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PAPER

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 polyunsaturated 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 polyunsaturated (P<0.001) and n-3 (P=0.002) fatty acids due to the lower contribution of the membrane phospholipids.

Introduction

Goat meat has been gaining acceptance over the past few years around the world (Devendra, 1990), especially in developed countries, mainly because of its low-fat content. Increased interest to enhance the nutritional quality of meat has stimulated research on fatty acid composition. The content and composition of intramuscular fat are important for human nutrition and health, as well as for m at quality and palatability (Babiker *et al*., 1990; Schönfeld *et al*., 1993a,b). Regardless of the importance of goat as a source of lean meat, compared to other species, there are few studies about the fatty acid profile of goat meat and the factors affecting its composition (Park and Washington, 1993; Cifuni *et al*., 2000; Wood *et al*. 2004). The effects of slaughter weight (Peña *et al*., 2009) and sex (Bonvillani *et al*., 2010) on meat quality from Criollo Cordobes (meat type) and Anglo Nubian (dairy type) goat breeds have been previously reported. However, in only a few investigations (Potchoiba *et al*., 1990; Park and Washington, 1993; Johnson *et al*., 1995; Matsuoka *et al*., 1997) has the fatty acid composition of lipids in different goat muscles been studied. The fatty acid composition of meat should be obtained from a mixture of the major muscles. However, this practice is expensive for what it is generally obtained from one muscle only, being *longissimus thoracis et lumborum* the most common reference muscle. Other muscles represent different anatomical regions and divergent functionalities (postural and motor muscles), which may affect their fatty acid profile (Costa *et al*., 2008; Jurie *et al*., 2006; Lefaucheur *et al*., 2006; Hocquette, 2006).

Hence, the aim of this study was to study the fatty acid profile of *longissimus* and *semitendinosus* muscles in Criollo Cordobes and Anglo Nubian goat kids raised under extensive management. These muscles represent 2 distinct regions of the carcass; namely, loin and round.

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 suckling until weaning (75 days of age; 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 -20ºC for up to 1 week. The day before the analysis, the samples were thawed overnight at 4°C (±1ºC).

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, Bulgary). 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% K_2CO_3 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 N_2. The total lipid mixture obtained was dissolved in 1 mL of *n*-hexane. Fatty acid methyl esters were measured using

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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 N_2 as carrier gas (2.5 psi). The oven temperature was programmed at 70ºC for 4 min, increased from 70 to 170ºC at a rate of 13ºC.min^{-1} and then increases from to 170 to 200ºC at 1ºC.min^{-1}. The injection port and detector temperature were maintained at 250ºC. 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) and expressed as a percentage of total fatty acids identified and grouped as follows: saturated (SFA), monounsaturated (MUFA), polyunsaturated (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 obtained 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 (Madruga *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 type 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		P value		
	Longissimus	*Semitendinosus*	*Longissimus*	*Semitendinosus*	Genotype	Muscle	Breed x muscle
IMF	1.15±0.08	1.31±0.07	1.33±0.05	1.52±0.09	0.097	0.042	0.354
Cholesterol	63.9±0.61^{a}	57.2±1.53^{b}	62.2±1.78a	61.5±1.10^{ab}	0.102	0.014	0.038
SFA	41.1±0.63^{a}	41.3±0.47^{a}	38.4±0.49b	40.0±0.46^{a}	<0.001	0.095	0.003
MUFA	36.1±0.78	37.39±0.56	39.0±0.75	39.5±0.46	<0.001	0.751	0.596
PUFA	21.7±0.79	20.6±0.52	22.3±0.62	19.4±0.54	0.002	0.005	0.781
n-6	16.0±0.37	15.13±0.44	17.9±0.50	16.6±0.51	0.601	0.067	0.748
n-3	4.91±0.53	4.75±0.31	3.68±0.19	3.45±0.19	<0.001	0.908	0.879
CLA	0.97±0.16	1.00±0.09	0.81±0.03	0.85±0.06	0.003	0.337	0.896
MUFA/SFA	0.87±0.02	0.91±0.02	1.04±0.03	0.98±0.02	<0.001	0.446	0.170
PUFA/SFA	0.53±0.03	0.50±0.04	0.56±0.02	0.51±0.01	0.261	0.696	0.589
n-6/n-3	3.29±0.19	3.19±0.08	4.72±0.15	4.80±0.21	<0.001	0.017	0.112
18:0+18:1/16:0	2.14±0.07	2.29±0.04	2.32±0.04	2.30±0.04	0.591	0.835	0.129

IMF, intramuscular fat; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; CLA, conjugated linoleic acid; ^{a,b}different 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*. (2008) recorded that intramuscular fat of meat from French Alpine x Boer kids (meat type) contained significantly less SFA, and significantly more total PUFA, compared to the IMF of meat from French Alpine kids (dairy type); differences can be attributed to the feeding system (doe's milk *vs* doe's milk + meadow hay + concentrate) and the muscles considered (LT, ST and *cuadriceps femoris*). A significant effect of the genotype of goat kids on the fatty acid profile of IMF was also demonstrated by Beserra *et al*. (2004).

