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RESEARCH ARTICLE

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A comparative study of fatty acid profiles of fat in commercial Spanish suckling kids and lambs

Alberto Horcada[1]*, Maria del Mar Campo[2], Oliva Polvillo[3], Maria Jesus Alcalde[1], Irene Cilla[2] and Carlos Sañudo[2]

[1] *Departamento de Ciencias Agroforestales. ETSIA. Universidad de Sevilla. 41013 Sevilla, Spain.* [2] *Departamento de Producción Animal y Ciencia de los Alimentos. Facultad de Veterinaria. Universidad de Zaragoza. 50013 Zaragoza, Spain.* [3] *Servicio General de Investigación Agraria (CITIUS). Universidad de Sevilla. 41013 Sevilla, Spain*

Abstract

Fatty acid profiles are a major contributor to meat quality in small ruminants. Nevertheless, while fatty acid profiles from suckling lambs have been extensively studied they are virtually unknown in suckling kids. Fatty acid profiles of intramuscular and kidney knob fat depots of suckling kids were compared with fatty acid profiles of lambs with a quality label in the Spanish market. Forty suckling kids from Blanca Celtibérica (BC), Moncaína (Mo), Negra Serrana (NS) and Murciano Granadina (MG) breeds and 20 Churra male suckling lambs labelled with 'Lechazo de Castilla y León' Protected Geographic Indication were slaughtered at commercial live weights (12 kg). In both depots differences in the unsaturated fatty acid profile were observed between breeds. The most pronounced differences were observed between meat goat breeds (BC, Mo and NS) and lambs, whilst a greater similarity in the fatty acid profile was observed between kids from dairy goat breeds (MG) and lambs. The lowest polyunsaturated fatty acid content was observed in meat goat breeds (approximately 21 to 22% of total fatty acids detected in the intramuscular fat). No significant differences in atherogenic index and desirable fatty acid content (range 68 to 70% of total fatty acids detected) were observed. However, a more favourable (lower than 8.07) *n*-6/*n*-3 ratio was observed in meat goat breeds. The use of fatty acid profiles from intramuscular and kidney knob fat could be proposed as a tool to differentiate goat kids and lambs. The fact that intramuscular fat from suckling kids and lambs shows appropriate lipid nutritional indices and their low carcass fatness indicate that moderate consumption of suckling kid and lamb meat may contribute to an overall balanced diet for humans.

Additional key words: goat kid; lamb kid; intramuscular fat; kidney knob fat; gas chromatography.

Introduction

In Mediterranean European countries around 25% of the total meat production is obtained from ruminants, from which approximately 14% correspond to small ruminants (12% for lambs and 2% for goats). Kid and lamb production systems are very similar in this region with both animals being raised on their mother's milk to produce suckling animals with a live weight of 10-12 kg (Marichal *et al*., 2003). The characteristics of goat meat are variable because of the large number of breeds and the small number of animals in each. In the goat production system, most of the animals are for milk production where the suckling kid is considered a by-product. Consequently, the kid meat industry offers a scarce product in contrast

* Corresponding author: albertohi@us.es
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Abbreviations used: AI (atherogenic index); BC (Blanca Celtibérica meat goat breed); Ch (Churra dairy ewe breed); CLA (conjugated linoleic acid); EEC (European Economic Community); FAME (fatty acid methyl ester); FID (flame ionisation detector; GLM (general linear model); IMF (intramuscular fat); KKF (kidney knob fat); MG (Murciano Granadina dairy goat breed); Mo (Moncaína meat goat breed); MUFA (monounsaturated fatty acids); NS (Negra Serrana meat goat breed); PCA (principal component analysis); PGI (protected geographic indication); PUFA (polyunsaturated fatty acids); SED (standard error of the difference); SFA (saturated fatty acids).

to the traditional and well-known lamb production. Currently in Spain there are five Protected Geographic Indications (PGI) for lamb but no protection schemes exist for kid goat meat.

