Fatty acid profile and cholesterol content of beef at retail of Piemontese, Limousin and Friesian breeds

A. Brugiapaglia, C. Lussiana, G. Destefanis

Department of Agricultural Sciences, Forestry and Food, University of Torino, Via L. da Vinci 44, 10095 Grugliasco, Torino, Italy

Abstract

Samples of longissimus thoracis muscle of young bulls belonging to Piemontese (n = 10), Limousin (n = 11) and Friesian (n = 10) breeds were analysed in order to study the chemical composition, fatty acids and cholesterol content of beef purchased at retail. The breeds and their differences in intramuscular fat content strongly influenced the fatty acids profile. The Piemontese animals displayed the lowest intramuscular fat and SFA content, while Friesian animals showed the highest intramuscular fat, SFA and MUFA content. In general, Limousin animals had intermediate characteristics. A higher PUFA proportion on total fatty acids was observed in Piemontese breed, but the PUFA absolute content (mg/100 g meat) did not differ among breeds. All the three breeds displayed a high content of n-6 fatty acids family and, consequently, a very unbalanced n-6/n-3 ratio. No differences were found for cholesterol content. Introduction The consumer's interest in the nutritional value of foods which may promote health and prevent diseases is increasing. In this context, fat content and fatty acid (FA) composition are of main concern for the potential adverse effects on health. Beef has a high nutritional value, being an important source of essential amino acids, vitamins (A, B6, B12, D) and minerals, including iron, zinc, selenium (Daley, Abbott, Doyle, Nader, & Larson, 2010). However, beef is often perceived as detrimental to health because it may contain high levels of cholesterol and saturated fatty acids (SFAs), which are known to raise total and low-density lipoprotein (LDL) cholesterol related to cardio-vascular diseases (Scollan et al., 2006). On the other hand, oleic acid has cholesterol-lowering effects and other healthful attributes, including reduced risk of stroke and beneficial effects on blood pressure (Daley et al., 2010). Among n-3 PUFA, the nutritional importance of α-linolenic acid is unclear, since α-linolenic acid is not as bioactive as longer chain of n-3 fatty acids, such as eicosapentaenoic acid (EPA) and docosaesaenoic acid (DHA) (Decker & Park, 2010). The long chain n-3 PUFA, such as EPA (C20:5), DPA (C22:5) and DHA (C22:6) are widely recognized for their beneficial effects on health, i.e. heart attack, depression and cancer and reduction of the inflammation caused by rheumatoid arthritis (Daley et al., 2010;McAfee et al., 2010). CLA is a collective term describing a mixture of conjugated isomers of linoleic acid. Among these isomers, cis9, trans11-CLA (which account for about 80% of total CLA isomers in red meat) and trans10, cis11-CLA are the most studied, due to their biological effects, such as prevention of cancer, atherosclerosis, obesity, diabetes and osteoporosis (Decker & Park, 2010). However, trans10, cis12-C18:2 isomer was also linked to insulin resistance and inflammation in human adipocytes and its anticarcinogenic activity seems dependent on tumor type (Dugan, Aldai, Aalhus, Rolland, & Kramer, 2011; Kelley, Hubbard, & Erickson, 2007). Polyunsaturated n-6 FAs tend to decrease LDL-cholesterol levels, while FAs of n-3 series have limited effects on blood cholesterol, although long chain n-3 PUFAs are effective in reducing blood triacylglycerol levels (Chizzolini, Zanardi, Dorigoni, & Ghidini, 1999). Moreover, a balanced n-6/n-3 ratio in cell membranes is associated with reduced risk of coronary heart disease (Aldai et al., 2006). Fatty acid profile shows a wide variability depending on several factors, such as breed, sex, age and diet (Daley et al., 2010). In particular, the breed effect on the overall fat content has an important impact on relative fatty acid composition of neutral lipid and phospholipid (Wood et al., 2008), with implications for the nutritional quality ofmeat. The Piemontese is the most important Italian autochthonous beef breed and contributes for

37% to the beef production and for about 50% to the gross sealable product in Piedmont (Associazione Nazionale Bovini di Razza Piemontese, 2007). It is characterized by the widely spread double muscled phenotype, associated with light red colour, very low content of intramuscular fat and high tenderness (Destefanis, Brugiapaglia, & Barge, 1993), but the information about fat quality and cholesterol content in the pure breed are relatively scarce. Therefore, the aim of this study was to analyze the fatty acid composition and cholesterol content of beef at retail of Piemontese breed, in comparison with meat of Friesian and Limousin breeds. The Friesian is an early maturing cattle with a more marked tendency in fattening, whose males contribute to beef supply in Italy, while the Limousin breed has a moderate increase of muscling and is widely fattened in Piedmont.

Material and methods

A total of 31 samples of longissimus thoracis muscle from 10 Piemontese, 11 Limousin and 10 Friesian young bulls, purchased at retail from local butcher shops were analyzed. The animal characteristics at slaughter (Table 1) reflect the different maturing degree of the three breeds. The water content was determined using the official method of the AOAC (2000). Then the samples were freeze-dried and analyzed for protein and intramuscular fat content (petroleum ether extraction; Soxhlet method) according to AOAC (2000). Fatty acid composition was analyzed by extraction of total lipids from 0.5 g of freeze-dried sample using chloroform/methanol (2/1; v/v), according to Folch, Lees, and Stanley (1957). Fatty acid methyl esters (FAME) were prepared according to IUPAC (1987) and quantified by gas-chromatography (SHIMADZU - GC 17A), using a HP88 capillary column (100 m × 0.25 mm ID, 0.25 μm film thickness; J&W Scientific). The column temperature was held at 60 °C for 1 min and then raised 20 °C/min to a final temperature of 190 °C, where it remained for 40 min. Temperature of the injector and flame-ionization detector was maintained at 250 °C and 280 °C, respectively; the injection volume was 0.1 μl (splitless mode); nitrogen constant linear flow rate was set at 40 ml/min. Peaks were identified by comparing the retention times with pure FAME standards (Matreya Inc., Pleasant Gap, PA, USA and Restek Corporation, Bellefonte, PA, USA) and, when no commercial standards were available, by using published chromatograms and with values published in the literature (Alfaia et al., 2009; Kramer, Hernandez, Cruz-Hernandez, Kraft, & Dugan, 2008). The fatty acid composition was expressed both as percentage of total fatty acids and as mg/100 g of edible portion, calculated using the total fat conversion factor reported by Greenfield and Southgate (1992). Desaturation index for C16 and C18 was calculated according to Aldai et al. (2006):

Desaturation index (C16)=100x[(C16 : 1cis9)/(C16 : 0 + C16 : 1cis9)];

Desaturation index (C18)=100x [(C18 : 1cis9)/(C18 : 0 + C18 : 1cis9)].

