Muscle and genotype effects on fatty acid composition of goat kid intramuscular fat

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Abstract

Little is known about the fatty acid composition of the major muscles in goats from different breeds. Forty entire male suckling kids, 20 Criollo Cordobes and 20 Anglo Nubian, were slaughtered at 75 days of age and the fatty acid composition of their longissimus thoracis (LT) and semitendinosus (ST) muscles was analysed to clarify the effects of genotype and muscle type on goat kid meat. Genotype had a great influence on the fatty acid composition of goat kid meat. Meat from Criollo Cordobes had greater saturated (P<0.001) and lower monounsaturated (P<0.001) and polysaturated fatty acids (P=0.002) concentration than meat from Anglo Nubian, showing higher saturated fatty acids (SFA). On the other hand, intramuscular fat content from both genotypes was higher (P=0.042) in ST muscle, while the lowest cholesterol levels were observed in ST of Criollo Cordobes (P=0.038). That higher fat content resulted in lower relative contents of total polysaturated (P<0.001) and n-3 (P=0.002) fatty acids due to the lower contribution of the membrane phospholipids.

Materials and methods

Animal management and meat sampling

Forty entire male suckling kids, 20 Criollo Cordobes and 20 Anglo Nubian, from two commercial herds (Cordoba, Argentina), were selected for the study. Adults were fed on pastures without concentrate supplements. Kids were reared with their mothers and kept to slaughter weight (Criollo Cordobes: 11.1±0.30 kg, Anglo Nubian: 10.7±0.16 kg). Then, kids were separated from their dams, transported to the abattoir (5 km away) and fasted for 12 h with free access to water. Animals were slaughtered (10 kids per group and 1 group per day) and dressed according to method of Colomer-Rocher et al. (1998). Carcasses were stored at 12°C (±2°C) for 6 h, to avoid cold shortening, and chilled at 2°C (±2°C) until 24 h post-mortem (Peña et al., 2009). After chilling, meat samples were taken from different regions of the left carcass side, i.e. medial region of longissimus thoracis (LT) and semitendinosus (ST) muscles, and separately vacuum packaged and aged for 72 h, frozen and stored at -20°C for up to 1 week. The day before the analysis, the samples were thawed overnight at 4°C (±1°C).

Fatty acid analysis

Total intramuscular fat (IMF) content of LT and ST muscles was determined according to official methods (AOAC, 1992) by using a Tekator analyzer (AB Soxtec 2050, Foss Tekator, Sofia, Bulgaria). IMF for fatty acid and cholesterol determinations was extracted (from 5 g of meat) as described by Folch et al. (1957). Total cholesterol was measured after saponification with 4% KOH in ethanol absolute, using an enzymatic and colorimetric reactive (BioSystem S.A., Barcelona, Spain). Fatty acid methyl esters were prepared according to the method of Pariza et al. (2001). Briefly, 1 mL of n-hexane and 3 mL of 5% in methanolic HCl were added to the samples, vortexed and heated for 90 min in a water bath at 70°C. Then 5 mL of 6% K2CO3 was added, followed by 2 mL of n-hexane. The contents of the tubes were vortexed, followed by centrifugation at 3500 rpm for 10 min. The upper organic phase was transferred to a culture tube and dried under N2. The total lipid mixture obtained was dissolved in 1 mL of n-hexane. Fatty acid methyl esters were measured using...
a chromatograph (Chrompack CP 900, Chrompack Inc., Middleburg, The Netherlands) equipped with a flame ionization detector and fitted with a silica capillary column CP-Sil 88 (100 m, 0.25 mm i.d., 0.2 μm film thickness, Chrompack Inc.), using N2 as carrier gas (2.5 psi). The oven temperature was programmed at 70°C for 4 min, increased from 70 to 170°C at a rate of 13°C.min⁻¹ and then increases from to 170 to 200°C at 1°C.min⁻¹. The injection port and detector temperature were maintained at 250°C. Tricosanoic acid methyl ester (C23:0 ME) at 10 mg.mL⁻¹ was used as an internal standard. Individual fatty acids were identified by comparing their retention times with those of an authenticated standard fatty acid mix Supelco 37 (Sigma Chemical Co. Ltd., Poole, UK). Conjugated linoleic acid (CLA) isomers were purchased from Matreya (>98% purity; Matreya, LLC, Pleasant Gap, USA). Individual fatty acids were corrected by their relative response factor (using the value of the internal standard expressed as a percentage of total fatty acids identified and grouped as follows: saturated (SFA), monounsaturated (MUFA), polysaturated (PUFA), omega-6 (n-6) and omega-3 (n-3). The following ratios were calculated: PUFA/SFA, n-6/n-3 and 18:0+18:1/16:0.