Fatty acid composition plays an important role in defining meat quality since it is related to differences in the nutritional value of fat for human consumption and in organoleptic attributes, especially flavour and marbling (Wood *et al.*, 2004). In recent years there has been a growing interest in ascertaining the fat composition of meat from small ruminants and, furthermore, the concept of the 'healthiness' of food is becoming a key quality issue for consumers. In the case of ruminant meat, this concept is largely related to its fat content and its fatty acid composition, in fact, various references to the incidence of *n*-6 and saturated fatty acids on human health have been reported (Trichopoulou & Lagiou, 1997).

The fatty acid composition of fat depots in lambs has been widely reported (Díaz *et al.*, 2005; Nuernberg *et al.,* 2008) where the use of the fatty acid composition of various fat depots has been recommended as a discriminator of the origin of lambs (Juárez *et al.,* 2010). Furthermore, recent experiments have shown the effectiveness of the fatty acid composition of intramuscular fat (IMF) depots as a tool to discriminate goat breeds (Horcada *et al.*, 2012) or the use of kidney knob fat (KKF) as a method of differentiating the fattening diet of goat kids (Mellado *et al.*, 2009). In spite of this there have been few comparative studies on the lipid composition of kid and certified lamb (Lee *et al*., 2008; Sinanoglou *et al.,* 2013).

The aim of the present work was to compare the fatty acid profiles of intramuscular and kidney knob fat depots of suckling kid goat of four breeds produced under typical production systems in Spain and a suckling lamb with a quality label in the market. The secondary objective of this work was also to assess the reliability of using fatty acid profiles to categorize species from small ruminants.

Material and methods

Animals

Four groups of 10 entire male suckling kids of the Blanca Celtibérica (BC), Moncaína (Mo), Negra Serrana (NS), Murciano Granadina (MG) goat breeds and 20 entire male suckling lambs of the Churra (Ch) sheep breed were used in this study. BC, Mo and NS goat breeds are classed as local Spanish meat breeds. MG is a recognised dairy breed that can be considered the main goat breed in Spain, with heads all around the world. These breeds were chosen as the most commercially available breeds from South Spain. On the other hand, Ch breed lambs are included in the '*Lechazo de Castilla y León*' European PGI quality label for suckling lamb production (Miguélez *et al.,* 2006).

The samples obtained for this study were similar to those bought by consumers in the marketplace. All the animals were reared in their respective local areas and were raised only on their mother's milk until slaughter time. The diet of goats and ewes was comprised of local pastures and commercial concentrate (range composition; 16.0-17.0% crude protein, 4.5-5.1% crude fibre, 3.5-4.0% total fat, 37-40% starch, 1.0-1.4% Ca, and 0.3-0.5% P), following the traditional production system. Animals were selected by their respective Breeders' Associations, and were slaughtered in winter at the usual commercial weight (around 12 kg live weight) and range of 30-35 days old.

Slaughter and post-slaughter conditions

Animals were slaughtered in licensed slaughter-houses accordingly to the guidelines of Council Regulation (EC) Nº 1099/2009 (EC, 2009) in their respective areas of origin, when they reached their commercial market weight. Carcass characteristics of suckling kids and lambs involved in the present study have been reported in a previous paper (Sañudo *et al.,* 2012). External fatness were assessed using the 15 point (1: not greasy; 15: very greasy) scale proposed by the Commission Regulation (EEC) No 461/93 (EEC, 1993). The *Longissimus lumborum* muscle of the left half carcass was dissected 24 h after slaughter and a slice of this muscle (IMF) and of KKF were obtained. All samples were vacuum-packed and stored at –20°C in order to determine the fatty acid composition.

Analytical procedure

Fatty acid methyl esters (FAMEs) of IMF and KKF depots were obtained using the method proposed by