Total cholesterol was determined through KOH saponification of meat sample (about 1 g), homogeneous-phase diethyl ether extraction of the unsaponifiables and derivatization with pyridine and BSTFA (N,O-Bis(trimethylsilyl)trifluoroacetamide) according to Adams, Sullivan, Smith, and Richter (1986). The sample was injected (injection volume 1 μl, split mode) in a gas-chromatograph (SHIMADZU - GC 17A), equipped with a capillary column Rxi-5ms (30 m × 0.32 mm; 0.25 μm), a split/splitless injector and a flame ionisation detector, both kept at a constant temperature of 295 °C. Nitrogen was used as carrier gas (speed: 40 cm/s; column flow: 1.9 ml/min; split ratio 11:1). Furnace temperature was increased from 200 °C to 260 °C at a rate of 5 °C/min; the final temperature was maintained for 20 min. The cholesterol content was expressed as mg/100 g of muscle. The data were analyzed by ANOVA GLM procedure,

considering the breed as fixed effect (SPSS, 1997). The correlation coefficient between fatty acid composition and intramuscular fat content was also calculated.

Results

Breed significantly affected the chemical composition of longissimus thoracis muscle (Table 2). In comparison with F animals, P animals showed a higher value of water and protein ($P < 0.05$), while P and F animals had the lowest and highest values of intramuscular fat, respectively ($P < 0.05$). The fatty acid composition, expressed both as percentage of total fatty acids and as mg/100 g muscle, is presented in Tables 3 and 4, respectively. The major FAs (% of total FAs) were C18:1 cis9 (25–34%), C16:0 (21–24%), C18:0 (17–20%) and C18:2n-6 (7–17%). Breed significantly affected individual fatty acids, MUFA and PUFA, but not SFA proportions. The largest differences between breeds were found for C18:1 cis9 (25% in P group and 34% in F group) and C18:2n- 6 (7% in F group and 17% in P group). Even if the observed differences for SFA were not significant, nevertheless L group had the highest percentage of C15:0 iso ($P < 0.01$) and, compared with F group, P group showed a lower proportion of C16:0 (P b 0.05) and C16:0 iso ($P < 0.01$). Significant differences ($P < 0.05$) were observed for MUFA percentage, with lower values in P and L, mainly consequence of the lower proportion ($P < 0.01$) of palmitoleic (C16:1 cis9) and oleic (C18:1 cis9) acids. The percentage of C18:1 trans6-11 isomers in F and P groups was higher than in L group ($P < 0.01$). Compared with F animals, P animals showed a higher value of PUFAs ($P < 0.05$), n-6 PUFAs series ($P < 0.01$) and n-3 PUFAs series ($P < 0.05$). With regard to individual PUFAs, compared with the other two groups, P group had higher percentage of linoleic acid (C18:2 n-6; $P < 0.05$), α-linolenic acid (C18:3 n-3; $P < 0.05$), γ-linolenic acid (C18:3 n-6; $P < 0.01$) and, compared with F group, of eicosopentaenoic acid (EPA: C20:5n-3; $P < 0.05$). Contrary to FA percentages, the FA concentrations (mg/100g meat) displayed significant differences for SFAs and no differences for PUFAs. P animals had the lower content of SFA ($P < 0.05$),while P and F animals had the lowest and the highest content of MUFA, respectively ($P < 0.05$). In general, compared with L and F animals, P animals showed a lower content of most individual SFAs. No differences were observed between L and F groups, except for C15:0 anteiso and C16:0 (higher values in F group) and for C15:0 iso (higher value in L group). As for SFAs, significant differences among groups were found for all MUFAs. In comparison with F animals, longissimus thoracis muscle of P animals always showed a lower content of individual MUFAs. No differences between P and L groups resulted for some MUFAs, in particular palmitoleic acid (C16:1 cis9) and C18:1 trans6-11 isomers. L group differed from F group only for lower concentrations of C16:1 cis9 ($P < 0.01$), C17:1 cis9, C18:1 trans6-11 isomers ($P < 0.05$) and C18:1 cis12 ($P < 0.01$). For PUFA concentrations, significant differences ($P < 0.05$) were observed only for the higher content of CLA cis9, trans11 in F group in comparison with P and L groups, and for the lower amount of C20:3 n-6 and C22:6 n-3 in P group in comparison with L group. The PUFA/SFA ratio (Table 4)was higher in P than F group (P b 0.05). Nevertheless, F and L groups showed a n-6/n-3 ratio lower than P group ($P < 0.05$). Desaturation indexes of palmitic (C16:0) and stearic (C18:0) acids into the correspondent n-9 MUFA were higher in F group compared with P and L groups ($P < 0.01$). No differences among breeds were found for cholesterol content.

