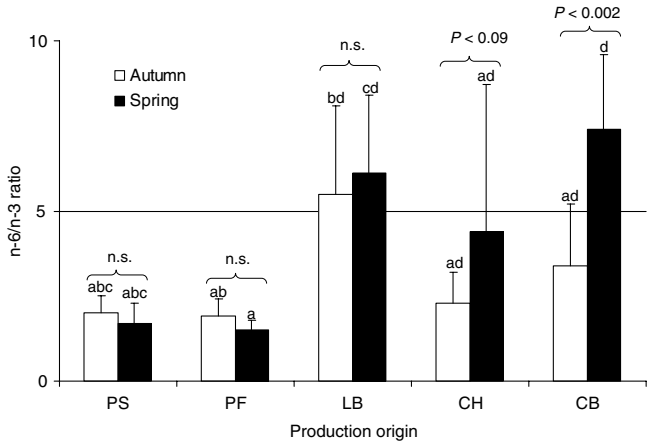


Fig. 2. Seasonal effects on the *n*−6/*n*−3 ratio in the phospholipids of beef of different origin. The horizontal line illustrates the recommended upper level of 5 for *n*−6/*n*−3 in human diets (DACH, 2000). PS, pasture beef from sucklers; PF, pasture beef from finished steers/heifers; LB, label beef from intensively fattened young bulls; CH, conventional beef from heifers; CB, conventional beef from young bulls. Error bars are standard deviations. Bars annotated without a common superscript are significantly different in multiple comparisons (Scheffé test; $P < 0.05$). Comparisons between seasons within the same origins were done with the *t*-test and *P*-values are given (n.s., not significant).

acids (particularly $C_{17}$), indicative of rumen microbial processes, but these were not systematic with respect to pasture beef and non-pasture beef. In the neutral lipids, but not in the phospholipids, there was a clear difference in the proportion of medium-chain fatty acids (10:0, 12:0).

The proportions of several fatty acids were affected by season in both phospholipids and neutral lipids. Noteworthy is the decline in CLA from autumn to spring found in all groups, but particularly in PS and CH, which led to significant interactions (data not shown in table). The increased *n*−6/*n*−3 ratios in spring were exclusively due to changes in the conventional beef, which presented low ratios in autumn and high ratios in spring. Fig. 2 gives an example of the change with season in the *n*−6/*n*−3 ratio in the phospholipids where it is obvious that only CH and CB showed a season effect, resulting in season × origin interactions. In both pasture beef origins and in beef from label bulls the *n*−6/*n*−3 ratio was remarkably constant, although on a different level (Fig. 2).

## 4. Discussion

In the present study, the quality of retail beef from pasture-based systems was compared with beef from intensive fattening systems not prescribing grazing. Differences between the underlying production systems also include fattening intensity, slaughter age, sex and the use of different feeding stuffs apart from grass versus no grass. Extensive beef production, for example, is typically carried out with steers and heifers rather than with young bulls, and at the same time less concentrate is used. It was not the aim of

the present study to evaluate effects of these single factors, which have been subject of extensive research before, but to focus on the effects of entire production systems on meat quality as displayed under the conditions of commercial production and marketing. The main focus was put on whether grass-based, extensive production systems result in a markedly different beef quality and whether this is of relevance for the consumer in terms of appearance, texture and nutritional value or even health benefits.