Elmore *et al.* (1999) and validated by Aldai *et al.* (2006). Thawed samples (1 g) were saponified in 6 mL of 5 M KOH in methanol:water (50:50, v/v) with hydroxyquinone (1 g L^{-1}) at 60°C for 1 h, after flushing with nitrogen. Following this, the mixture was diluted with 12 mL of 0.5% NaCl and 5 mL of petroleum ether. The non-saponifiable fraction was removed. To neutralise the KOH, 3 mL of glacial acetic acid was added. To extract the FAMEs, a double petroleum ether clearance was developed. The solvent was evaporated using nitrogen and the extracted FAMEs were methylated using 200 µL of trimethylsilyldiazomethane in methanol:toluene (2:1, v/v) at 40°C for 10 min, dried under nitrogen and dissolved in 1mL of n-hexane containing 50 ppm of butylated hydroxytoluene. Samples were centrifuged at 15,000 rpm for 5 min and supernatant was transferred for analysis. Separation of FAMEs was carried out using a gas chromatograph (GC, Agilent 6890N, Inc., CA, USA) equipped with a flame ionisation detector (FID), and HP 7683 automatic sample injector fitted with an HP-88 capillary column (100 m, 0.25 mm i.d., 0.2 µm film thickness, Agilent Technologies Spain, S.L., Madrid). The chromatographic conditions were as follows: initial column temperature 100°C, programmed to increase at a rate of 3°C min^{-1} up to 158°C and then at a rate of 1.5°C min^{-1} up to 190°C maintaining this temperature for 15 min, then at a rate of 2°C min^{-1} up to 200°C and then increasing again at a rate of 10°C min^{-1} up to final temperature of 240°C where the temperature was maintained for 10 min. The injection and detector were maintained at 300°C and 320°C respectively. Hydrogen was used as the carrier gas at a flow-rate of 2.7 mL min^{-1}. The split ratio was 17.7:1, and 1 µL of solution was injected. Nonadecanoic acid methyl ester at 10 mg mL^{-1} was used as an internal standard. Individual FAMEs, including the main CLA isomer (9*cis,* 11*trans*), were identified by comparing their retention times with those of the standard fatty acid mix *Supelco 37* (Sigma Chemical Co. Ltd., Poole, UK). Fatty acids were expressed as a percentage of total fatty acids identified and grouped as follows: saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), Σ*n*-3 PUFA, Σ*n*-6 PUFA and total of conjugated linoleic acid (CLA). Lipid quality indices in relation with human health were calculated as follows: Σ*n*-6PUFA/Σ*n*-3PUFA (*n*-6/*n*-3 ratio), [C12:0 + 4 (C14:0 + C16:0)] / [(Σ*n*-6 + Σ*n*-3) PUFA + C18:1 + ΣMUFA)] (atherogenic index, AI; Ulbricht & Southgate, 1991) and MUFA + PUFA + C18:0 (desirable fatty acids; Huerta-Leidenz *et al.*, 1991).

Data analysis

A least-square means analysis was performed for each fat depot using general linear model (GLM) procedures with one fixed factor (breed) and using the SAS statistical package (SAS, 1999), with the model:

$$Y_{ij} = \mu + X_{i\,(1....5)} + e_{j(i)}$$

where Y_{ij} = dependent variables (percentage of fatty acids and ratios); µ = mean value; X_i = mean breed effect (Blanca Celtibérica; Moncaína; Negra Serrana, Murciano Granadina goat and Churra sheep breeds); e_j = residual error.

When F-tests were significant ($p < 0.05$) a Tukey test was used to compare means, with significance being set at $p < 0.05$. In order to summarise the differences between animal groups in relation to overall fatty acid profiles and to analyze the relative contribution of fatty acid and their different ratios to these differences, two principal component analyses (PCA) were carried out, one for each fat depot (IMF, and KKF). PCA analyses were performed using the Factor procedure of SAS software.

Results

Fatty acid profile of intramuscular fat

Mean values of fatty acid composition from IMF of kids and lambs are shown in Table 1. Twenty-five fatty acid molecular species were identified according to their relative retention times. C18:1 fatty acids (including *cis* and *trans* isomers) were the more abundant unsaturated fatty acids in IMF. Among saturated fatty acids palmitic (C16:0) and stearic (C18:0) acids were the more abundant. For both kids and lambs breeds, the percentage of total unsaturated fatty acids (PUFA + MUFA) in IMF was higher than total SFA (range 45.3-46.2%). Differences in SFA percentages between breeds were not observed, while significant differences in MUFA ($p = 0.042$) and PUFA ($p = 0.022$) were observed among breeds. MG kids contained significantly less MUFA than other breeds,

Table 1 Mean values of fatty acids (percentage by weight of total fatty acids detected) of intramuscular fat depot from *Longissimus lumborum* muscle of suckling kids (BC: Blanca Celtibérica, Mo: Moncaína and NS: Negra Serrana), dairy suckling kids (MG: Murciano Granadina) and suckling lambs (Ch: Churra)