Discussion

The low fat content of P breed (half of the content of the Friesian breed) is noteworthy and this is in agreement with data indicating that double muscling trait decreases intramuscular fat content, while increases water and protein content (Aldai et al., 2006; Barge, Brugiapaglia, Destefanis, & Mazzocco, 1993). In relation to the major fatty acid concentrations (palmitic, stearic, oleic and linoleic acids)

expressed as percentage of total fatty acids, our data confirms those reported by Barge et al. (1993) for longissimus thoracis muscle of Friesian and Piemontese young bulls, except for C18:2n-6 in Piemontese animals, which in this study showed a lower percentage (16.78% vs 27.40%). In particular, in agreement with the results of previous studies (Barge et al., 1993; De Marchi, Berzaghi, Boukha, Mirisola, & Gallo, 2007), it is noteworthy the low percentage of palmitic acid (C16:0) in Piemontese breed, considering that this acid has detrimental implication on health. Especially as a consequence of the lower proportion of palmitoleic and oleic acids, P and L animals showed lower values for MUFAs. Rule, Rule, Short, Grings, and Mac Neil (2001) reported a lower MUFA percentage also in F2 Piemontese crossbred in comparison with crossbred Limousin and Hereford and Raes, De Smet, and Demeyer (2001) observed in Belgian Blue breed a significantly lower oleic acid proportion (mean values of five muscles) in double muscle genotype, compared with crossbred and normal animals. Similarly, Moreno, Keane, Noci, and Moloney (2008) found a lower MUFA percentage in Belgian Blue × Holstein– Friesian steers compared with Holstein–Friesian steers. As MUFAs are mainly located in neutral lipids (Wood et al., 2008), the lower content of MUFAs and oleic acid of the beef breeds (Piemontese and Limousin), observed in our study, can be related with their reduced tendency in fattening. This result is consistent with data of Indurain, Beriain, Goñi, Arana, and Purroy (2006), who reported a positive correlation between MUFAs, oleic acid and intramuscular fat content in Pirenaica yearling bulls. Also our results indicated a significant positive correlation ($P< 0.001$) between MUFAs, oleic acid and intramuscular fat percentage (Table 5). As for the Piemontese breed, our results are substantially comparable for SFA and MUFA content with those of De Marchi et al. (2007), who analysed 148 samples of longissimus thoracis muscle of Piemontese young bulls. On the contrary, the same authors observed a lower PUFA percentage (14.66% vs 21.87%), probably due to higher intramuscular fat content of the analysed samples (1.99% vs 1.10%). According to Wood et al. (2008), breeds or genetic types with low concentration of total lipids in muscle, where phospholipids are a high percentage of the total, have higher proportion of PUFA in total lipids. Therefore, the high PUFA proportion of Piemontese breed (twice as much as Fiesian breed) could be associated with the double muscled genotype and its reduced tendency in fattening. This finding is in agreement with those of De Smet,Webb, Claeys, Uytterhaegen, and Demeyer (2000), who reported that the unsaturated nature of the intramuscular fat of Belgian Blue bulls can be partially explained by the low fat content and the accompanying high ratio of phospholipids to triacylglycerols in the fat fraction. Concerning individual PUFA, higher percentage of linoleic, α-linolenic and eicosapentaenoic acids were observed in Piemontese breed. Similarly, in Belgian Blue breed Raes et al. (2001) found a higher proportion of C18:2n-6 in mh/mh genotype in comparison with +/+ genotype, as a consequence of the low concentration of total lipids in muscle and higher ratio of phospholipids to total lipid. In this respect, Wood et al. (2008) assert that in genetically lean animals the lower C18:1 cis9 and the higher C18:2n-6 content of phospholipids have a major influence on total muscle fatty acid composition. According to Enser, Hallett, Hewitt, Fursey, and Wood (1996), the increase of linoleic acid raises arachidonic acid (C20:4 n-6). On the contrary, in our study the higher amount of C18:2 n-6 in P group corresponds to a lower amount of arachidonic acid (C20:4 n-6), both no significant. Recent studies established that some n-3 PUFA play a crucial role in preventing atherosclerosis, heart attack, depression and cancer, and in reducing the inflammation of rheumatoid arthritis (Daley et al., 2010). High percentage of α-linolenic acid was also observed in hypertophied Belgian Blue (Raes et al., 2001) and in Asturiana de los Valles breeds (Aldai et al., 2006), as well as in crosses with Piemontese (Šubrt et al., 2006). Therefore, the influence of double muscling on n-3 content is further confirmed. Raes et al. (2003) emphasized that beef provides only a small amount of the recommended intake of n-3 series and CLA. However, the contribution of beef to the supply of essential fatty acids, even if small, is important for people in Western countries. While the fatty acid composition

expressed as percentage of total FAs quantified refers to the relative proportions among FA concerning lipid quality, the fatty acid concentration (mg/100 g muscle) regards the actual amount of FA in muscle and is useful for calculating nutritional intake values. According to Aldai et al. (2006), the effect of the breed was more pronounced when individual FA concentrations were compared; in fact, in our study significant differences were observed for 81% of individual FA, in contrast with 45% when FA percentages were considered. Unlike the FA percentages, the FA concentrations displayed significant differences for SFAs and no differences for PUFAs. This indicates that increasing intramuscular fat content the SFA proportion (% of total fatty acids) was unchanged and the PUFA proportion decreased, while the SFA content (mg/100 g muscle) increased and PUFA content did not differ. According to Wood et al. (2008), our results confirm that variation in intramuscular fat content has a fundamental effect on fatty acid composition. While the concentration of phospholipids, rich in PUFA, is nearly constant and relatively independent from the total fat amount, the content of neutral lipids, consisting mainly of triacylglycerols, is associated with a higher intramuscular fat level (Fig. 1). In fact, the SFA and MUFA content had a significant and positive correlation coefficient with intramuscular fat percentage ($r = 0.98$; Table 5). Breeds and their differences on fattening affected all individual SFA and MUFA concentrations. Limousin and Friesian breeds had an amount of SFA, myristic (C14:0), palmitic (C16:0) and stearic (C18:0) acids like 1.6 fold and 2 fold or more, respectively, than P breed. From a nutritional point of view, while stearic acid is thought to be neutral in influencing plasma cholesterol, myristic and palmitic acids are significantly associated with coronary hearth risk, due to their cholesterol raising effect (McAfee et al., 2010; Scollan et al., 2006). Therefore, the high potential for lean beef production of the late maturing cattle, associated with double muscled genotype, like the Piemontese breed, is a positive characteristic of these animals. On the other hand, the oleic acid (C18:1 cis9) content in Friesian breed was 1.5 fold and 2.7 fold higher than L and P breeds. Oleic acid has favourable cholesterol lowering effects and other healthful attributes, including reduced risk of stroke and beneficial effects on blood pressure (Daley et al., 2010). Regarding PUFA concentrations, differences were observed only for the higher content of CLA cis9, trans11 in F group than in P and L groups and for the lower amount of C20:3 n-6 and C22:6 n-3 in P group than in L group. The Δ9-desaturase is the enzyme responsible for the conversion of C18:1 trans11 into CLA cis9, trans11. In agreement with Raes et al. (2001), Siebert et al. (2003), Aldai et al. (2006), differences in fat content and a possible higher activity of Δ9 desaturase in fatter animals, could explain the higher CLA cis9, trans11 content in fatter animals in comparison with leaner animals. Besides our data showed that the CLA cis9, trans11was highly positively correlated with intramuscular fat content (P b 0.001; Table 5). Important evidences of the FA nutritional value are the PUFA/SFA ratio, n-6/n-3 ratio and desaturation indexes of palmitic and stearic acids. The PUFA/SFA ratio of P group was above 0.4,which is considered the minimum value recommended (British Department of Health, 1994). In Belgian Blue and Limousin breeds, Raes et al. (2003) found PUFA/SFA values comparable to those of the present study. Moreover, Aldai et al. (2006), in Asturiana de los Valles breed, observed a relationship between PUFA/SFA ratio and number of mh alleles (or double muscling character). The results confirm that double muscling is associated to a more favourable PUFA/SFA ratio (Scollan et al., 2006). Concerning n-6/n-3 ratio, the values of the three groups are much higher than the recommended value, which should be lower than 4 (British Department of Health, 1994). Even if it was impossible to get information on feeding of the animals, it can be supposed that the model of finishing animals, based on high concentrate diet, such as corn or corn byproducts, led to an imbalance in n-6/n-3 ratio. This situation is even worse in double muscled animals depending on the high level of C18:2n-6 (Raes et al., 2001). It should also be taken into consideration that there is a higher efficiency of incorporation of C18:2n-6 compared with C18:3n-3 and that the grass-based diets or specific feed promote the increased incorporation of n-3 fatty acids into