Statistical analysis

The effects of genotype and muscle on fatty acid profiles of intramuscular fat were analysed using the General Linear Model (GLM) procedures of the Statistica package (Statistica, 2001). The statistical model included the effects of genotype, muscle and their interaction, as well as experimental error. When the effects were significant (P<0.05) means were compared by pairwise comparison using the Tukey test.

Results and discussion

The intramuscular fat contents (Table 1) were comparable to earlier reported data (0.96-1.6%) for IMF from longissimus muscle of Canary Caprine Groups kid goats slaughtered at 6 and 10 kg (Marichal et al., 2003), and lower than those observed in other genotypes (Talpur et al., 2008). The results were also lower than those found by Nudda et al. (2008) in suckling kids goats of Sardinian breed slaughtered at 9-10 kg and 6 weeks of age (2.85%-2.9%). The differences with the latest studies may be due to the use of different breeds, feeding practices and weight at slaughter, as breed and diet are two major factors affecting IMF content.

In the present study, no significant effect of genotype on IMF content was observed (P>0.05). In general, the lipid deposition on the goat carcass only occurs when the animal reaches maturity or a body weight of 40 kg (Marichal et al., 2009), which may explain the similarity between both genotypes. In general, meat from dairy breeds has been reported to have higher IMF than meat breeds (Choi et al., 2000), as observed in the present study.

The ST muscle contained higher (P<0.05) levels of IMF than the LT muscle (1.33 vs 1.12). Several authors reported that the type of muscle significantly influenced the intramuscular lipid content (Talpur et al., 2008; Marichal et al., 2003), although the sign of the differences may vary with age (Mahgoub et al., 2002) and genotype (Santos et al., 2007; Velasco et al., 2004; Barton et al., 2008). Rusman et al. (2003) explained the lower fat content in biceps femoris muscle compared to LT due to its higher activity.

The mean for total cholesterol content of the goat kid meat for all animals was 60.9 mg. 100 g⁻¹ muscle, and the cholesterol levels from both genetic groups were within 57.1 and 63.9 mg.100g⁻¹ (Table 1). This range can be considered moderate-low (<90 mg.100g⁻¹; Briggs, 1987). The cholesterol concentrations in goat meat from both genetic groups were similar to those described by Almeida et al. (1997) and Bañón et al. (2006). While both muscles from Anglo Nubian goat kids had similar cholesterol content, the levels in LT were higher than those from ST muscle from Criollo Cordobes goat kids (P=0.038). Lower cholesterol values, from 33.48 to 45.46 mg. 100 g⁻¹, were determined by Madruga et al. (2006) when studying the chemical composition of biceps femoris and semimembranosus muscles from goat meat from different genotypes (½ Boer + ½ SPRD cross-breed, ½ Anglo Nubian + ½ SPRD and only SPRD) and systems (feedlot and field). These authors reported that the system influenced the cholesterol and phospholipids concentrations, and that the genotype × muscle interaction influenced the levels of lipids and cholesterol, which were higher in animals raised under feedlot system. Also, Werdi Pratiwi et al. (2006) reported that the LT muscle from Boer goat had lower cholesterol concentration (55-60 mg.100g⁻¹) compared to the infraspinatus (70-88 mg.100g⁻¹) and biceps femoris (65-83 mg.100g⁻¹) muscles.

