Fatty acid profile of three adipose depots in seven Spanish breeds of suckling kids

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A B S T R A C T
Intramuscular, subcutaneous and kidney knob fat depot fatty acid profiles were studied in 104 male suckling kids from seven Spanish breeds: Blanca Andaluza, Blanca Celtibérica, Moncaina, Negra Serrana-Castiza, Pirenaica, Malagueña and Murciano-Granadina. Kids were raised in the traditional production system on mother’s milk and slaughtered at around 7 kg live weight. Differences were observed between dairy (Malagueña) and meat breeds (Blanca Andaluza, Blanca Celtibérica, Moncaina, Negra Serrana-Castiza, and Pirenaica). Malagueña showed higher monounsaturated and conjugated linoleic fatty acid levels than the other breeds. Highest percentages of saturated fatty acids were observed in meat breeds. For intramuscular fat depot, the range for desirable fatty acids was 66.16–72.27% was. The influence of breed on fatty acid profiles of intramuscular, subcutaneous and kidney knob fat depots studied was evident. Intramuscular fat depot is proposed as a differentiating factor between dairy and meat breed goat kids, but not between meat breed kids.

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1. Introduction

Goats are an important species due to their contribution to the development of both rural areas and the people who inhabit them (Dubéuf, Morand-Fehr, & Rubino, 2004), and according to DAD-IS (2010) 512 local goat breeds are recognized worldwide, of which 170 are in Europe. The EU accounts for 13.1% of the total annual world production of goat milk and 1.9% of goat meat (FAOSTAT, 2010) and Mediterranean countries such as Greece, Spain, France and Italy are Europe’s main goat producers (Castel et al., 2010). In 2009, Spain was the second largest goat producer in Europe (2.3 million heads; FAOSTAT, 2010), and 22 local breeds are recognized in this country (MARM, 2011). Although most of the goats are dairy breeds (68.05%), goat meat farming is also a significant activity (Castel et al., 2010). Dairy goat breeds are mainly reared intensively with concentrate supplements, whereas meat breeds are frequently reared extensively or semi-extensively. Regardless of whether the breed is for dairy or meat purposes, in these different production systems all kids are fed exclusively on their mothers’ milk to produce suckling goat kids for meat, with a live weight of 10–11 kg because the market prefers carcass weights of 5–7 kg (Marichal, Castro, Capote, Zamorano, & Argüello, 2003).

Goat meat is almost universally considered to be acceptable, but cultural traditions and social and economic conditions influence consumers’ preferences (Casey, Van Nierkerk, & Webb, 2003). Traditionally, goat meat has been considered an expensive product that is consumed on festive occasions. On the other hand, consumers’ purchasing decisions are influenced by their perception of “food healthiness” that, in the case of meat, is largely related to fat content (McAfee et al., 2010). Indeed, the saturated fatty acid content of animal fat is one of the main reasons for rejecting meat (Biesalski, 2005) since it has been widely reported that high consumption of saturated fatty acids is related to cardiovascular diseases (Wood et al., 2004). However, it is important to highlight the beneficial effects of edible animal fats (intramuscular and subcutaneous) on human health. Particularly, the advantageous nutritional value of the meat of small ruminants is related to their n–3 PUFA and to the cis-9, trans-11 CLA (conjugated linoleic acid) isomer content, there being evidence that these fatty acids have the potential to improve long-term human health (Banskalieva, Sahlu, & Goesch, 2000).

It has been widely reported that various factors such as diet (Wood et al., 2004), slaughter weight (Horcada, Beriain, Chasco, Indurain, & Purroy, 2010), fatness degree (Nürnberg, Wegner, & Ender, 1998) and fat depot location (Banskalieva et al., 2000) all have an influence on the fatty acid profile of fat depots. Differences between internal (kidney knob fat) and external (subcutaneous) fat depots have been widely demonstrated. Internal fat depots show higher saturated fatty acid concentrations than external fat depots or intramuscular fat (Horcada, Beriain, Lizaso, Insauti, & Purroy, 2009). Although the extent of breed has been studied (Díaz et al., 2005), it is usually difficult to assess the real contribution of genetics to differences in fatty acid composition because other factors such as diet, degree of fatness or origin and the production system can influence it (Sañudo et al., 2000). However, fatty
acid profile determination has been shown to be an effective method to differentiate breeds and production systems in veal (Dias et al., 2008). Furthermore, Juárez et al. (2010) showed that using the lipid profile information of two fat depots (including intramuscular, or combining an external and an internal fat depot), 100% of lamb carcasses can be correctly assigned according their breed-production system.