muscle lipids (Wood et al., 2008). Today, in the Western Europe and United States the n-6/n-3 ratio is very unbalanced, reaching values between 15:1 and 20:1 in food supply and represents a risk factor for cardiovascular diseases, cancer, inflammatory and autoimmune diseases (Simopoulos, 2001). Moreover, an excess of one family of fatty acids can interfere with the metabolism of the other, reducing its incorporation into tissue lipids and altering their overall biological effects (Daley et al., 2010). According to Bartoň et al. (2010), the differences in FA composition may be plausibly explained with different enzymatic activities in FA synthesis and modification. Desaturation indexes of palmitic and stearic acids into the correspondent n-9 MUFA were lower in P and L groups than F group. This result could suggest a more intense Δ9 desaturase activity in Friesian breed. Likewise, Siebert et al. (2003) observed a breed effect on Δ9 desaturase activity, which was higher in Jersey sired cattle than in Limousin sired cattle. Fatty acid desaturase introduces a double bond in a specific position of long-chain fatty acids. Of the three desaturases present in animal tissues (Δ5, Δ6 and Δ9), only Δ9 desaturase acts upon saturated fatty acids to convert them to their respective monounsaturated fatty acids. Some authors suggested that the Δ9 desaturase activity could be affected by genetic factors: for example, the polymorphism of the gene encoding for Δ9 desaturase (stearoyl-CoA desaturase) was shown to significantly affect MUFA content in beef breeds (Bartoň et al., 2010). Moreover, the interaction between breed type, age and diet on Δ9 desaturase activity should be taken into account (Chung, Lunt, Kawachi, Yano, & Smith, 2007). Cholesterol content of meat has become an important issue to consumers. Exogenous cholesterol represents only about ¼ of haematic cholesterol. Several studies indicated that in the adult man the serum cholesterol level is essentially independent from the cholesterol intake (Chizzolini et al., 1999), while Nelson, Schmidt, and Kelley (1995) suggested that the ratio of the various fatty acids in the diet determines changes in the blood cholesterol levels. Moreover, it is now believed that only people with genetic predisposition toward high cholesterol values would benefit from a reduction in dietary cholesterol. In our study, the meat cholesterol content of the three breeds was comparable to the values reported by other authors, independently from breed, age, carcass weight and fat content (De Marchi et al., 2007; Rhee, Dutson, Smith, Hostetler, & Reiser, 1982). Some studies reported that the amount of intramuscular fat is not related to the cholesterol content of meat (Smith, Smith, & Lunt, 2004). In fact, the increase of intramuscular fat (as far as 11.2%) changes the cholesterol distribution, with an increase of the cytoplasmic cholesterol, but also a decrease of the membrane cholesterol, resulting in very small variations of total cholesterol content, so in negligible practical consequences (Chizzolini, Novelli, & Zanardi, 1997). This is especially true for the meats of our study, in which the intramuscular fat content varied from 1.10% in the Piemontese breed to 2.29% in the Friesian breed. 5. Conclusions This study confirms that beef has a different fat composition related to the breed of origin. The double muscled genotype of Piemontese animals, reducing intramuscular fat content, has an essential lowering effect on overall SFA content, and especially myristic and palmitic acids, which are related to cardiovascular diseases. Even if the Friesian breed has a higher content of oleic acid and CLA cis9trans11, with several positive nutritional effects, it also has a double content of SFAs than Piemontese breed. In general, Limousin breed shows intermediate characteristics between Piemontese and Friesian breeds. So, the beef at retail shows high variability for fat content and fatty acid profile and the general message that red meat is unhealthy, being rich in intramuscular fat and SFAs, is misleading for the consumer. Therefore, more detailed information on meat properties might be useful to help consumers in decision making.

Acknowledgment

This study was supported by the Ministry for Education, University and Research (MIUR 60%).

References

Adams, M. L., Sullivan, D.M., Smith, R. L., & Richter, E. F. (1986). Evaluation of direct saponification method for determination of cholesterol in meats. Journal of the Association of Official Analytical Chemistry, 69, 844–846.

Aldai, N.,Murray, B. E., Oliván, M., Martínez, A., Troy, D. J., Osoro, K., & Nájera, A. I. (2006). The influence of breed and mh-genotype on carcass conformation, meat physicochemical characteristics, and the fatty acid profile of muscle from yearling bulls. Meat Science, 72, 486–495.