	Kids				Lambs	SED[1]	Sig.
	BC	Mo	NS	MG	Ch		
C10:0	0.15	0.14	0.15	0.14	0.10	0.010	0.512
C12:0	0.15	0.13	0.16	0.16	0.15	0.013	0.366
C14:0	2.82	2.91	3.02	3.22	2.91	0.558	0.243
C14:1	0.29^{ab}	0.31^{b}	0.28^{ab}	0.23^{a}	0.27^{ab}	0.011	0.008
C15:0	0.27	0.28	0.30	0.23	0.26	0.010	0.137
C16:0	26.29	26.34	26.71	27.32	26.39	3.755	0.356
C16:1	2.51	2.12	2.03	2.30	2.04	0.488	0.402
C17:0	0.53^{b}	0.44^{ab}	0.40^{a}	0.43^{ab}	0.53^{b}	0.029	0.049
C18:0	15.88^{b}	15.82^{b}	15.04^{b}	14.59^{a}	14.81^{a}	1.622	0.005
C18:1*n*-9*t*	2.52	2.73	2.48	2.36	2.52	0.417	0.830
C18:1*n*-11*t*	1.25^{c}	1.12^{b}	1.09^{b}	1.14^{b}	0.94^{a}	0.076	0.037
C18:1*n*-9*c*	25.84^{ab}	25.84^{ab}	26.57^{b}	24.87^{a}	26.86^{b}	2.599	0.045
C18:2*n*-6*c*	12.52^{a}	13.10^{b}	13.58^{b}	14.19^{c}	13.93^{c}	2.595	0.044
C18:3*n*-6	0.22^{b}	0.26^{b}	0.22^{b}	0.16^{a}	0.13^{a}	0.005	0.000
C20:0	0.10	0.14	0.09	0.11	0.10	0.004	0.754
C18:3*n*-3	0.13	0.11	0.12	0.12	0.10	0.001	0.351
C21:0	0.12^{b}	0.10^{ab}	0.09^{a}	0.11^{ab}	0.08^{a}	0.001	0.005
C20:2	0.16	0.13	0.13	0.18	0.15	0.005	0.512
C20:3*n*-6	0.85^{b}	0.72^{ab}	0.79^{ab}	0.90^{b}	0.61^{a}	0.100	0.037
C20:3*n* -3	0.09^{b}	0.09^{b}	0.08^{b}	0.08^{b}	0.06^{a}	0.001	0.041
C20:4*n*-6	4.40	4.17	3.92	4.57	4.55	1.113	0.295
C20:5*n*-3	0.46^{c}	0.46^{c}	0.45^{b}	0.42^{a}	0.43^{a}	0.001	0.008
C22:5*n*-3	1.32^{b}	1.31^{b}	1.25^{ab}	1.21^{a}	1.24^{a}	0.011	0.007
C22:6*n*-3	0.44^{c}	0.44^{c}	0.43^{b}	0.40^{a}	0.41^{a}	0.001	0.008
CLA[2] 9*c*,11*t*	0.69^{c}	0.79^{c}	0.71^{c}	0.56^{b}	0.43^{a}	0.042	0.001
SFA[3]	46.18	46.15	45.72	46.17	45.35	3.155	0.193
MUFA[4]	32.42^{b}	32.12^{b}	32.45^{b}	30.92^{a}	32.51^{b}	3.159	0.042
PUFA[5]	21.40^{a}	21.73^{a}	21.83^{a}	22.92^{b}	22.14^{b}	2.297	0.022
n-6/*n*-3	7.46^{a}	7.60^{b}	8.07^{b}	8.90^{c}	8.61^{c}	1.005	0.000
AI[6]	0.70	0.71	0.71	0.75	0.71	0.005	0.563
Desirable fatty acid[7] (%)	69.70	69.67	69.32	68.42	69.67	3.638	0.662

[1] SED: standard error deviation; [2] CLA: conjugated linoleic acid; [3] SFA: saturated fatty acids; [4] MUFA: monounsaturated fatty acids; [5] PUFA: polyunsaturated fatty acids; [6] AI: atherogenic index: [C12:0 + 4(C14:0 + C16:0)] / [(Σn-6 + Σn-3)PUFA + C18:1 + ΣMUFA]; [7] Desirable fatty acid: MUFA + PUFA + C18:0; [a-c] values in rows with different letters are significantly different ($p \leq 0.05$).

while higher PUFA percentage was observed in MG kids and Ch lambs ($p < 0.05$).