There is a reasonable amount of literature showing the effect of breed and production system on the fatty acid profile of different fat depots, such as intramuscular, subcutaneous and kidney knob fat in light lambs (Choi, Enser, Wood, & Scollan, 2000), in calves (Indurain, Beriaín, Goñi, Arana, & Purroy, 2006) and in pigs (Muriel, Ventanas, Petrón, & Antequera, 2004). In general, these studies revealed that fat depots in ruminants show higher saturated and mono-unsaturated fatty acid contents than species, such as pigs (Wood et al., 2008). Little literature is available for kids and especially for light animals. In fact, as far as the authors are aware there are no research describing fatty acid profiles from various fat depots in kids, and certainly not with reference to Spanish breeds. However, information on the lipid profile of fat can contribute to the development of quality marks in relation to different goat breeds. In general, Spanish consumers show great interest in origin-linked products such as the Protected Geographical Indication (PGI), since they associate these products with high-quality, healthy foods. Nevertheless, and although in Spain there are five PGI for sheep and ten for veal, there is no PGI for goat meat (MARM, 2011).

Therefore, the aims of this study were to analyze the natural dissimilarity in the characteristics of intramuscular, subcutaneous and kidney knob fat from various fat depots in kids, and certainly not with reference to Spanish breeds. However, information on the lipid profile of fat can contribute to the development of quality marks in relation to different goat breeds. In general, Spanish consumers show great interest in origin-linked products such as the Protected Geographical Indication (PGI), since they associate these products with high-quality, healthy foods. Nevertheless, and although in Spain there are five PGI for sheep and ten for veal, there is no PGI for goat meat (MARM, 2011).

2. Material and methods

2.1. Animals

A total of 104 single male suckling kids from five Spanish meat goat breeds (BA, Blanca Andaluza; BC, Blanca Celtibérica; MO, Moncaina; NE, Negra Serrana-Castiza and PI, Pirenaica) and 2 dairy breeds (MA, Malagueña; MU, Murciano-Granadina) were used. The number of animals per treatment and their carcass characteristics is shown in Table 1. Kid goats were reared on the farm of origin with dams’ milk until slaughter. All mothers were reared under semi-extensive husbandry conditions, and fed with forage and concentrates. Dairy breed (MA, Malagueña; MU, Murciano-Granadina) was obtained from the right shoulders and a sample of intramuscular (IM) fat was obtained from the Longissimus lumborum muscle of the left carcass half. KK and SC were chosen as reference depots because they are easily obtained and are representative of internal and external carcasses, respectively. Moreover, usually, the nutritional value of the meat refers to edible IM depot. All samples were vacuum-packed and frozen at −18 °C. The carcasses were chilled for 24 h at 4 °C. After chilling, a sample of subcutaneous fat (SC) was obtained from the right shoulders and a sample of intramuscular (IM) fat was obtained from the Longissimus lumborum muscle of the left carcass half using the Ankom Procedure based on high-temperature (50 °C) solvent extraction (AOCS, 2004) with an Ankom extractor (Model XT10, Ankom Technology, Madrid, Spain).

2.2. Slaughter and post-slaughter conditions

Kid goats were chosen at each farm of origin and were slaughtered at the usual commercial weight, which represents the typical production systems of each breed. When the animals reached the target live weight (7.4±0.51 kg) at between 42 and 46 days of age, they were transported in accordance with welfare specifications and slaughtered in a slaughterhouse according to the EU Council Directive 86/609/EEC that establishes guidelines regarding the protection of animals used for experimental and other scientific purposes.

Immediately after slaughter, the degree of carcass fatness was assessed by two trained assessors according the EU photographic standards for carcasses of light lambs (EEC Regulation nº 22, 2008). Each fatness level (1, low; 2, slight; 3, medium; 4, high) was divided into three sublevels in order to discern small differences in the degree of fatness. Therefore, a scale of scores ranging from 1 to 12 points was used. Thereafter, kidney knob fat (KK) was extracted, weighed, vacuum-packed and frozen at −18 °C. The relative fat content was quantified in the L. lumborum muscle of the left carcass half using the Ankom Procedure based on high-temperature (50 °C) solvent extraction (AOCS, 2004) with an Ankom extractor (Model XT10, Ankom Technology, Madrid, Spain).