Alfaia, C. P.M., Alves, S. P., Martins, S. I. V., Costa, A. S. H., Fontes, C. M. G. A., Lemos, J. P. C., Bessa, R. J. B., & Prates, J. A.M. (2009). Effect of the feeding system on intramuscular fatty acids and conjugated linoleic acid isomers of beef cattle, with emphasis on their nutritional value and discriminatory ability. Food Chemistry, 114, 939–946.

AOAC (2000). Official methods of analysis (17th ed.), 2nd Vol., Gaithersburg, MD, USA: Association of the Official Analytical Chemist.

Associazione Nazionale Bovini di Razza Piemontese (2007). Retrieved 12 June 2012 from. http://www.ANABORAPI.it/Pan-Zootc.htm

Barge, M. T., Brugiapaglia, A., Destefanis, G., & Mazzocco, P. (1993). The influence of muscle type, ethnic group, muscular hypertrophy on the composition of beef meat. Proceedings of 39th International Congress of Meat Science and Technology, S5P02.WP. 1-6 August, Calgary, Alberta, Canada.

Bartoň, L., Kott, T., Bureš, D., Řehák, D., Zahrádková, R., & Kottová, B. (2010). The polymorphisms of stearoyl-CoA desaturase (SCD1) and sterol regulatory element binding protein-1 (SREBP-1) genes and their association with the fatty acid profile of muscle and subcutaneous fat in Fleckvieh bulls. Meat Science, 85, 15–20.

British Department of Health (1994). Nutritional aspects of cardiovascular diseases. Report on health and social subjects, no. 46. London: HMSO.

Chizzolini, R., Novelli, E., & Zanardi, E. (1997). Grassi, colesterolo e fenomeni ossidativi: relazione con la salute del consumatore e la qualità dei prodotti carnei. Annali della Facoltà di Medicina Veterinaria, Vol. XVII, Italy: Università degli Studi di Parma.

Chizzolini, R., Zanardi, E., Dorigoni, V., & Ghidini, S. (1999). Calorific value and cholesterol content of normal and low-fat meat and meat product. Trends in Food Science & Technology, 10, 119–128.

Chung, K. Y., Lunt, D. K., Kawachi, H., Yano, H., & Smith, S. B. (2007). Lipogenesis and stearoyl-CoA desaturase gene expression and enzyme activity in adipose tissue of short-and long-fed Angus and Wagyu steers feed corn- or hay based diets. Journal of Animal Science, 85, 380–387.

Daley, C. A., Abbott, A., Doyle, P.S., Nader, G. A., & Larson, S. (2010). A review of fatty acid pro- files and antioxidant content in grass-feed and grain-fed beef. Nutrition Journal, 9, 1–12.

DeMarchi,M., Berzaghi, P., Boukha, A.,Mirisola,M., & Gallo, L. (2007). Use of near infrared spectroscopy for assessment of beef quality traits. Proceedings 17th National Congress ASPA (pp. 421–423).

De Smet, S., Webb, E. C., Claeys, E., Uytterhaegen, L., & Demeyer, D. I. (2000). Effect of dietary energy and protein levels on fatty acid composition of intramuscular fat in double-muscled Belgian Blue bulls. Meat Science, 56, 73–79.

Decker, E. A., & Park, Y. (2010). Healthier meat products as functional foods. Meat Science, 86, 49–55.

Destefanis, G., Brugiapaglia, A., & Barge, M. T. (1993). The influence of breed type on texture and sensory characteristics of beef meat. Proceedings 39th International Congress of Meat Science and Technology, S2P06.WP. 1-6 August 1993, Calgary, Alberta, Canada.

Dugan, M. E. R., Aldai, N., Aalhus, J. L., Rolland, D. C., & Kramer, J. K. G. (2011). Review: Trans-forming beef to provide healthier fatty acid profile. Canadian Journal of Animal Science, 91, 545–556.

Enser,M.,Hallett, K.,Hewitt, B., Fursey,G.A. J., & Wood, J.D. (1996). Fatty acid content and composition of English beef, lamb and pork at retail. Meat Science, 42(4), 443–456.

Folch, J., Lees, M., & Stanley, G. H. S. (1957). A simple method for the isolation and purification of total lipids fromanimal tissues. Journal of Biological Chemistry, 226, 494–509.

Greenfield, H., & Southgate, D. A. T. (1992). Food composition data – Production, management and use. London and New York: Elsevier Applied Science.

Indurain, G., Beriain, M. J., Goñi, M. V., Arana, A., & Purroy, A. (2006). Composition and estimation of intramuscular and subcutaneous fatty acid composition in Spanish young bulls. Meat Science, 73, 326–334.

IUPAC (1987). Standard methods for the analysis of oils, fats and derivates. Oxford, UK: Pergamon Press.

Kelley, N. S., Hubbard, N. E., & Erickson, K. L. (2007). Conjugated linoleic acid isomers and cancer. Journal of Nutrition, 137(12), 2599–2607.

Kramer, J. K. G., Hernandez, M., Cruz-Hernandez, C., Kraft, J., & Dugan, M. E. R. (2008). Combining results of two GC separation partly achieves determination of all cis and trans 16:1, 18:1, 18:2 and 18:3 except CLA isomers of milk fat as demonstrated using Ag-Ion SPE fractionation. Lipids, 43, 259–273.

McAfee, A., McSorley, E.M., Cuskelly, G. J., Moss, B.W., Wallace, J.M.W., Bonham, M. P., & Fearon, A.M. (2010). Red meat consumption: An overview of the risk and benefit. Meat Science, 84, 1–13.

Moreno, T., Keane,M. G., Noci, F., & Moloney, A. P. (2008). Fatty acid composition of M. Longissimus dorsi from Holstein-Friesian steers of New Zealand and European/ American descent and from Belgian Blue x Holstein-Friesian steers, slaughtered at two weights/ages. Meat Science, 78, 157–169.

Nelson, G. J., Schmidt, P. C., & Kelley, D. S. (1995). Low-fat diets do not lower plasma cholesterol levels in healthy men compared to high-fat diets with similar fatty acid composition at constant caloric intake. Lipids, 30, 969–976.

