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Domenico Pietro Lo Fiego, Paolo Macchioni, Giovanna Minelli & Piero Santoro

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Lipid composition of covering and intramuscular fat in pigs at different slaughter age

Domenico Pietro Lo Fiego, Paolo Macchioni, Giovanna Minelli, Piero Santoro
1 Dipartimento di Scienze Agrarie e degli Alimenti, Università di Modena e Reggio Emilia, Italy
2 Dipartimento di Protezione e Valorizzazione Agroalimentare, Università di Bologna, Italy

Abstract

To study age-related variations in fatty acid composition of covering and intramuscular fat (IMF), 60 half siblings, Pic X Camborough, of the same age, 30 barrows and 30 gilts, chosen from 10 litters were used. Groups of 20 subjects each, 10 castrated males and 10 females, balanced for litter, were slaughtered at 6, 8.5 and 9.5 months of age, corresponding to the common slaughter age of the three Italian pig production types, at live weights averaging approximately 90, 145 and 160 kg, respectively. Samples of backfat and longissimus thoracis (LT) muscle, taken at the last rib, were analysed. On LT samples, moisture, fat content and drip loss were determined. Fatty acid composition was determined in lipids from subcutaneous adipose tissue and in lipid fractions from LT. Further, backfat lipids were submitted to iodine value (I.V.) determination. The data were evaluated by means of analysis of variance with age at slaughter and sex as the independent variables. As age increased (6, 8.5 and 9.5 months), higher contents of saturated fatty acids (SFA) (36.36, 39.08 and 39.19%, respectively; P<0.01) and monounsaturated fatty acids (MUFA) (41.78, 43.44 and 44.37%, respectively; P<0.01) were observed in backfat, whereas polyunsaturated fatty acids (PUFA) content, PUFA/SFA ratio and I.V. lowered (P<0.01). As total IMF is concerned, by increasing age, MUFA content increased (43.30, 46.76 and 47.28%, respectively; P<0.01), PUFA content decreased (18.63, 15.14 and 14.82%, respectively; P<0.01) and PUFA/SFA decreased as well (P<0.05); neutral lipids followed the same pattern, while an opposite trend was observed in polar lipids. IMF content (1.65%) was modified neither by sex nor age. The study shows that fatty acid composition of subcutaneous and intramuscular fats differs among the 3 slaughtering ages typical of the Italian pig industry. The variations observed, which could be ascribed to the increase of carcass fatness at increasing slaughter age, can affect both the nutritional and technological quality of pork.

Introduction

Factors affecting quality traits of adipose tissue and lipids draw the ever-increasing attention of those involved at different levels in pork production, processing and consumption. In fact, animal fats are usually thought to be rich in saturated fatty acids (SFA) and therefore held responsible for health problems. It is for this reason that consumers may eventually develop an aversion to meat products (Woodward and Weelock, 1990). This attitude stems from the awareness that an excessive intake of SFA may favour coronary diseases associated with elevated cholesterol levels in blood and atherosclerosis (Rose, 1990; Ulbricht and Southgate, 1991; Azain, 2004).

Furthermore, the technological characteristics of lipids must also be taken into account, with main reference to the cuts of the Italian heavy pig, manufactured into cured and aged products. It is well known that processing parameters and the quality of the outcome are affected by fat amount and composition (Santoros, 1983; Santoro and Lo Fiego, 1985; Santoro et al., 1985; Santoro, 1989; Santoro and Lo Fiego, 1992; Lo Fiego et al., 2005b). The above mentioned literature reported as well that nutritional and technological qualities of pork fat composition have sometimes opposite requirements.

Moreover, a number of research studies showed that the accumulation of lipids and fatty acid (FA) composition are affected by environmental factors, mostly associated with different feeding strategies (Wood et al., 1986; Cameron et al., 2000; Lo Fiego et al., 2005a), as well as by genetic factors related to the adipogenic capacity of breeds (Wood, 1973; Cameron et al., 2000; Piedrafita et al., 2001). In addition, other factors, including age and live weight (LW) at slaughter, may influence these parameters (Lebret and Mourot, 1998; Lo Fiego et al., 2005b).