Fatty acid profile of kidney knob fat

In KKF depot, 24 fatty acid molecular species were identified according to their relative retention times (Table 2). The major unsaturated fatty acid in the five breeds was C18:1 *n*-9*c*, while in the case of saturated fatty acids they were C16:0, C18:0 and C14:0. All of the breeds showed higher SFA percentage (range 55.8-61.0%) than total unsaturated fatty acid (MUFA + PUFA). Differences in SFA percentage between breeds were observed ($p < 0.001$). Ch lambs showed the lowest SFA and the highest MUFA percentage ($p < 0.05$). There were differences in PUFA percentage between breeds ($p = 0.001$). Highest PUFA content was observed in MG breed ($p < 0.05$), while lowest was showed in the Mo breed ($p < 0.05$).

Table 2. Mean values of fatty acids (percentage by weight of total fatty acids detected) of kidney knob fat depot from meat suckling kids (BC: Blanca Celtibérica, Mo: Moncaína and NS: Negra Serrana), dairy suckling kids (MG: Murciano Granadina) and suckling lambs (Ch: Churra)

	Kids				Lambs	SED[1]	Sig
	BC	Mo	NS	MG	Ch		
C10:0	0.56^{c}	0.50^{bc}	0.55^{c}	0.27^{a}	0.36^{ab}	0.079	0.001
C12:0	1.19^{ab}	1.13^{ab}	1.53^{b}	2.35^{c}	0.91^{a}	0.359	0.001
C14:0	10.06^{b}	10.13^{b}	9.99^{b}	9.69^{b}	7.79^{a}	0.731	0.000
C14:1	0.23^{ab}	0.24^{ab}	0.19^{a}	0.16^{a}	0.31^{b}	0.062	0.007
C15:0	0.69^{cd}	0.54^{b}	0.60^{bc}	0.37^{a}	0.74^{d}	0.095	0.000
C16:0	28.81^{b}	27.19^{b}	27.83^{b}	28.41^{b}	24.43^{a}	1.030	0.001
C16:1	3.84^{b}	3.98^{b}	4.11^{b}	3.19^{a}	4.13^{b}	0.296	0.001
C17:0	1.28^{b}	1.31^{b}	1.44^{b}	0.71^{a}	1.71^{c}	0.113	0.000
C18:0	17.59^{ab}	18.60^{bc}	18.70^{bc}	16.36^{a}	19.62^{d}	1.314	0.006
C18:1*n*-9*t*	2.06^{bc}	1.56^{a}	1.80^{ab}	2.00^{ab}	2.46^{c}	0.304	0.000
C18:1*n*-11*t*	nt	nt	nt	nt	nt	—	—
C18:1*n*-9*c*	27.50^{a}	28.30^{b}	26.76^{a}	27.86^{ab}	30.37^{c}	0.918	0.001
C18:2*n*-6*c*	2.45^{a}	1.99^{a}	2.57^{a}	4.91^{b}	2.74^{a}	0.549	0.000
C18:3*n*-6	0.27^{bc}	0.32^{c}	0.33^{c}	0.25^{ab}	0.19^{a}	0.045	0.000
C20:0	0.14^{a}	1.12^{a}	0.20^{b}	0.09^{a}	0.19^{b}	0.100	0.000
C18:3*n*-3	0.04	0.04	0.05	0.04	0.04	0.000	0.351
C21:0	0.02	0.02	0.03	0.03	0.03	0.000	0.225
C20:2	0.02^{ab}	0.01^{a}	0.02^{ab}	0.03^{c}	0.02^{ab}	0.000	0.000
C20:3*n*-6	0.12^{ab}	0.11^{a}	0.11^{a}	0.15^{b}	0.13^{ab}	0.020	0.044
C20:3*n*-3	0.02^{a}	0.02^{a}	0.02^{a}	0.03^{b}	0.02^{a}	0.000	0.035
C20:4*n*-6	2.54^{b}	2.17^{a}	2.56^{b}	2.58^{b}	2.90^{c}	0.221	0.000
C20:5*n*-3	0.01^{a}	0.02^{b}	0.02^{b}	0.01^{a}	0.01^{a}	0.000	0.007
C22:5*n*-3	0.07^{b}	0.07^{b}	0.07^{b}	0.06^{a}	0.07^{b}	0.000	0.008
C22:6*n*-3	0.03^{a}	0.03^{a}	0.03^{a}	0.03^{a}	0.04^{b}	0.002	0.008
CLA[2] 9*c*,11*t*	0.46^{a}	0.60^{b}	0.49^{a}	0.42^{a}	0.79^{c}	0.079	0.000
SFA[3]	60.33^{c}	59.85^{c}	60.87^{c}	58.27^{b}	55.76^{a}	1.043	0.000
MUFA[4]	33.63^{ab}	34.76^{b}	32.86^{a}	33.21^{a}	37.27^{c}	1.018	0.000
PUFA[5]	6.03^{ab}	5.38^{a}	6.27^{b}	8.52^{d}	6.97^{c}	0.592	0.001