Raes, K., Balcaen, A., Dirinck, P., DeWinne, A., Claeys, E., Demeyer, D., & De Smet, S. (2003). Meat quality, fatty acid composition and flavour analysis in Belgian retail beef. Meat Science, 65, 1237–1246.

Raes, K., De Smet, S., & Demeyer, D. (2001). Effect of double-muscling in Belgian Blue young bulls on the intramuscular fatty acid composition with emphasis on conjugated linoleic acid and polyunsaturated fatty acids. Animal Science, 73, 253–260.

Rhee, K. S.,Dutson, T. R., Smith,G. C.,Hostetler, R. L.,&Reiser, R. (1982). Cholesterol content of raw and cooked beef longissimus muscles with different degrees of marbling. Journal of Food Science, 47, 716–719.

Rule, D. C., Rule, J. M., Short, R. E., Grings, E. E., & Mac Neil, M.D. (2001). Genotype effects on cholesterol and fatty acids in longissimus and semitendinosus muscles from Hereford, Limousin, and Piedmontese F2 crossbred cattle at slaughter. Proceedings, Western Section, American Society of Animal Science, 52 (pp. 266-269), USA: Bozeman, MT.

Scollan, N., Hocquette, J. F., Nuernberg, K., Dannenberger, D., Richardson, I., & Moloney, A. (2006). Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. Meat Science, 74, 17–33.

Siebert, B.D., Pitchford, W. S., Kruk, Z. A., Kuchel, H., Deland, M. P. B., & Bottema, C. D. K. (2003). Differences inΔ9 desaturase activity between Jersey and Limousin sired cattle. Lipids, 38(5), 539–543.

Simopoulos, A. P. (2001). n-3 fatty acids and human health: Defining strategies for public policy. Lipids, 36, S83–S89 (Suppl.).

Smith, S. B., Smith, D. R., & Lunt, D. K. (2004). Adipose tissue. InW. K. Jensen, C. Devine, & M. Dikeman (Eds.), Encyclopedia of meat sciences (pp. 225–238). London, UK: Elsevier Academic Press.

SPSS (1997). SPSS base for windows. Chicago, IL, USA: SPSS Inc.

Šubrt, J., Filipčík, R., Župka, Z., & Fialová, M. (2006). The content of polyunsaturated fatty acids in intramuscular fat of beef cattle in different breed and crossbreeds. Archiv Tierzucht, Dummerstorf, 49(4), 340–350.

Wood, J.D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, R. I., Richardson, R. I., Hughes, S. I., & Whittington, F. M. (2008). Fat deposition, fatty acid composition and meat quality: A review. Meat Science, 78, 343–358.

Table 1 Animal characteristics at slaughter in Piemontese (P), Limousin (L) and Friesian (F) breeds.

	Breed					
	P		L		F	
	Mean	s.d.	Mean	s.d.	Mean	s.d.
Numbers (*n*)	10		11		10	
Age (d)	608	75.32	427	19.09	519	65.45
Live weight (kg)	650	56.15	600	15.26	570	49.80
Carcass weight (kg)	430	37.39	382	15.49	337	40.34

s.d. = standard deviation.

Table 2 Chemical composition (%) of longissimus thoracis muscle in Piemontese (P), Limousin (L) and Friesian (F) breeds.

	Breed			s.e.
	P	L	F	
Numbers (*n*)	10	11	10	
Water	75.38 ^{b}	75.03 ^{ab}	74.60 ^{a}	0.136
Protein	22.45 ^{b}	22.26 ^{ab}	21.80 ^{a}	0.098
Fat	1.10 ^{a}	1.70 ^{b}	2.29 ^{c}	0.109

s.e. = standard error of mean.
a, b, c means in the same row with different superscript letters differ significantly ($P < 0.05$).

Table 3 Fatty acid proportion (g/100 g of total fatty acids) of longissimus thoracis muscle in Piemontese (P), Limousin (L) and Friesian (F) breeds.

	Breed			s.e.
	P	L	F	
Numbers (*n*)	10	11	10	
C10:0	0.212	0.325	0.228	0.032
C12:0	0.220	0.313	0.215	0.032
C14:0	2.05	2.11	2.08	0.097
C15:0	1.10	1.07	1.22	0.085
C15:0 *iso*	0.674 ^{A}	1.64 ^{B}	0.537 ^{A}	0.119
C15:0 *anteiso*	0.387	0.361	0.358	0.011
C16:0	20.83 ^{a}	21.96 ^{ab}	24.08 ^{b}	0.517
C16:0 *iso*	0.109 ^{A}	0.13 ^{AB}	0.144 ^{B}	0.005
C17:0	1.49	1.44	1.27	0.046
C18:0	18.84	19.79	17.02	0.597
C20:0	0.120	0.114	0.095	0.005
C21:0	0.029	0.029	0.017	0.005
C14:1 *cis*9	0.217 ^{a}	0.311 ^{b}	0.282 ^{ab}	0.019
C16:1 *cis*7	0.691	0.765	0.705	0.031
C16:1 *cis*9	1.42 ^{A}	1.63 ^{A}	2.60 ^{B}	0.109
C17:1 *cis*9	0.379 ^{a}	0.423 ^{a}	0.544 ^{b}	0.022
C18:1 *trans*6-11	2.13 ^{B}	1.32 ^{A}	1.78 ^{AB}	0.113
C18:1 *cis*9	25.29 ^{A}	29.31 ^{A}	34.04 ^{B}	0.928
C18:1 *cis*11	1.35	1.26	1.29	0.048
C18:1 *cis*12	0.211 ^{ab}	0.194 ^{a}	0.275 ^{b}	0.016
C18:1 *cis*13	0.307 ^{a}	0.375 ^{b}	0.476 ^{c}	0.013
C20:1 *cis*11	0.090	0.102	0.095	0.005
C18:2n-6	16.78 ^{b}	10.97 ^{a}	7.36 ^{a}	1.036
C18:3n-3	0.557 ^{b}	0.381 ^{a}	0.329 ^{a}	0.027
C18:3n-6	0.073 ^{B}	0.044 ^{A}	0.048 ^{A}	0.003
CLA *cis*9, *trans*11	0.272	0.219	0.277	0.015
C20:2n-6	0.089	0.081	0.063	0.008
C20:3n-6	0.543	0.534	0.382	0.049
C20:4n-6	3.10	2.44	1.96	0.266
C20:5n-3	0.132 ^{b}	0.100 ^{ab}	0.080 ^{a}	0.010
C22:6n-3	0.316	0.319	0.202	0.037
Σ SFA^{s}	46.05	49.25	47.25	0.836
Σ MUFA^{t}	32.08 ^{a}	35.68 ^{a}	42.08 ^{b}	1.032
Σ PUFA^{u}	21.87 ^{b}	15.08 ^{ab}	10.69 ^{a}	1.402
Σ n-6 PUFA^{v}	20.59 ^{B}	14.06 ^{AB}	9.81 ^{A}	1.349
Σ n-3 PUFA^{z}	1.01 ^{b}	0.800 ^{ab}	0.595 ^{a}	0.067