The variation of FA composition in the pig carcass has been analysed mainly in growing animals and up to a LW of approximately 100 kg (Secondi et al., 1994; Bragagnolo and Rodriguez-Amaya, 2002), while other studies investigated the subject at a higher weight range (Franci et al., 1995; Geri et al., 1988; Geri et al., 1990; Virgili et al., 2003).

The Italian pig industry relies on heavy pigs slaughtered aging 9 to 10 months and reaching an average LW of 160-170 kg. They are mostly processed into typical, high quality, dry cured products. Pork for fresh consumption is commonly provided by light pigs, slaughtered at about 6 months, weighing 95-100 kg. Mention must also be made of pigs of intermediate slaughter weight, averaging 140 kg at about 8 months of age. Their meat is destined for both fresh consumption and products like salami, sausages and cooked hams.

The aim of the present study was to investigate the fatty acid composition of lipid fractions in covering and intramuscular fat of pigs, sacrificed at the 3 slaughtering ages typical of the Italian pig industry: 6, 8.5 and 9.5 months.

Materials and methods

Animals and sampling procedure

This study involved initially 100 piglets produced by 13 Camborough sows, which had been fertilised with the semen of the same PIC breeding boar. At an average LW of 45 kg, 60 pigs were selected, three litters were left out and research was geared towards 6 pigs (3 castrated males and 3 females) from each of the...
remaining 10 litters. Three groups of 20 pigs each (10 barrows and 10 gilts) of similar LW and age were housed in three adjoining pens and received the same diet until they reached their target age. A balanced commercial feed based on cereals, cereal by-products and soybean meal (15.5% crude protein and 4.0% ether extract) was given ad libitum up to 80 kg LW. Later, feed allowance was restricted at 9% of the metabolic weight (kg LW$^{0.75}$) starting from 2.4 kg and then increased fortnightly up to a maximum of 3.3 kg per pig per day.

A group of 20 pigs was slaughtered when reaching the age of 6 months and a LW of about 90 kg. The remaining groups were slaughtered at the age of 8.5 and 9.5 months, with a LW of about 145 and 160 kg, respectively. After slaughtering, the carcass was graded using Fat-o-Meater, as described in a previous paper (Lo Fiego et al., 2005b). Samples of subcutaneous adipose tissue from the loin, trimmed from visible fat and connective tissue, weighed and suspended in an inflated bag, ensuring that the bag did not touch the sample. After a storage period of 48 h at 2-4°C, sample was again weighed. Drip loss was expressed as a percentage of the initial weight.

**Statistical analysis**

Statistical analysis was performed by means of variance analysis using the GLM procedure of SAS (SAS Institute, 1996) with age at slaughter and sex as the independent variables. Further, reciprocal correlations between some of the main composition parameters of lipids in different lipid fractions were calculated.

**Table 1. Effect of age and sex on carcass and longissimus thoracis (LT) muscle traits (least squares means and root-mean square error).**

| Age at slaughter (months) | Sex | R-MSE |
|--------------------------|-----|------|
|                          | 6   | 8.5  | 9.5  | Castrated males | Females |
| Number of subjects       | 20  | 20   | 20   | 30              | 30     |
| Live weight (LW), kg     | 90.6$^{a}$ | 145.3$^{b}$ | 159.4$^{b}$ | 135.1 | 128.4$^{b}$ | 12.98 |
| Cold carcass weight, kg  | 70.4$^{a}$ | 115.5$^{b}$ | 129.1$^{b}$ | 107.7 | 102.3$^{b}$ | 10.43 |
| Backfat thickness, mm$^{a}$ | 16.4$^{a}$ | 29.5$^{b}$ | 35.4$^{b}$ | 27.9 | 26.3 | 6.13 |
| Lean meat content, %     | 54.8$^{a}$ | 49.1$^{b}$ | 46.5$^{b}$ | 49.4 | 50.8 | 3.30 |
| LT moisture content, %   | 74.43$^{a}$ | 73.86$^{b}$ | 73.41$^{b}$ | 73.78 | 74.03 | 0.54 |
| LT fat content (IMF), %  | 1.57 | 1.66 | 1.71 | 1.80 | 1.49 | 0.70 |
| LT drip loss, %          | 6.80 | 5.22 | 4.95 | 5.25 | 6.07$^{b}$ | 1.29 |