### 4.1. Visual appearance, pH and cooking loss

Meat colour is one important determinant of the visual appearance of meat (Sapp, Williams, & Mc Cann, 1999), where light beef is often preferred, although some consumers may favour intensively red beef by associating this appearance with a more natural production method. With a growing market share for pink veal, a more intense red colour of 'mature' beef can meanwhile even be desired by retailers allowing a better differentiation of beef from veal. In our study, beef from intensively fattened young bulls was lightest and suckler beef had the least red colour as opposed to pasture beef from finished steers and heifers. This is in accordance with the age of the animals (Aass, 1996). Moreover, when also regarding the rather high $L^*$-values of the probably older LB compared with PS, it shows again the known (Priolo et al., 2001) darker colour of beef from animals finished on pasture and not on concentrate. Muir, Beaker, and Brown (1998) explained this by the higher ultimate pH values found in beef from grass-fed compared to grain-fed steers. They hypothesised that grass-fed steers are more susceptible to pre-slaughter stress and associated pre-slaughter glycogen depletion than grain-fed steers as the latter would be better accustomed to penning and handling. However, in our study no such difference in ultimate pH was obvious, which is in agreement with French et al. (2000). Also water-holding capacity, as determined by cooking loss, was not different between origins, which is in line with the lack of differences in ultimate pH. It has to be mentioned that in the present study ultimate pH was recorded after presumable ageing of the meat and not at a defined time post mortem as is common in most of the published studies. The reported slight increase of pH during ageing (Penney, Bell, & Moorhead, 1998) may explain why values in this study were comparatively high.

Another visual trait potentially affecting purchase decision is the degree of marbling, i.e., the visibility and distribution of intramuscular fat (IMF; AAA, 2005). In the US this is the primary criterion for quality grading of beef carcasses (Dubeski, Aalhus, Jones, Robertson, & Dyck, 1997), while consideration of this criterion is uncommon in Europe. Marbling is often assumed to be linked to beef palatability, but its quantitative importance is seen controversially (Lusk, Fox, Schroeder, Mintert, & Koohmaraie, 1999). Jeremiah, Alhus, Robertson, and Gibson (1996) reported higher panel scores for juiciness and flavour intensity of LD steaks with higher IMF contents, while a consumer study suggested that marbling is obviously not relevant for beef palatability for the majority of consumers (Savell et al., 1987). When compared at similar IMF contents, the eating quality obviously does not differ between beef from grass fed-cattle and grain-fed cattle (French et al., 2000). In the present survey, the IMF content was not significantly different between origins, although suckler beef displayed the numerically lowest contents. The higher IMF content found in spring beef compared to autumn beef might have resulted from a higher feeding intensity in winter. One reason might have been that even in conventional fattening in summer-time grass-products seem to have been used. This can be assumed from the corresponding fatty acid profiles.

### 4.2. Tenderness

The texture of meat is of utmost importance to consumer acceptance (Dransfield, 1998). Pasture beef, as purchased in the present study, turned out be lower in shear force and energy than conventional beef and, when directly comparing the meat processed in the same slaughter plant, even to beef from the non-pasture related label (PF versus LB; $P < 0.05$, $t$-test). The average Warner–Bratzler peak shear forces of pasture beef from mature animals was clearly below the threshold of 40 N, suggested by Branscheid, Honikel, von Lengerken, and Troeger (1998) for tender meat, while it was at this borderline for the pasture beef from sucklers and was clearly exceeded by conventional beef. Results obtained with the Volodkevich device confirmed the differences found with the Warner–Bratzler device. French et al. (2000) found no difference in Warner–Bratzler shear force between beef produced on grass-based and concentrate-based diets. It is, therefore, likely that the differences found in the present study are mainly the result of a different mode of producing the meat, including transport, slaughter, chilling, and aging (Rogov, Kuznetsova, Snezhko, Borisova, & Rozantsev, 2002). Previously (Gerhardy, 1995), tenderness of beef from steers and heifers produced under commercial conditions had been found to be similar to beef from young bulls, although the latter had been clearly younger. Adverse effects of animal age on tenderness are likely to predominantly affect muscles with higher collagen content (Shorthose & Harris, 1990). Nevertheless, the study of Shorthose and Harris (1990) showed that even in the LD tenderness markedly declines between about 10 and 18 month of age. However, under commercial conditions, effects of slaughter, chilling, and aging may be much more decisive (Gerhardy, 1995). This could partly explain why the beef from the young sucklers was not lower in shear force than mature pasture beef and to that from young bulls from label production. On the other hand, the degree of tenderness achieved in the LD of PF was already very high and probably could have been hardly further improved. It has to be mentioned at this point that aging of the striploins for at least 4 weeks was

a declared provision within the quality assurance system of this organic pasture beef label.