s.e. = standard error of mean.
a, b, c means in the same row with different superscript letters differ significantly ($P < 0.05$).
A, B means in the same row with different superscript letters differ significantly ($P < 0.01$).
s Sum of saturated fatty acids.
t Sum of monounsaturated fatty acids.
u Sum of polyunsaturated fatty acids.
v Sum of n-6 polyunsaturated fatty acids.
z Sum of n-3 polyunsaturated fatty acids.

Table 4 Fatty acid concentration (mg/100 g meat) and cholesterol content (mg/100 g meat) of longissimus thoracis muscle in Piemontese (P), Limousin (L) and Friesian (F) breeds.

	Breed			s.e.
	P	L	F	
Numbers (*n*)	10	11	10	
C10:0	1.79 ^{A}	4.52 ^{B}	4.17 ^{B}	0.324
C12:0	1.86 ^{A}	4.11 ^{B}	4.18 ^{B}	0.294
C14:0	21.81 ^{A}	34.38 ^{AB}	45.19 ^{B}	3.135
C15:0	11.57 ^{a}	18.11 ^{ab}	26.23 ^{b}	1.670
C15:0 *iso*	5.74 ^{A}	22.40 ^{B}	10.88 ^{A}	1.251
C15:0 *anteiso*	3.85 ^{a}	5.47 ^{b}	7.27 ^{c}	0.312
C16:0	218.70 ^{a}	347.40 ^{a}	517.60 ^{b}	27.827
C16:0 *iso*	1.10 ^{a}	1.87 ^{b}	3.04 ^{c}	0.147
C17:0	14.42 ^{a}	21.72 ^{b}	26.35 ^{b}	1.139
C18:0	186.52 ^{a}	304.73 ^{b}	368.65 ^{b}	21.182
C20:0	1.16 ^{A}	1.73 ^{AB}	2.07 ^{B}	0.124
C21:0	0.323 ^{b}	0.083 ^{a}	0.174 ^{ab}	0.045
C14:1 *cis*9	2.15 ^{A}	4.53 ^{B}	6.03 ^{B}	0.331
C16:1 *cis*7	7.12 ^{a}	12.05 ^{b}	14.89 ^{b}	0.837
C16:1 *cis*9	15.98 ^{A}	27.86 ^{A}	52.97 ^{B}	3.033
C17:1 *cis*9	4.088 ^{A}	6.87 ^{A}	11.55 ^{B}	0.667
C18:1 *trans*6-11	22.19 ^{a}	21.23 ^{a}	36.51 ^{b}	2.356
C18:1 *cis*9	265.94 ^{a}	482.65 ^{b}	726.31 ^{c}	41.709
C18:1 *cis*11	13.22 ^{a}	19.59 ^{b}	25.31 ^{b}	1.216
C18:1 *cis*12	1.99 ^{A}	2.88 ^{A}	5.55 ^{B}	0.239
C18:1 *cis*13	3.30 ^{A}	6.10 ^{B}	9.85 ^{C}	0.512
C20:1 *cis*11	0.936 ^{a}	1.69 ^{b}	1.96 ^{b}	0.151
C18:2n-6	153.75	147.24	131.56	6.784
C18:3n-3	5.38	5.51	6.54	0.390
C18:3n-6	0.690	0.733	1.01	0.072
CLA *cis*9, *trans*11	3.10 ^{a}	3.57 ^{a}	5.88 ^{b}	0.432
C20:2n-6	0.832	1.06	1.12	0.059
C20:3n-6	4.84 ^{a}	7.28 ^{b}	6.77 ^{ab}	0.392
C20:4n-6	27.63	31.98	33.88	1.807
C20:5n-3	1.18	1.38	1.17	0.091
C22:6n-3	2.69 ^{a}	4.32 ^{b}	3.65 ^{ab}	0.309
Σ SFA ^{q}	468.86 ^{a}	766.49 ^{b}	1011.82 ^{b}	53.202
Σ MUFA ^{r}	336.91 ^{a}	585.44 ^{b}	890.90 ^{c}	49.685
Σ PUFA ^{s}	200.08	203.07	191.54	9.177
Σ n-6 PUFA ^{t}	187.74	188.29	174.30	8.708
Σ n-3 PUFA ^{u}	9.25	11.21	11.37	0.604
PUFA/SFA	0.490 ^{b}	0.321 ^{ab}	0.239 ^{a}	0.038
n-6/n-3 PUFA	22.90 ^{b}	17.07 ^{a}	15.79 ^{a}	1.172
Desaturation index (C16) ^{v}	6.14 ^{A}	6.78 ^{A}	9.74 ^{B}	0.350
Desaturation index (C18) ^{z}	56.99 ^{A}	59.43 ^{A}	66.66 ^{B}	1.130
Cholesterol	50.986	50.86	50.99	0.990

s.e. = standard error of mean.
a, b, c means in the same row with different superscript letters differ significantly ($P < 0.05$).
A, B means in the same row with different superscript letters differ significantly ($P < 0.01$).

q Sum of saturated fatty acids.
r Sum of monounsaturated fatty acids.
s Sum of polyunsaturated fatty acids.
t Sum of n-6 polyunsaturated fatty acids.
u Sum of n-3 polyunsaturated fatty acids.
v Desaturation index (C16) = 100*[(C16:1 cis9)/(C16:0 + C16:1 cis9)].
z Desaturation index (C18) = 100*[(C18:1 cis9)/(C18:0 + C18:1 cis9)].