[1]SED: standard error deviation; [2]CLA: conjugated linoleic acid; [3]SFA: saturated fatty acids; [4]MUFA: monounsaturated fatty acids; [5]PUFA: polyunsaturated fatty acids; [a-d]: values in rows with different letters are significantly different ($p \leq 0.05$); nt: not detected.

Lipid quality indices

A comparison of fatty acid ratios of IMF in kids and lambs in relation to human health are reported in Table 1. Breeds differed significantly in *n*-6/*n*-3 ratio ($p < 0.001$) and CLA content ($p < 0.001$) in IMF, although there were not significant differences in other ratios, such as AI and total desirable fatty acid content.

Principal component analysis from fat depots

Two principal components explained 94.2% of the total variation in intramuscular fatty acid composition (Fig. 1a). The first component (66.9% of total variance) was more associated with PUFA and MG and Ch breeds on the left side, opposite to MUFA and SFA on the right side. The second principal component explained 27.3% of variability and was mainly defined by SFA, associated with Mo on the upper side. In KKF (Fig. 1b), the first two principal components explained 91.1% of the total variability in fatty acid composition. Function 1 (50.8% of the variability) was essentially determined by total CLA and MUFA and Ch breed on its right side, whereas Function 2 (40.3% of the variability) was mainly determined by PUFA content associated with MG kid breed on the upper side.

Discussion

All of the carcass morphology was as expected for the Spanish market (see Sañudo *et al.,* 2012). Average