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).

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) in various genotypes and similar to those reported by Belo *et al*. (2009) and Todaro *et al*. (2002) for the Serpentina and Girgentana breeds; while the SFA content was similar in both muscles from Criollo Cordobes goat kids, Anglo Nubian LT had lower SFA content than ST muscle (P=0.003). Both muscles from Anglo Nubian were higher in MUFA than meat from Criollo Cordobes (P<0.001). Intramuscular PUFA content was higher (P=0.002) in LT than in ST muscle, being highest (P=0.005) in meat from Anglo Nubian goat kids. The levels of total CLA (P=0.003) and n-3 (P<0.001) fatty acids were higher in meat from Criollo Cordobes, leading to a higher (P<0.001) n-6/n-3 ratio. On the other hand, the MUFA/SFA ratio was higher (P<0.001) in meat from Anglo Nubian goat kids. The PUFA/SFA ratio was not affected by genotype or muscle type (P>0.05), and was always above the nutritional recommendations for the human diet. As reported in Juárez *et al*. (2009), differences in suckling goat kids' meat fatty acid composition are mainly attributed to differences in the amount and composition maternal milk (Zygoyiannis *et al*., 1992). On the other hand, the higher PUFA and n-3 contents in LT muscle were due to its lower IMF content. It is well known that as IMF content increases, the relative contribution of membrane phospholipids, rich in PUFA, decreases in the total fatty acids content (Wood *et al*., 2008). Thus, Popova (2007) reported higher IMF and triglyceride (66% *vs* 58%, respectively) and lower phospholipid (34% *vs* 42%) in *semimembranosus* than in *longissimus* muscle. In a study performed on oxidative muscle (masseter) and a predominantly glycolytic muscle (*longissimus dorsi*), Muriel *et al*. (2002) found higher SFA and MUFA fatty acid content from *longissimus* muscle as compared to the oxidative muscle. In lambs, Salvatori *et al*. (2004) found significant differences in SFA and PUFA fatty acid content when compared the fatty acid profile of *longissimus dorsi* and *semimembranosus* muscles (43-47% *vs* 41-44% and 11-12% *vs* 14.8%-15.3%, respectively) from crossbred lambs (Ile

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

	Criollo Cordobes		Anglo Nubian		P value		
	Longissimus	*Semitendinosus*	*Longissimus*	*Semitendinosus*	Genotype	Muscle	Breed x muscle
14:0	3.62±0.10^{bc}	3.42±0.21^{c}	3.91±0.09^{b}	4.56±0.14^{a}	<0.001	0.002	0.026
15:0	0.52±0.03	0.56±0.02	0.41±0.01	0.45±0.02	0.194	0.178	0.503
16:0	21.0±0.25^{ab}	21.3±0.33^{a}	20.7±0.09^{b}	21.1±0.23^{a}	0.758	0.033	0.043
16:1	2.25±0.07	1.88±0.05	2.41±0.09	2.04±0.03	<0.001	0.285	0.76
17:0	1.05±0.04	1.01±0.02	0.79±0.02	0.84±0.03	<0.001	0.068	0.748
18:0	13.8±0.26	14.1±0.40	11.8±0.21	12.1±0.22	<0.001	0.756	0.218
18:1 n-9	32.8±0.41	34.6±0.56	35.9±0.33	36.5±0.42	<0.001	0.038	0.546
18:2 n-6	8.60±0.27	8.61±0.25	9.55±0.09	9.03±0.17	0.710	0.303	0.845
18:3 n-3	1.50±0.16	1.56±0.09	1.18±0.02	1.07±0.03	<0.001	0.226	0.423
20:4 n-6	5.41±0.22	4.84±0.20	6.75±0.14	5.85±0.03	0.007	0.038	0.669
20:5 n-3 (EPA)	1.66±0.11	1.47±0.11	0.85±0.03	0.69±0.04	<0.001	0.054	0.206
22:4 n-6	0.85±0.08^{a}	0.47±0.05^{b}	0.52±0.02^{b}	0.55±0.03^{b}	<0.001	0.426	0.004
22:5 n-3 (DPA)	1.97±0.11	1.90±0.09	1.48±0.03	1.22±0.04	<0.001	0.009	0.413
22:6 n-3 (DHA)	0.63±0.05	0.60±0.09	1.04±0.02	0.68±0.03	0.174	0.236	0.201

^{a,b,c}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 majoritary 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 Pratiwi *et al*. (2006). Concentrations of 15:0, 16:0, 18:2n-6 and 22:6n-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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