Beside the mean level of tenderness, its variation within steak and among individual steaks within origin is relevant for consumer satisfaction and, consequently, loyalty. Within-muscle variation has been described already quite some time ago (Ginger & Weir, 1958). More recently, Kerth, Montgomery, Lansdell, Ramsey, and Miller (2002) reported that the lateral region of LD steaks consistently showed the highest Warner–Bratzler shear forces compared to any other region, while Berry (1993) did not detect such differences in the entire cross-section of the LD. In a previous own study (Scheeder, 1998), a systematic variation of texture within the LD of young bulls also occurred, with the highest shear force values at the ventral location, where the muscle touches the ribs, and the lowest shear force values at the dorso-medial and dorso-lateral locations. At the same time short sarcomere lengths corresponded well with shear force data. This indicates that shortening of the muscle fibers occurring in one zone of the muscle may be compensated by stretching of the fibers elsewhere, when the skeleton–muscle arrangement is intact (Marsh & Leet, 1966). Within-muscle variation of texture therefore provides evidence for partial sarcomere shortening and indicates suboptimal chilling conditions. This was probably the case for beef from the conventionally fattened young bulls. The still rather high within-slice variation found in PS and LB beef may also be a sign of a chilling intensity reaching the borderline to cold-shortening conditions. Since the producers of the PF label were encouraged to deliver animals with fatness scores of at least 3 according to the five-score European carcass grading system, those carcasses might have been less susceptible to improper chilling conditions (Jennings, Berry, & Joseph, 1978) than the younger, slightly lighter and supposedly less fat carcasses of LB, slaughtered under the same conditions.

The variation among samples of the same origin was lowest for PF and LB and only slightly higher for PS, each of these being beef produced under label conditions. This indeed underlines an advantage of an effective label program. On the other hand, it was quite surprising that also in butcher shops tough steaks were sold (Fig. 1), although heifers were used and a supply of high quality products would have been expected from butchers.

In the present study, we did not detect a clear relationship between Warner–Bratzler shear force and intramuscular fat (IMF) content, but it was observed that really high shear force values only occurred in steaks with less than 1.5 g IMF/100 g beef (Fig. 1). Improper chilling conditions could be one underlying cause of the often claimed relationship between tenderness and IMF content. A high IMF content, when associated with a pronounced fat cover of the carcass, therefore, could indicate some protection against cold-shortening (Jennings et al., 1978). However, this does not exclude that lean beef can be tender, provided animals and beef are treated and processed properly.

### *4.3. Relevance for human nutrition of changes in the fatty acid profile of beef*

While the IMF seems less decisive for beef tenderness, its composition is an important determinant of the dietetic value of beef. Animal-derived lipids have often been blamed as health-risk factors although it has become evident now that they provide a couple of physiologically functional and potentially health-beneficial fatty acids. This supports strategies aiming to enhance health-promoting compounds in animal products (MacRae, O'Reilly, & Morgan, 2005).