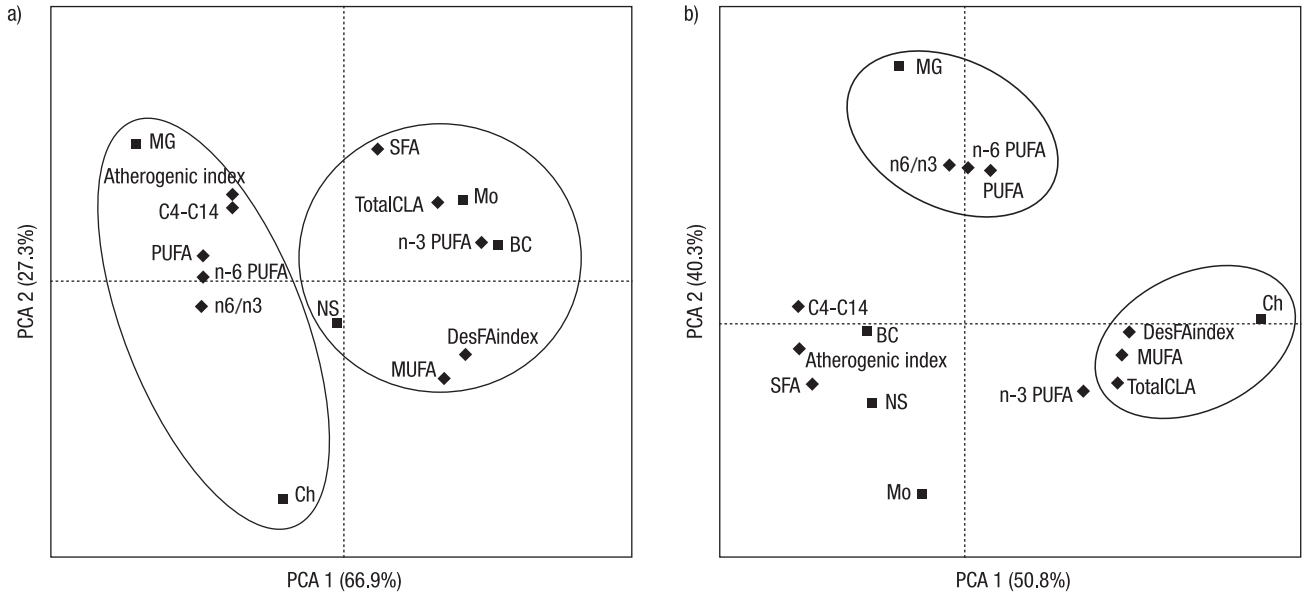

Figure 1. Projection of fatty acid percentages and ratios of intramuscular fat depot (a) and kidney knob fat depots (b) on the plane defined by two principal components. CLA: conjugated linoleic acid; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; BC: Blanca Celtibérica goat breed; Mo: Moncaína goat breed; NS: Negra Serrana goat breed; MG: Murciano Granadina goat breed; Ch: Churra sheep breed; DesFAindex: MUFA + PUFA + C18:0. Atherogenic index: [C12:0 + 4(C14:0 + C16:0)] / [(Σn-6 + Σn-3)PUFA + C18:1 + ΣMUFA].

carcass weight ranged from 6.56 kg (BC breed) to 4.38 kg in MG. Carcass weight of Ch lambs showed an intermediate value (5.49 kg). When data were covariated by carcass weight Ch lambs and MG goat showed the highest fatness scores (5.37 and 4.05 respectively). Nevertheless, results for fatness of the meat goat breeds did not differ significantly (2.81, 2.78 and 2.75 for BC, Mo and NS respectively; see Sañudo *et al.,* 2012). Usually, in the abattoir the goat carcass have lower fatness score than sheep. In this case, there were fewer differences between carcass fatness of Ch and dairy goat breed (MG) than among meat goat breeds. The fatness of the Ch carcasses was the typical of the commercial type according to *Lechazo de Castilla y León* PGI (Miguélez *et al.,* 2006).

Fatty acid profile of intramuscular and kidney knob fat

Fatty acid profile of IMF from kids (BC, Mo, NS, MG breeds) and Ch lambs (Table 1) are in line with those reported in small ruminant animals raised in countries of the Mediterranean area (Sinanoglou *et al*., 2013). In fact, total C18:1 fatty acids (28.4 to 30.3%) are in agreement with those reported by Horcada *et al.* (2012) in kids and Díaz *et al.* (2005) in lambs. The greatest percentages of SFA were for C16:0 and C18:0 fatty acids, as expected in the IMF depot of ruminants (Banskalieva *et al.*, 2000; Wood *et al.*, 2008). Differences in most of SFA between breeds were not observed, in disagreement with Tshabalala *et al.* (2003) and Lee *et al.* (2008) who reported different SFA percentages in intramuscular depot between goat and lambs. In the case of MUFA, MG kids contained proportionally less MUFA than other breeds, including Ch lambs, because of the lowest C18:1*n*-9*c* showed. Regarding PUFA, higher percentage of PUFA was observed in Ch lambs and dairy kids (MG) than in the meat goat breeds. Many researchers have reported the influence of mother's milk in the fatty acid composition of fat depots of suckling small ruminants (Rojas *et al.,* 1994; Wood *et al*., 2008). At this age of slaughter, where fat saturation by ruminal effect is not evident, evidence of a higher efficiency of deposition of unsaturated fatty acids in greased animals than in lean animals could be expected. This observation was reported by Madruga *et al.* (2006) and Horcada *et al.* (2009) that showed higher content of unsaturated fatty acids in greased lambs (females) than in leaner animals (males).