2.3. Fatty acid analysis

The total fatty acids of IM, SC and KK fat depots were extracted, methylated and analyzed by an adaptation of the method described by Aldai, Osoro, Barron, and Najera (2006). Separation and quantification of the fatty acid methyl esters (FAMEs) were performed using a gas chromatograph (GC, Agilent 6890N, Inc., California, USA) equipped with a flame ionization detector (FID) and fitted with a BPX-70 capillary column (120 m, 0.25 mm i.d., 0.2 µm film thickness, SGE, Australia.). Individual FAMEs were identified using standards, where available (Sigma Chemical Co. Ltd., Poole, UK). The different types of fatty acids were expressed as a percentage of total fatty acids identified and grouped as follows: saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), Σn-3 PUFA, Σn-6 PUFA and total CLA. The Δ-9 desaturase activity index was calculated by the ratio C18:1/(C18:0+C18:1) (Malau-Aduli, Siebert, Bottema, & Pitchford, 1998).

2.4. Statistical analysis

A one-way analysis of variance using the GLM procedure of the Statistical Analysis System package (SPSS 15.0) was carried out to

Table 1

Means and standard deviation for several kid carcass characteristics from seven breeds of Spanish kids.

<table>
<thead>
<tr>
<th></th>
<th>BA</th>
<th>BC</th>
<th>MO</th>
<th>NE</th>
<th>PI</th>
<th>MA</th>
<th>MU</th>
<th>SED</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Live weight (kg)</td>
<td>7.43b</td>
<td>7.65b</td>
<td>7.44b</td>
<td>7.95b</td>
<td>7.73b</td>
<td>7.46b</td>
<td>6.34b</td>
<td>0.208 ***</td>
</tr>
<tr>
<td>Hot carcass weight (kg)</td>
<td>3.92b</td>
<td>4.10b</td>
<td>4.17b</td>
<td>4.17b</td>
<td>4.17b</td>
<td>4.64b</td>
<td>3.63b</td>
<td>0.128 ***</td>
</tr>
<tr>
<td>Carcass fatness (1−12)</td>
<td>2.00ab</td>
<td>2.87b</td>
<td>2.69b</td>
<td>1.47a</td>
<td>2.13b</td>
<td>3.87d</td>
<td>3.13c</td>
<td>0.216 ***</td>
</tr>
<tr>
<td>Kidney knob fat (g)</td>
<td>34.98a</td>
<td>80.85b</td>
<td>86.60b</td>
<td>81.11b</td>
<td>50.66ab</td>
<td>120.83c</td>
<td>69.35b</td>
<td>10.638 ***</td>
</tr>
<tr>
<td>Intramuscular fat (%)</td>
<td>1.15b</td>
<td>1.12a</td>
<td>1.55a</td>
<td>1.46a</td>
<td>2.05d</td>
<td>1.26c</td>
<td>0.62a</td>
<td>0.182 ***</td>
</tr>
</tbody>
</table>

abc Least square means in the same row with different superscript letters are significantly different (p ≤ 0.05); ***: (p ≤ 0.001); SED: standard error deviation; BA, Blanca Andaluza; BC, Blanca Celtibérica; MO, Moncaina; NE, Negra Serrana-Castiza; PI, Pirenaica; MA, Malagueña; MU, Murciano-Granadina.
determine the statistical significance of the effect of breed on fat content and the percentage of fatty acids in each fat depot studied. The model used was as follows:

$$Y_{ij} = \mu + X_{i1} + \ldots + X_{i7} + e_{ij}$$

where $Y_{ij}$ is the percentage fatty acids or carcass characteristic; $\mu$ is the mean value; $X_i$ is the effect of breed (Blanca Andaluza; Blanca Celtibérica; Moncaina; Negra Serrana-Castiza, Pirenaica, Malagueña; Murciano-Granadina) and $e_i$ is the residual error. A Bonferroni test was used to compare means, with significance being set at $p < 0.05$.