#### *4.3.1. Omega−3 (n−3) fatty acids*

Increasing public awareness of the health benefits attributable to $n-3$ PUFA has stimulated interest in sources of these fatty acids for human consumption (Bourre, 2005; Calder & Deckelbaum, 2003). In vertebrates, including man, the essential and basic $n-3$ fatty acid (ALA; 18:3$n-3$) can be converted to longer and more unsaturated $n-3$ fatty acid such as EPA and DHA through desaturation, elongation and, in the case of DHA, chain-shortening steps (Sprecher, 2000). The extent of conversion is, however, rather limited (Burdge & Calder, 2005), making farm animals as additional converters of ALA to $n-3$ LC-PUFA and, thus, animal-derived food as a potential source of preformed EPA and DHA even more interesting. In fact, it has been shown that meat contributes to about 20% of the intake of $n-3$ LC-PUFA in an average Australian diet (Meyer et al., 2003), representing a western type of diet. The share of land-animal derived food of total $n-3$ LC-PUFA supply can be further increased when the ALA content in the animal's diets is increased, e.g., by switching to grass-based diets or by supplementing linseed. The experiment of Nürnberg et al. (2002) showed that 100 g beef from grass-fed bulls can supply on average about 40–47 mg $n-3$ LC-PUFA while only 16–19 mg were found in 100 g beef from bulls fattened on concentrates. Similarly, Raes et al. (2003) found in retail beef derived from extensive, grass-based production (Irish beef) about twice as much $n-3$ LC-PUFA (38 mg/100 g beef) than in beef from intensive production systems (18 mg/100 g). In the present study, the $n-3$ LC-PUFA content of pasture beef was also nearly twice that of LB and CB beef (26.7 and 25.7 versus 14.7 and 14.1 mg/100 g), although the absolute level was slightly lower than reported in the above mentioned studies.

There was also a difference in individual $n-3$ PUFA between the two pasture beef types investigated, with suckler beef having higher contents of $n-3$ LC-PUFA. It has been shown that milk from grass-fed cows is not only higher in ALA content but concomitantly also in $n-3$ LC-PUFA (Leiber, Kreuzer, Nigg, Wettstein, & Scheeder, 2005). Therefore, milk in the suckler beef diet may have specifically contributed to the high LC-PUFA concentration in its beef, while ALA was not elevated relative to mature pasture beef. However, since not only $n-3$ LC-PUFA but also arachidonic acid were highest in phospho-

lipids of suckler beef, it may also be speculated that the rate of conversion of 18-PUFA precursors to LC-PUFA does not keep up with tissue growth, leading to a sort of dilution of LC-PUFA with growing age and body mass of the cattle.

Pasture beef showed no major difference in $n-3$ fatty acids between autumn and spring although there are claims that conserved grass is inferior in ALA content to fresh grass (Dewhurst, Moorby, Scollan, Tweed, & Humphreys, 2002). Another interesting finding was that Swiss producers of conventionally and intensively fattened beef obviously do not refrain from using substantial amounts of grass products in summer, thus making such conventional beef in summer an equally valuable source of $n-3$ PUFA.

Regarding recommended dietary allowances, which go up to 650 mg/day (Meyer et al., 2003) and which are probably based on the assumption that paleolithic hunter-gatherer diets contained about 1.1 g/day $n-3$ LC-PUFA (Simopoulos, 1999), an additional intake of about 20 mg $n-3$ LC-PUFA from 100 g of beef seems negligible, particularly regarding the actual disappearance of retail beef, which is clearly below 100 g/day in Western countries (about 82 g per capita and day in the USA and 30 g in Europe-15; calculated from USDA, 2005, Eurostat, 2005). However, the average fat content and, therefore, also the content of $n-3$ LC-PUFA in the actually consumed beef is likely to be higher than in the pure muscle tissue analysed in this study. Furthermore, considering official US and Canadian recommendations (135 mg $n-3$ LC-PUFA/day, i.e., 10% of ALA intake) and the actual human intake of 189 mg $n-3$ LC-PUFA/day as reported by Meyer et al. (2003), e.g., for Australians, it seems reasonable to conclude that increasing $n-3$ contents in beef and other animal-derived food can be relevant to improve human supply with $n-3$ LC-PUFA. This is underlined by the findings that the consumption of animal products, which had been fortified with $n-3$ fatty acids by supplementing extruded linseed in farm animal's diet, markedly increased the $n-3$ fatty acids in the blood of volunteers (Weill et al., 2002). In the same study, the $n-6/n-3$ ratio in the total human diet was found to decrease close to the recommended level of 5:1 (DACH, 2000) simply by increasing the $n-3$ fatty acid content and decreasing the $n-6/n-3$ ratio in the animal products (meat, milk, eggs) consumed. In the present study, beef from grass-based production systems had $n-6/n-3$ ratios considerably below 5:1, while beef from conventional production was sometimes slightly above that threshold. Raes et al. (2003) also reported that $n-6/n-3$ ratios were higher for animals fattened under highly intensive production conditions (5–7), compared with values of 2.5–3 for animals from extensive production systems. Along with the lower $n-6/n-3$ ratio, the ratio of arachidonic acid to EPA was decreased in the present study, which might be particularly favourable regarding the competition of these fatty acids as precursors of antagonistic eicosanoids and, specifically, the pro-inflammatory character of eicosanoids derived from arachidonic acid. Increasing the $n-3$ fatty acid content of animal feed can therefore be a promising and sustainable way to improve the dietetic value of beef without forcing consumers to change their eating habits.