IMF: intramuscular fat. $^{a,b}$ indicates a significant difference at $P<0.05$. $^{a,b,c}$ indicates a significant difference at $P<0.01$.
eraly in agreement with the findings of Lebret and Mourot (1998), as most differences were only present in subcutaneous fat of the youngest pigs. This group was characterized by less SFA than other groups, with the exception of myristic acid (C14:0) and margaric acid (C17:0).

Stearic acid (C18:0), which has been shown to have no impact on high cholesterol levels in blood (Bonamone and Grundy, 1988), was lower (P<0.01) in the youngest subjects. This fatty acid reached values reported as suitable for processing, as indicated by Girard et al. (1988). Among MUFA, a significant increase in oleic acid (C18:1) and eicosanoic acid (C20:1) was observed. This must be considered as a favourable factor, with special reference to oleic acid (C18:1), which is supposed to play a role in preventing cardiovascular disease (Kris-Etherton, 1999). Except for eicosadinoic acid (C20:2), all PUFA decreased with the increase in slaughter age (P<0.01 in the first age interval). High concentrations of linoleic acid (C18:2) should be avoided, being established a maximum threshold (15%) for processing fresh thigh into typical dry-cured hams (Consortium for Parma Ham, 1992). This value is to be kept under control in order to fulfill the specific needs of the processing industry and favour the aging of the product (Wood, 1984). Females showed a higher degree of unsaturation, due to a greater proportion of PUFA (P<0.01), and a higher PUFA/SFA ratio (P<0.01).

FA composition of total IMF is shown in Table 3. Age did not considerably affect the total content of SFA, except for margaric acid (C17:0) content, which decreased significantly (P<0.01) as age increased. As a whole, a significant rise (P<0.01) in total MUFA content was observed as age increased. The increment was mostly due to an increased content of oleic acid (C18:1) in the first stage, while a significant reduction of linoleic (C18:2), linolenic (C18:3) and eicosadienoic acid (C20:2) contents (P<0.01). As a consequence, PUFA/SFA ratio lowered from 0.49, at 6 months, to 0.40 in the next stages. This decreasing ratio as the age and carcass weight grew was also observed by other authors (De Smet et al., 2004). The gradual drop in linoleic acid (C18:2) content should result in a higher oxidative-stability of lipids (Wood and Enser, 1982) which better suits processing needs. Sex of pigs affected only SFA, with lower values (P<0.05) detected in females due mainly to a lower content (P<0.01) of stearic acid (C18:0).

Females also showed slightly lower concentrations of MUFA, higher concentrations of PUFA and a higher PUFA/SFA ratio. These results, though the differences were not statistically significant, confirmed the findings in subcutaneous adipose tissue.

FA composition of neutral fraction of IMF is reported in Table 4. The overall values of SFA did not significantly change in relation to slaughter age. The only difference (P<0.01) concerned margaric acid (C17:0) content, which was lower in heavier pigs. Females