Since there were significant differences in carcass weights among breeds, the effect of carcass weight was tested as a covariate. Because the effect of carcass weight as a covariate was not significant ($p > 0.05$) only breed was included in the statistical model as the main effect. In order to assess the differences among breeds, and to determine the contribution of fatty acids to these differences, a canonical discriminant analysis based on individual fatty acids and ratios of fatty acid percentages was performed for each of the depots considered. Discriminant analysis was performed using the discriminant procedure of SPSS 15.0 (SPSS, 2007).

3. Results and discussion

3.1. Fat carcass content

No differences in slaughter and carcass weight between meat breeds were observed (Table 1). However, MU kids had lower carcass weights than other breeds (6.34 vs 7.61 kg respectively) ($p < 0.05$). According to the traditional system, MU was sacrificed with lighter weights to avoid an excessive degree of fatness. The effect of carcass weight was covariate as noted in Material and methods. Significant differences in carcass fat content were observed between breeds (Table 1). Carcasses of different breeds are expected to differ in fat content, even when no difference is observed in carcass weight (Dhanda, Taylor, Mccosker, & Murray, 1999). Highest carcass fatness (“light fatness” range) was observed in MA and MU, consistent with dairy breeds. This observation is in agreement with Prescott (1982) who stated that fat is the carcass component that shows the highest variability, even at the same carcass weight, and that it depends on genotype and feed. The highest and lowest ($p < 0.05$) kidney knob fat contents were observed in carcasses from MA and BA, respectively. This effect was due to differences in the breeds’ milk production, since MA is a highly preserved in carcasses from MA and BA, respectively. This effect was due at the same carcass weight, and that it depends on genotype and feed. The effect of carcass weight as a covariate was not significant ($p > 0.05$) only breed was included in the statistical model as the main effect. In order to assess the differences among breeds, and to determine the contribution of fatty acids to these differences, a canonical discriminant analysis based on individual fatty acids and ratios of fatty acid percentages was performed for each of the depots considered. Discriminant analysis was performed using the discriminant procedure of SPSS 15.0 (SPSS, 2007).

3.2. General effects

Fatty acid profiles from IM, SC and KK fat depots are shown in Tables 2, 3 and 4, respectively. It is generally accepted that IM, SC and KK have differences in their physical and chemical properties (Wood et al., 2008). In all depots, oleic (C18:1n-9 cis), palmitic (C16:0) and stearic (C18:0) were the most abundant fatty acids and represented approximately 70%, 77% and 80% of total fatty acids in IM, SC and KK, correspondingly. Similar relations have been reported ininspecies such as lambs (Horcada et al., 2010). C18:1n-9 cis was the most abundant fatty acid, accounting for 31.8% of total fatty acids in IM, 36.4% in SC and 29.7% in KK. These values are in line with (Peña et al., 2009; Rhe, Waldron, Ziprin, & Rhe, 2000) other goat breeds. Mean values for C16:0 were 22.8%, 27.7% and 29.4% in IM, SC and KK, respectively, whereas for C18:0 percentages were 13.3%, 13.1% and 20.9% in IM, SC and KK, respectively. These results agree with those by Banskalieva et al. (2000) Mahgoub et al. (2002) and Lee et al. (2008) in goats. Hence all of the results of this work are in line with those relating to small ruminants.

3.3. Short chain fatty acids

The mean percentage of short-chain (C4-C13) fatty acids was 1.0% in IM fat, whereas it increased to 1.7% in SC and to 1.8% in KK. This is in agreement with Peña et al. (2009). In all three fat depots, differences in short-chain fatty acid content between breeds were observed ($p < 0.001$). Lowest short-chain fatty acid content was in BA, but clear evidence of higher short-chain fatty acid associated with a breed cannot be demonstrated. It is generally accepted that in suckling animals, which are pre-ruminants, the fatty acid profile of their fat is related to the composition of the maternal milk, that is naturally rich in these short-chain fatty acids (Osorio, Zumalacarregui, Figueire, & Javier, 2007; Sanz Sampelayo, Chilliard, Schmidely, & Boza, 2007; Zygoianni, Kufidis, Katsaounis, & Phillips, 1992). In this case, the lowest short-chain fatty acids observed in BA could be explained by the traditional production system of BA, based on pasture and forage, a diet which has been shown to be rich in long-chain fatty acids. Dhanda, Taylor, Murray, and Mccosker (1999) found significant differences between goat breeds in terms of their fatty acids profile and they also attributed variations to milk composition.