Table 5 Correlation between fatty acid (FA) composition and intramuscular fat content of longissimus thoracis muscle.

	FA (% of total fatty acids)		FA (mg/100g meat)	
	r	Significance	*r*	Significance
Σ SFA[u]	0.371	*	0.981	***
Σ MUFA[v]	0.774	***	0.982	***
Σ PUFA[z]	−0.797	***	−0.001	n.s.
C10:0	−0.390	*	0.380	*
C12:0	−0.407	*	0.414	*
C14:0	0.434	*	0.922	***
C15:0	0.352	n.s.	−0.899	***
C15:0 *iso*	−322	n.s.	0.256	ns
C15:0 *anteiso*	−0461	**	0.920	***
C16:0	0.662	***	0.978	***
C16:0 *iso*	0.215	n.s.	0.905	***
C17:0	−498	**	0.922	***
C18:0	−0.051	n.s.	0.910	***
C20:0	−226	n.s.	0.832	***
C21:0	−193	n.s.	0.101	n.s.
C14:1 *cis*9	0.052	n.s.	0.787	***
C16:1 *cis*7	0.145	n.s.	0.921	***
C16:1 *cis*9	0.584	**	0.900	***
C17:1 *cis*9	0.584	**	0.918	***
C18:1 *trans*6-11	−0.068	n.s.	0.819	***
C18:1 *cis*9	0.796	***	0.981	***
C18:1 *cis*11	−0.427	*	0.863	***
C18:1 *cis*12	−0.066	n.s.	0.841	***
C18:1 *cis*13	0.640	***	0.960	***
C20:1 *cis*11	0.240	n.s.	0.846	***
C18:2n-6	−0.805	***	−0.113	n.s.
C18:3n-3	−0.621	***	0.591	***
C18:3n-6	−0.238	n.s.	0.743	***
CLA *cis*9, *trans*11	0.360	*	0.859	***
C20:2n-6	−0.662	***	0.036	n.s.
C20:3n-6	−0.674	***	0.197	n.s.
C20:4n-6	−0.746	***	−0.042	n.s.
C20:5n-3	−0.703	***	−0.008	n.s.
C22:6n-3	−0.558	**	0.178	n.s.

r = Pearson correlation coefficient.
n.s. = not significant correlation; *significant correlation (P < 0.05); **significant correlation (P < 0.01); *** significant correlation (P < 0.001).
u Sum of saturated fatty acids.
v Sum of monounsaturated fatty acids.
z Sum of polyunsaturated fatty acids.

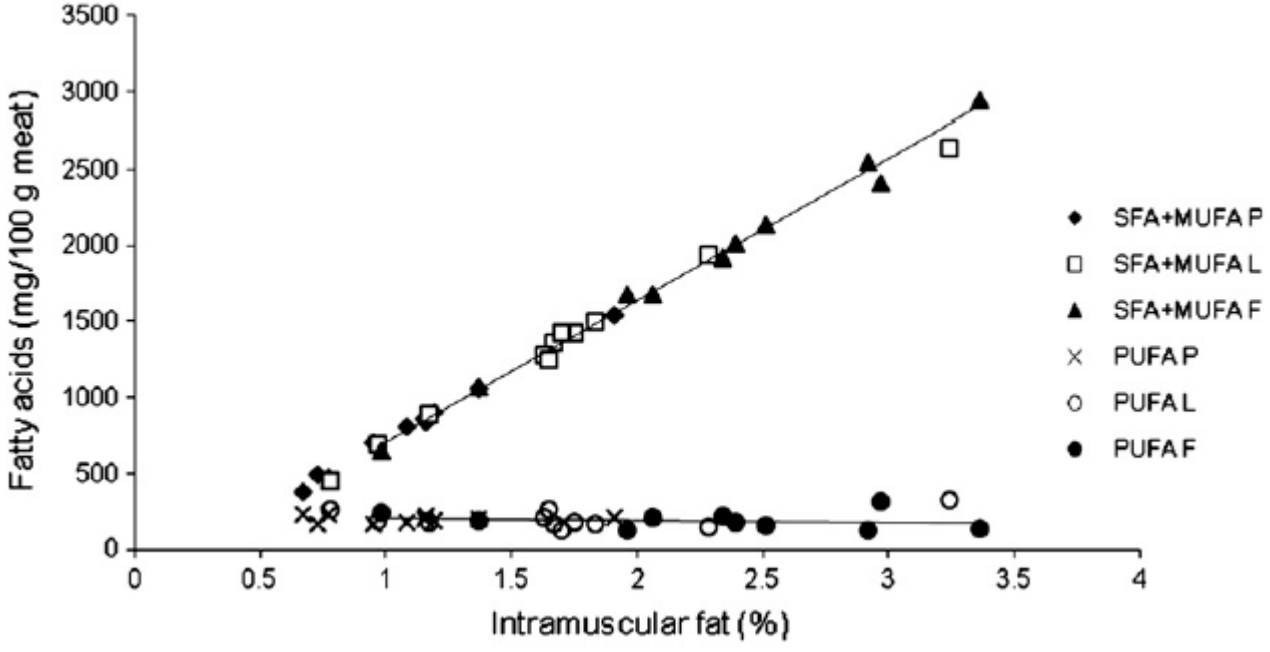

Fig. 1. Relationship between intramuscular fat content and saturated (SFA) + monounsaturated (MUFA) fatty acids and polyunsaturated fatty acids (PUFA) contents of longissimus thoracis muscle of Piemontese (P), Limousin (L) and Friesian (F) breeds. The regression equations were: $y = 929.98x - 223.2$ ($R^2 = 0.9926$) for relationship between intramuscular fat content and SFA + MUFA. $y = -13.721x + 222.91$ ($R^2 = 0.028$) for relationship between intramuscular fat content and PUFA, where: y is the fatty acids content (mg/100 g) and x is the intramuscular fat content (%).