| Table 2. Effect of age and sex on fatty acid composition (%) of subcutaneous adipose tissue (least squares means and root-mean square error). |
| Age at slaughter (months) | Sex | R-MSE |
|-------------------------|------|-------|
|                        | 6    | 8.5   | 9.5  | Castrated males | Females |
| Number of subjects     | 20   | 20    | 20   | 30              | 30      |
| C14:0                  | 1.28 | 1.18  | 1.25 | 1.23            | 1.24    |
| C16:0                  | 22.41| 23.34 | 23.56| 23.55           | 22.65** |
| C17:0                  | 0.23 | 0.28  | 0.24 | 0.28            | 0.28    |
| C18:0                  | 11.98| 13.29 | 13.76| 13.44           | 13.00   |
| C20:0                  | 0.21 | 0.24  | 0.25 | 0.24            | 0.23    |
| Saturated (SFA)        | 36.36| 39.08 | 39.19| 38.88           | 37.54** |
| C16:1                  | 2.50 | 2.11  | 2.06 | 2.24            | 2.21    |
| C17:1                  | 0.26 | 0.23  | 0.20 | 0.23            | 0.23    |
| C18:1                  | 38.18| 40.20 | 41.14| 40.19           | 39.48** |
| C20:1                  | 0.83 | 0.91  | 0.97 | 0.93            | 0.88    |
| Monounsaturated (MUFA) | 41.78| 43.44 | 43.37| 43.59           | 42.81** |
| C18:2                  | 19.26| 15.62 | 14.64| 15.54           | 17.47** |
| C18:3                  | 1.45 | 0.87  | 0.78 | 0.98            | 1.08**  |
| C20:2                  | 0.70 | 0.66  | 0.69 | 0.66            | 0.71*   |
| C20:3                  | 0.29 | 0.28  | 0.20 | 0.20            | 0.23*   |
| C20:4                  | 0.18 | 0.13  | 0.14 | 0.14            | 0.15**  |
| Polysaturated (PUFA)   | 21.85| 17.47 | 16.43| 17.51           | 19.65** |
| PUFA/SFA ratio         | 0.61 | 0.45  | 0.42 | 0.45            | 0.53**  |
| Iodine value           | 74.67| 69.24 | 67.02| 68.43           | 72.19** |

* a, b: P<0.05; ** a, b, c: P< 0.01; #: other fatty acids detected: C10:0, C12:0.

| Table 3. Effect of age and sex on fatty acid composition (%) of total lipids of longissimus thoracis muscle (least squares means and root-mean square error). |
| Age at slaughter (months) | Sex | R-MSE |
|-------------------------|------|-------|
|                        | 6    | 8.5   | 9.5  | Castrated males | Females |
| Number of subjects     | 20   | 20    | 20   | 30              | 30      |
| C14:0                  | 1.23 | 1.13  | 1.23 | 1.23            | 1.17    |
| C16:0                  | 23.56| 23.69 | 23.67| 23.88           | 23.40   |
| C17:0                  | 0.22 | 0.17  | 0.15 | 0.17            | 0.19    |
| C18:0                  | 12.81| 12.86 | 12.82| 13.01           | 12.51** |
| Saturated (SFA)        | 38.07| 38.10 | 37.91| 38.54           | 37.51** |
| C18:1                  | 3.53 | 3.71  | 3.85 | 3.59            | 3.66   |
| C17:1                  | 0.16 | 0.17  | 0.11 | 0.15            | 0.15    |
| C18:1                  | 39.00| 42.23 | 42.81| 41.69           | 41.00   |
| C20:1                  | 0.62 | 0.64  | 0.71 | 0.63            | 0.69    |
| Monounsaturated (MUFA) | 43.30| 46.76 | 47.28| 46.06           | 45.50   |
| C18:2                  | 14.31| 11.24 | 10.93| 11.66           | 12.67   |
| C18:3                  | 0.66 | 0.33  | 0.30 | 0.40            | 0.47    |
| C20:2                  | 0.49 | 0.30  | 0.17 | 0.28            | 0.30    |
| C20:4                  | 0.43 | 0.39  | 0.38 | 0.39            | 0.41    |
| Polysaturated (PUFA)   | 18.63| 15.14 | 14.82| 15.40           | 16.99   |
| PUFA/SFA ratio         | 0.49 | 0.40  | 0.40 | 0.40            | 0.46    |

* a, b: P<0.05; ** a, b, c: P< 0.01; #: other fatty acids detected: C14:0, C12:0, C14:1.
showed a lower content (P<0.05) of palmitic acid (C16:0) and a reduction in the total SFA concentration. Significant variations could be observed in the proportion of MUFA in the neutral fraction, where oleic (C18:1) and palmitoleic acids (C16:1) considerably rose (P<0.01) with age. Sex did not affect significantly the concentration of any of these MUFA found in the neutral fraction. As age and carcass fatness increased, PUFA noticeably decreased (P<0.01): this may be due to a synthesis de novo of SFA and MUFA and, consequently, to a dilution effect (De Smet et al., 2004). In detail, linoleic (C18:2), linolenic (C18:3) and eicosadienoic (C20:2) acids decreased, whereas eicosatrienoic (C20:3) and arachidonic acid (C20:4) initially rose and then decreased in the oldest pigs. Females showed a higher content of PUFA (P<0.05), especially linoleic acid (P<0.01). In agreement with the findings of Warnants et al. (1996), this result confirms that the lipids of females have a better nutritional quality than those of barrows.