The main intramuscular fatty acid indices for ST and LT muscles are presented in Table 1. In agreement with Johnson et al. (1995), the predominance of unsaturated fatty acids was

### Table 1. Effect of genotype and muscle on intramuscular fat (g.100g⁻¹) and cholesterol (mg.100g⁻¹) content, and intramuscular fatty acid indices (% total fatty acids) of goat kid meat.

|                      | Criollo Cordobes | Anglo Nubian |
|----------------------|-----------------|--------------|
|                      | Longissimus     | Semitendinosus| Longissimus | Semitendinosus|
| IMF                  | 1.15±0.08       | 1.31±0.07    | 1.32±0.05   | 1.52±0.09    |
| Cholesterol          | 63.9±0.61      | 57.2±1.53    | 62.2±1.78a  | 61.5±1.10a   |
| SFA                  | 41.1±0.63      | 41.3±0.47    | 38.4±0.49b  | 40.0±0.46b   |
| MUFA                 | 36.1±0.78      | 37.3±0.56    | 39.0±0.75   | 39.5±0.46    |
| PUFA                 | 21.7±0.79      | 20.6±0.52    | 22.3±0.62   | 19.4±0.54    |
| n-6                  | 16.0±0.37      | 15.13±0.44   | 17.9±0.50   | 16.5±0.51    |
| n-3                  | 4.9±0.53       | 4.75±0.31    | 3.68±0.19   | 3.45±0.19    |
| CLA                  | 0.97±0.16      | 1.00±0.09    | 0.81±0.03   | 0.85±0.06    |
| MUFA/SFA             | 0.87±0.02      | 0.91±0.02    | 1.04±0.03   | 0.98±0.02    |
| PUFA/SFA             | 0.53±0.03      | 0.50±0.04    | 0.56±0.02   | 0.51±0.01    |
| IMF/muscle           | 0.32±0.19      | 0.31±0.08    | 0.47±0.15   | 0.48±0.21    |
| IMF/18:0+18:1/16:0   | 2.14±0.07      | 2.29±0.04    | 2.32±0.04   | 2.30±0.04    |

IMF: intramuscular fat; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; CLA, conjugated linoleic acid; a,bdifferent superscript indicate statistical differences (P<0.05).
observed in the present study in both LT and ST muscles. The average fatty acid composition of muscles studied was composed of SFA (40.9%), MUFA (36.7%) and PUFA (22.3%). These results are similar to those reported by Nudda et al. (2008) in suckling kid goats of Sarda breed. However, there are large differences with the results of Mahgoub et al. (2002) and Talpur et al. (2008), among other authors, who reported higher percentages of SFA and lower PUFA in weaned kids slaughtered at higher age than the present study. The meat from Criollo Cordobes kids (meat type), in relation to meat from Anglo Nubian kids (dairy type) contained significantly more SFA and less MUFA. As a result of these differences, the IMF of meat from Anglo Nubian kids contained significantly less hypercholesterolemic acids (OFAs) and had a more desirable UFA/SFA ratio. In contrast, Brzostowski et al. (2000) suggested that the proportion of desirable fatty acids (18:0+MUFA+PUFA) ranged within 69.9% to 72.8%, percentages slightly higher than those recorded by Nudda et al. (2008).

It has been suggested that 16:0 increases blood cholesterol, 18:0 has no effect and 18:1 decreases blood cholesterol content. Banskalieva et al. (2000) suggested that the ratio (18:0 + 18:1)/16:0 could be useful in describing the potential health effects of different types of lipids. Values reported for this index may range from 2.06, for kids slaughtered at 11 kg LW (Todaro et al., 2004), to 3.39, for kids slaughtered at 5 kg LW (Todaro et al., 2002). The value of this ratio (average of 2.27 for all animals) was slightly higher in the present study than the values reported by Santos et al. (2007) and within the range reported by other authors (Talpur et al., 2008; Potchoiba et al., 1990).