3.4. Unsaturated fatty acids

The proportion of unsaturated (UFA) fatty acids (MUFA + PUFA) was higher than that of the SFA. Mean values of MUFA were 36.5% in IM, 42.4% in SC and 33.3% in KK fat depots, whereas the average percentages for PUFA were 19.9%, 4.9% and 3.7% in IM, SC and KK, respectively. The values in the KK fat were in accordance with those found by other authors (Torado et al., 2006 in Girgentana breed; Bañón, Villa, Price, Ferrandini, & Garrido, 2006 in Murciano-Granadina breed). However, in general the percentage of UFA in IM in the present study was higher than that reported by Mahgoub et al. (2002) or Banskalieva et al. (2000) for Omani Jebel Akhdar breed, and by Santos et al. (2007) for “Cabrito de Barroso”. The relatively higher percentage of PUFA observed in IM fat is because IM fat depots contain a high ratio of membranes in myocytes and adipocytes and high concentrations of the long-chain n – 6 and n – 3 fatty acid are present in cell membranes (Eichhorn et al., 1986). Similar differences in PUFA percentages between peripheral and internal fat depots have been reported by Mahgoub et al. (2002) in goat kids and Horcada et al. (2010) in weaning lambs.
Regarding all fat depots, MA had a significantly higher MUFA percentage (mainly represented by C18:1–9 cis) than other breeds. Besides, the Δ-9 desaturation ratios were significantly higher in MA than in other breeds (p < 0.05). These results are consistent with the differences of these breeds, since MA is a dairy breed which suggests higher mammary desaturase activity. This observation could explain the higher meat proportion of C18:1–9 cis in this breed. The endogenous synthesis of MUFA is specifically catalyzed by Δ-9 desaturase enzyme (stearoyl-CoA desaturase) (Grinnari, 2000). These results are in line with those of Wood et al. (2008) who reported that Holstein–Friesian dairy breeds have a greater activity or expression of Δ-5 and Δ-6 desaturase enzymes. Chilliard, Rouel, and Leroux (2006) showed that genotype has a specific and important effect on goat milk fat and its fatty acid composition, particularly in the case of medium-chain fatty acids and their desaturation capacity. Furthermore, Jackson and Winkler (1970) reported that an increase in fatness level is in relation to the enhanced activity of Δ-9 desaturation, which is responsible for the synthesis of oleic acid (C18:1) from stearic acid (C18:0). In all of the fat depots studied, MA was found to have the highest activity of Δ-9 desaturase, which is in line with a breed with a greater fatness level (Table 1).

Higher PUFA content is in the intramuscular fat of farm animals rather than in other fat depots (Banskalieva et al., 2000; Horcada et al., 2010). The results for the PUFA percentage in IM fat depots were considerably higher (in the range of 16.3–25.8%) than those reported by Santos et al. (2007) for Serrana and Bravía goats or by Peña et al. (2009) for Criollo Cordobés and Anglonubian breeds. Enser, Hallet, Hewitt, Fursey, and Wood (1996) showed that IM fat from meat is an important source of essential PUFA (EFA). These include linoleic acid (C18:2n–6, majority), alpha-linolenic (C18:3n–3) and their derivatives. These EFAs can be anticancerogenic (Banskalieva et al., 2000), yet they cannot be synthesized in the body and have to be obtained via diet (Potchoiba, Lu, Pinkerton, & Sahlu, 1990). The results for EFA percentage (around 10%) were higher than those reported by Mahgoub et al. (2002) in Asian breeds (4%) or by Rhee et al. (2000) in North American breeds (7.8%) and comparable to those described by Peña et al. (2009) in some South American breeds. Thus, there is evidence of the influence of different production systems associated with breed on the characteristics of goat kid fat in breeds around the world. This is particularly evident in edible IM fat. In edible IM fat depots (Table 2), MA showed the lowest percentage of PUFA and EFA, as low percentages of C18:2 and C18:3 were observed in SC and KK fat depots where differences in PUFA and EFA, as low percentages of C18:2 and C18:3 were observed in SC and KK fat depots where differences in PUFA and EFA, as low percentages of C18:2 and C18:3 were observed in SC and KK fat depots where differences in PUFA and EFA, as low percentages of C18:2 and C18:3 were observed in SC and KK fat depots.
totally evident because in SC fat, BC had the highest PUFA content, while in KK, PI breed had the highest content. These differences could be because the lowest effect of genotype on the PUFA/SFA ratio is not evident in small ruminants. The PUFA/SFA and n-3 PUFA ratio than other breeds.