PUFA/SFA ratio of neutral lipids dropped (P<0.01) from 0.29 to 0.18 with increasing age, and was significantly higher in females (P<0.01). Therefore, previous observations are confirmed as a whole.

Table 5 shows fatty acid composition of the polar lipid fraction. SFA decreased from 6 to 8.5 months of age, while main single FA, palmitic (C16:0) and stearic (C18:0) showed a different pattern variation. Sex-related differences were not significant. As a whole, MUFA were lower in the oldest pigs. No main differences were recorded between the first and second age group under investigation. Age did not affect the value of C17:1, while C20:1 was highest at 9.5 months of age. Contents of MUFA were similar between genders. PUFA gradually increased with slaughter age (P<0.01), mainly on account of their major components, namely linoleic (C18:2) and arachidonic (C20:4) acids. Linolenic acid (C18:3) decreased with increasing age (P<0.01), while eicosadienoic (C20:2) and eicosatrienoic (C20:3) decreased at first and then rose. Between 8.5 and 9.5 months, variations were not statistically significant. As a whole, these differences brought about a gradual increase in PUFA/SFA ratio (P<0.01) of the polar fraction with increasing slaughter age. It can also be assumed that polar lipids may vary considerably with age, despite their commonly acknowledged quite stable composition, due to their role in cellular membranes (De Smet et al., 2004).

The concentration of linoleic acid (C18:2) only, which was higher in barrows (P<0.05), varied significantly depending on sex. PUFA content in polar fraction was similar in both male and female pigs, as also observed by Warnants et al. (1996).

Table 6 shows reciprocal correlations between some of the main composition parameters of lipids in different lipid fractions. If fatty acid composition of subcutaneous fat changed, so did the composition of IMF and its neutral fraction. Actually, all parameters observed, except for palmitoleic acid (C16:1), showed a positive reciprocal correlation (P<0.01, C18:0 P≤0.09). In the polar fraction,
on the contrary, only palmitoleic acid (C16:1) showed a significant positive correlation with subcutaneous fat (P<0.05), while other components, namely stearic acid (C18:0), linoleic acid (C18:2), and the total PUFA, showed a negative one (P<0.01). With reference to IMF, its composition proved to be mostly influenced by the composition of the neutral fraction, with the correlations coefficients between these two components ranging from 0.49 to 0.79 (P<0.01). Polar fraction exerted a slight influence on fatty acid composition of total IMF; as correlations coefficients were smaller and statistically less significant (P<0.09).

Correlation coefficients between neutral and polar fractions showed a negative value for PUFA (P<0.05), palmatic acid (P<0.05) and stearic acid (P<0.01).

**Conclusions**

The present study shows that fatty acids composition of subcutaneous and intramuscular fats differs among the 3 slaughtering ages typical of the Italian pig industry. These changes, which could be ascribed to the increase of carcass fatness at increasing slaughter age, can affect both the nutritional and the technological quality of pork. As slaughter age rises, the total content of MUFA increases in subcutaneous adipose tissue, as well as in the IMF and its neutral fraction, while PUFA decrease. Saturated fatty acids content (SFA) varies only in subcutaneous adipose tissue. The most significant changes occur in the first age interval (6 to 8.5 months). Polar lipids of IMF follow an opposite pattern and a considerable increase in PUFA is recorded as age advances. The meat of females shows a significant positive correlation with IMF, and the technological quality of pork. As slaughter age, can affect both the nutritional and the relationship with flavour of pig meat. Meat Sci. 55:187-195.

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