It is well known that a higher concentration of long chain SFA raises plasma cholesterol, while MUFA and PUFA concentrations will decrease it (Grundy and Denke, 1990). Thus, PUFA/SFA and n-6/n-3 ratios are accepted as dietetic indicators for meat quality (British Department of Health, 1994). Sanz-Sampelayo et al. (2006) reported values of 0.44 and 2.89 for PUFA/SFA and n-6/n-3, respectively, obtained in intramuscular fat of the leg in suckling kids slaughtered at 9.5 kg LW, lower values than those recorded in the present study (0.55 and 4.00, respectively). Likewise, significant differences in the values were obtained in the relationship between these fatty acids, especially PUFA / SFA (0.53 vs 0.29). Comparable values for CLA to those obtained in the present study (1.27%-1.41%) have been reported by Nudda et al. (2008). The proportions of desirable fatty acids (18:0+MUFA+PUFA) ranged within 69.9% to 72.8%, percentages slightly higher than those recorded by Santos et al. (2007) and within the range reported by other authors (Talpur et al., 2008; Potchoiba et al., 1990).

Table 2. Effect of genotype and muscle type on the individual intramuscular fatty acid composition (% total fatty acids) of goat kid meat.

| Genotype   | Muscle Type | Breed x Muscle | Genotype | Pvalue | Breed x Muscle |
|------------|-------------|----------------|----------|--------|----------------|
| Criollo Cordobes | Longissimus | Semitendinosus | Longissimus | Semitendinosus | Genotype | Pvalue | Breed x Muscle |
| 14.0       | 3.62±0.10a | 3.42±0.21b | 3.91±0.09c | 4.56±0.14d | <0.001 | 0.002 | 0.026 |
| 15.0       | 0.52±0.03a | 0.56±0.02a | 0.41±0.01a | 0.45±0.02a | 0.194 | 0.178 | 0.503 |
| 16.0       | 21.0±0.25a | 21.3±0.33a | 20.7±0.09a | 21.1±0.23a | 0.758 | 0.033 | 0.043 |
| 16.1       | 22.5±0.07a | 1.88±0.05a | 2.41±0.09a | 2.04±0.03a | <0.001 | 0.285 | 0.76 |
| 17.0       | 1.05±0.04a | 1.01±0.02a | 0.79±0.02a | 0.84±0.03a | <0.001 | 0.068 | 0.748 |
| 18.0       | 13.8±0.26a | 14.1±0.40a | 11.8±0.21a | 12.1±0.22a | <0.001 | 0.756 | 0.218 |
| 18.1 n-9   | 32.8±0.41a | 34.6±0.56a | 35.9±0.33a | 36.5±0.42a | <0.001 | 0.038 | 0.546 |
| 18.2 n-6   | 8.60±0.27a | 8.61±0.25a | 9.55±0.09a | 9.03±0.17a | 0.710 | 0.303 | 0.845 |
| 18.3 n-3   | 1.50±0.16a | 1.56±0.09a | 1.18±0.02a | 1.07±0.03a | <0.001 | 0.226 | 0.423 |
| 20.4 n-6   | 5.41±0.22a | 4.84±0.20a | 6.75±0.14a | 5.85±0.03a | 0.007 | 0.038 | 0.669 |
| 20.5 n-3 (EPA) | 1.66±0.11a | 1.47±0.11a | 0.85±0.03a | 0.89±0.04a | <0.001 | 0.054 | 0.206 |
| 22.4 n-6   | 0.85±0.08a | 0.47±0.05a | 0.52±0.02a | 0.55±0.03a | <0.001 | 0.426 | 0.004 |
| 22.5 n-3 (DPA) | 1.97±0.11a | 1.90±0.09a | 1.46±0.03a | 1.22±0.04a | <0.001 | 0.009 | 0.413 |
| 22.6 n-3 (DHA) | 0.83±0.05a | 0.60±0.09a | 1.04±0.02a | 0.08±0.03a | 0.174 | 0.236 | 0.201 |