3.6. Fatty acid ratios

The PUFA/SFA and n-6/n-3 PUFA ratios are two indices to determine how fatty acids affect human health. According to recommendations of the Department of Health (Webb, Casey, & Simela, 2005), the PUFA/SFA balance to prevent of coronary heart disease is 0.4, while for n-6/n-3 PUFA, a value 4 is recommended. In this study these ratios have only been examined in the edible fat depot, i.e., the IM depot. In all breeds, the PUFA/SFA ratio ranged from 0.4 to 0.6. These results are better for human health than those reported by Werdi Pratiwi, Murray, Taylor, and Zhang (2006) (0.1–0.3) for Boer and Australian feral goats and by Talpur, Bhangera, and Sherazia (2008) (0.2–0.3) for Peteri goats. In the present study IM fat from BA showed a higher PUFA/SFA ratio (0.61) than the other breeds (around 0.4) (p < 0.05). However, differences between other meat breeds (BC, MO, NE and PI) were not found. Santos et al. (2007) reported that the effect of genotype on the PUFA/SFA ratio is not evident in small ruminants and other factors, such as the effect of nutrition, should be taken into account. IM fat from the dairy animals with a greater fatness level (MA) had a more unfavorable n-6/n-3 PUFA ratio than other breeds. Thus there is evidence of the effect of breed combined with degree of fatness on the fatty acid composition of fat depots in goat kids.

<table>
<thead>
<tr>
<th>BA</th>
<th>BC</th>
<th>MO</th>
<th>NE</th>
<th>PI</th>
<th>MA</th>
<th>MU</th>
<th>SED</th>
<th>Sig</th>
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<tbody>
<tr>
<td>C14:0</td>
<td>3.5. Saturated fatty acids</td>
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</table>

The SFA percentages in the present study ranged from 42.09 to 45.05% in IM fat depots (Table 2), from 44.95 to 58.05% in SC fat depots (Table 3) and from 59.2 to 66.1% in KK fat depots (Table 4). These results are in agreement with Mahgoub et al. (2002) who reported values of 55.4% and 69.7% for SFA content in SC and KK depots from goat kids with similar characteristics.

In all fat depots, differences in SFA content between breeds were observed (p < 0.001). SFA content in IM, SC and KK was higher in meat breed animals (fundamentally MO and NE) than in the other breeds. According to Huerta-Leidenz et al. (1991) the amount of fat deposited, and therefore the degree of fatness affects fatty acid composition. The present study is in agreement with this observation because MA showed highest fatness levels and kidney knob fat amounts (Table 1). In this regard, MA showed a lower percentage of myristic acid (C14:0), than MO and NE. Similar findings have been reported by Diaz et al., (2002), who observed that lambs with more fat displayed a lower percentage of SFA, basically C14:0. Despite being a dairy breed, MU showed a relatively high SFA content in all fat depots, compared to the other breeds. In fact, the C14:0 content was significantly higher in MU than the other breeds. This is because MU breed kids were slaughtered at a lighter weight to prevent excessive fatness.

Thus there is evidence of the effect of breed combined with degree of fatness on the fatty acid composition of fat depots in goat kids.
Bravia breeds and from 61.3 to 79.8% (Park & Washington, 1993) in Spanish breeds were observed (p ≤ 0.05); SED: standard error deviation; BA, Blanca Andaluza; BC, Blanca Celtibérica; MO, Moncaína; NE, Negra Serrana-Castiza; PI, Pirenaica; MA, Malagueña; MU, Murciano-Granadina; MUFa, mono-unsaturated fatty acids; PUFa, poly-unsaturated fatty acids; SFA, saturated fatty acids.

The nutritional implications of IM fat on human diet, the desirable fatty acids (DFA) were calculated (MUFA+PUFA+C18:0) according to Huerta-Leidenz et al. (1991). Values ranging from 66.2% to 79.8% (DFA) were calculated (MUFA+PUFA+C18:0) in concentrates (French et al., 2000; Raes, De Smet, & Demeyer, 2004).