#### 4.3.2. Conjugated linoleic acids

The CLA are also a group of fatty acids that raised interest for being fortified in animal products (Bourre, 2005) because of various potentially beneficial effects and physiological functions (Belury, 2002). However, scientific evidence for beneficial health effects in humans is variable and still unconvincing (Angel, 2004). Among the various CLA isomers, *cis*-9, *trans*-11 18:2 (18:2*c*9*t*11), measured in the present study, is the predominant isomer naturally occurring in ruminant products and is particularly believed to be beneficial for human health (Kramer et al., 1997). The 18:2*c*9*t*11 is mainly a product of endogenous desaturation of *trans*-vaccenic acid (18:1*t*11), which is the predominant 18:1-*trans* isomer in grass-fed cattle (Dannenberger et al., 2004). Accordingly, Chin, Liu, Storkson, Ha, and Pariza (1992) claimed that the best dietary sources of CLA are foods produced by grass-fed ruminants. Dannenberger et al. (2004) found 1.15 and 2.54 mg of 18:2*c*9*t*11/100 g fresh muscle tissue of concentrate- and grass-fed bulls, respectively. In the present study, the mean concentrations of 18:2*c*9*t*11 ranged from 4.4 to 6.7 mg/100 g meat (probably including traces of the *t*7,*c*9 and *t*8,*c*10 isomers) with slightly higher proportions found in the lipid fractions of pasture beef. The absolute content and therefore its contribution to the supply was, however, not significantly higher than in beef of the other origins. The highest proportion of 18:2*c*9*t*11 was found in beef from suckler calves, although they showed only a low proportion and the lowest content of 18:1-*trans* fatty acids. This leads to the assumption that part of the CLA in that group was provided preformed through the milk ingested. The elevated proportions of 10:0 and 12:0 are further indicators of the significant contribution of milk fat to the lipids deposited in the body tissues of the suckler beef.

## 5. Conclusions

For consumers not regularly eating seafood, meat is an important source of long-chain $n-3$ fatty acids. This study demonstrated that pasture-derived beef can be helpful in this respect, although the overall contribution to the supply with $n-3$ LC-PUFA remains limited. Beef from grass-based production systems did not differ in contents of the desired fatty acids at the respective ends of summer and winter feeding, presumably because winter diets in these systems were heavily relying on (conserved) grass, too. In addition, retail beef from pasture-fed animals displayed a rather intensive colour, but was not inferior in texture properties to beef from intensive fattening. One reason for that seems to be the use of steers or heifers, which is common in grass-based beef production systems anyhow, and proper slaughter, chilling and aging techniques. Finally, $n-3$ fatty acid related traits appear to be not sufficiently exclusive for authentication of origin from pasture beef

labels in other fattening systems the use of $n-3$ rich feeds such as grass and/or linseed is also common. For this purpose other markers are available. It is still open how rapid muscle $n-3$ fatty acid stores are depleted once grazing is terminated and maize- or concentrate-based winter or finishing diets are fed.

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