Different superscript indicate statistical differences (P<0.05).
de France x Pagliarola and Gentile di Puglia x Sopravissana). The lowest content of PUFA in muscles was found in LT (Matsuoka et al., 1997), and the highest in m. biceps femoris of Alpine goats (Park and Washington, 1993). However, there was a difference between Alpine and Nubian breeds in the level of PUFA in m. biceps femoris, as well as in the PUFA content in longissimus dorsi muscle in different experiments with goats.

The main fatty acids identified from the intramuscular fat were 18:1, 16:0 and 18:0 (Table 2). The majority fatty acid in meat from Criollo Cordobes and Anglo Nubian goat kids was 18:1. Nevertheless, the percentage recorded in this study were lower than those obtained by other authors, such as Rhee et al. (2000) from different genotypes. These differences are probably due to the use, in addition to breed, of a different type of feed or slaughter weight, since a change in diet after weaning and the increased slaughter weight changed significantly the fatty acid profiles. Also, Bañón et al. (2004) noted that the type of milk (natural or artificial) in the feeding of suckling kids had a significant effect on the fatty acid content of meat.

Genotype had a significant influence on most SFA, MUFA and PUFA individual fatty acids, in disagreement with Werdi Pratwi et al. (2006). Concentrations of 15:0, 16:0, 18:2n-6 and 22:5n-3 fatty acids did not differ (P>0.05) between genotypes. While the proportions of 17:0 and 18:0 were clearly higher in meat from both Criollo Cordobes muscles (P<0.001), 14:0 values were higher only in LT from Anglo Nubian goat kids (P=0.026). Levels of the main MUFA, 16:1 and 18:1n-9, were also higher (P<0.001) in Anglo Nubian meat. On the other hand, while 18:3n-3, 20:5n-3 and 22:5n-3 concentrations were higher (P<0.001) in meat from Criollo Cordobes, 20:4n-6 and 22:6n-3 values were higher (P<0.001) in Anglo Nubian muscles. The levels of 22:4n-6 were highest (P=0.004) in LT muscle from Criollo Cordobes. Besides the interactive effects with genotype, such as the lower 16:0 content in LT from Anglo Nubian goat kids (P=0.043), muscle type also affected the levels of 18:1n-9 (P=0.038) and 22:5n-3 (P=0.038), resulting higher in ST, and 20:4n-6 (P=0.009), higher in LT muscle. Talpur et al. (2008) in goats have previously reported differences between longissimus and ST muscles in the profile of fatty acids. Also, Barton et al. (2008) noted significant differences significant in fatty acid composition between muscles.

It can be questioned whether this is related to the metabolic fibre type, since it is generally believed that glycolytic muscles contain less fat than oxidative ones. Although metabolic fibre type is related to the differences between muscles for meat quality, it does not seem to explain much of the differences in fatty acid composition between the muscles. In contrast, Manner et al. (1984) and Costa et al. (2008) found no differences in content of the SFA and unsaturated fatty acids between the LT and ST muscles.

Conclusions

As previously reported, genotype had a great influence on lipid profile, total IMF content and fatty acid composition of meat from Criollo Cordobes and Anglo Nubian goat kid goat. On the other hand, muscle type (LT and ST) did not determine the lipid profile of meat from Criollo Cordobes and Anglo Nubian kid goats, leading to small differences, such as high percentage of PUFA in LT muscle, mainly related to the slightly higher IMF content in ST muscle.

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