CLA ranged from 0.7 to 1.0% of the total fatty acids identified, while the meat breeds (BA and PI) were separate from the rest in terms of their higher SFA content, essentially C16:0 (p < 0.05), whilst the highest DFA proportion was observed in BA (72.7%) because of its higher DFA content. Thus, evidence of the effect of breed and of the indigenous production system of different goat breeds on the DFA content may be inferred. However, a clear influence of dairy or meat breed on desirable fatty acid content cannot be shown.

Table 4
Means and standard deviation of fatty acids (percentage by weight of total fatty acids detected) of kidney knob fat depot from seven breeds of Spanish kids.

<table>
<thead>
<tr>
<th>BA</th>
<th>BC</th>
<th>MO</th>
<th>NE</th>
<th>PI</th>
<th>MA</th>
<th>MU</th>
<th>SED</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ9 desaturase</td>
<td>0.57b</td>
<td>0.58b</td>
<td>0.61b</td>
<td>0.61b</td>
<td>0.56b</td>
<td>0.64b</td>
<td>0.63b</td>
<td>0.043***</td>
</tr>
<tr>
<td>MUFA</td>
<td>3.17b</td>
<td>3.72c</td>
<td>3.58b</td>
<td>3.38b</td>
<td>3.78ab</td>
<td>4.01a</td>
<td>3.99c</td>
<td>3.33c</td>
</tr>
<tr>
<td>PUFa</td>
<td>62.40c</td>
<td>64.43c</td>
<td>66.05b</td>
<td>60.77ab</td>
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...
n-6 PUFA. In SC fat depot two breeds (MA and BC) were separate from the rest in terms of their fatty acids profile. The figure depicts MA and BC separately because they have lower n-6 PUFA percentages than the others breeds. Dias et al. (2008) and De Smet, Raes, and Demeyer (2004) proposed the n-6/n-3 ratio and PUFA/SFA as an effective tool for discriminating breeds in bovines. However, in the present study on SC fat depot, 5 of the 7 breeds were close enough to each other to invalidate this possibility.

Finally, for KK fat depot (Fig. 3), function 1 accounted for 56.6% of variability and was determined mainly by long chain PUFA fatty acids (C18:3 n-3, C22:5 n-3 and C22:6 n-3). In KK, only one breed (MA), located on the right side, was clearly separate from the other breeds in terms of its fatty acid profile. MU also was located on the right side, although this is not so evident because less fatness degree and kidney knob fat content were observed in this breed of goats. The influence of breed on KK fatty acid profile could hence be shown. Other authors (Mellado, Nárvaez, Alcalde, Cano, & León, 2009) have proposed the KK PUFA (C18:2 and C18:3) content from KK fat as a method to differentiate between goat’s milk, milk replacement and milk-based starter fattening diets for goat kids. Function 2 accounted for 17.3% of total variability and was determined by short-chain C4–C13 fatty acids, MUFA and SFA. This function is in relation to mothers’ milk. MA was located in the top part of the graph because it is a breed with high milk production. It is generally accepted that short-chain fatty acids and SFA (especially C14:0) are present in goat’s milk (Tsiplakou & Zervas, 2008) and that fat composition of very young suckling animals is mainly related to the fat composition of the milk they consume (Velasco et al., 2001).

4. Conclusions

From the present study, it can be concluded that breeds, together with the production system, are important factors that influence the fatty acid profile of fat from intramuscular, subcutaneous and kidney knob fat depots in goat kids. Differences among breeds are mainly related to breed and fatness degree of kid goats. Hence, the fatty acid profile of selected dairy breeds, especially the Malagueña, was clearly different to the fatty acids profile of meat-specialized breeds. The fatty acid profile of each fat depot from goat kids was not enough to discriminate between breeds of similar purpose because animals were very young and evidence of the influence of maternal milk on fatty acid profiles can be seen. However, the IM fat depot is proposed as the most potential fat depot for discriminating goat breeds according to their fatty acid profile, ahead of SC and KK fat depots. Fatty acid composition values of the animals studied were comparable, in quality and nutritive values, to other ruminant farm animals. Furthermore, their lower total carcass fat content and high CLA and PUFA contents suggest that kid meat can be a good for human consumption.

Acknowledgments

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