Variation in fatty acid composition has an important effect on flavour development during cooking (Campo *et al.*, 2003). Along these lines, it has been reported that branched-chain fatty acids of medium chain length

are important constituents of the flavour and odour of lamb meat (Young *et al.*, 1997). The ability of unsaturated fatty acids, especially those with more than two double bonds, to rapidly oxidise during cooking and produce aromatic compounds such as aldehydes, alcohols and ketones has been assessed (Wood *et al.*, 2004). Some of these aldehydes are more likely to derive from C18:3*n*-3 and C18:3*n*-6 isomers. In IMF depot, differences in C18:3*n*-3 proportions between kid breeds and Ch lambs were not observed, while C18:3*n*-6 proportion was higher in meat kids than in dairy kids and lambs. We could assume that C18:3*n*-6 differences observed between breeds of young kids and lambs could help to differentiate the flavour of meat from meat kids and other breeds analyzed. On the other hand, Sañudo *et al.,* (2000) reported that C18:0 is positively correlated with odour and flavour intensity and negatively with C18:2. In the current study, samples from meat breed kids (BC, Mo and NS) contained higher percentages of C18:0 and lower percentages of C18:2*n*-6 than dairy kids or Ch lambs. Hence, a higher flavour intensity could be expected from samples from meat kids than dairy kid or Ch lambs. However, other criteria in relationship with total fat content in meat must be considered when intensity of odour and flavour of meat is evaluated. In fact, Madruga *et al.* (2013) reported that high total fat content from lambs is associated with a higher intensity of flavour compared with goats because it has a higher concentration of volatile compounds derived from lipids, mainly saturated lipids. In our study, Ch lambs showed higher fatness scores (see Sañudo *et al.,* 2012). Hence, a greater intensity of odour and flavour in meat from lambs than kids can be expected.

In reference to KK fat (Table 2), the major unsaturated fatty acid in the five breeds was C18:1*n*-9*c* (range 27.5 to 30.37) as reported by Zygoyiannis *et al.* (1992) in suckling kids and Cañeque *et al.* (2005) in lambs. The highest SFA were C16:0, C18:0 and C14:0, as corresponding to KK fat of ruminants (Díaz *et al.*, 2005; Mellado *et al.*, 2009). These four fatty acids accounted for over 82% of total fatty acids in KK fat for all breeds studied. Clear significant differences between kids and lambs were observed for total SFA, MUFA and PUFA percentages (Table 2). The relative content of SFA was higher in all kid breeds than in lambs, and the highest SFA content was observed in meat kids (BC, Mo and NS). Influence of breed on SFA of KK fat can be proposed (Sinanoglou *et al.,* 2013). Higher MUFA content was observed in Ch lambs than in kids (Table 2), while for PUFA content there were no clear differences between kids and Ch lambs.

Lipid quality indices

There has been increasing interest over recent years to investigate more about the implications of fat consumption on human health and various fatty acid ratios have been proposed as recommendations (Van Horn *et al.*, 2008). For some time, the *n*-6/*n*-3 ratio has been used as an indicator of the role of fatty acids in the incidence of cardiogenic diseases. Nutritionists reported that a balance in the diet between *n*-6 PUFA and *n*-3 PUFA with a ratio below 4 is recommended to prevent coronary heart diseases. The *n*-6/*n*-3 ratio of IMF in kids and Ch lambs shown in this work (Table 1) is in line with the ratios reported for commercial Spanish lambs (range 6.4 to 8.4; Díaz *et al.,* 2005) and higher that those reported by Sinanoglou *et al.* (2013) in Greek breeds of small ruminants (range 2.9 to 5.8). Ch lambs and MG kids displayed a higher and unfavourable *n*-6/*n*-3 ratio than meat kid breeds (BC, Mo and NS), as they showed the highest percentage of PUFA C18:2 *n*-6*c* and lowest of long chain *n*-3 fatty acids (C20:5*n*-3; C22:5*n*-3 and C22:6*n*-3) (Table 1). These differences can be attributed to differences in carcass fatness between kids from meat breeds and kids from dairy breeds (MG) and Ch lambs. Sañudo *et al.* (2012) reported higher carcass fatness in MG and Ch lambs than meat kid breeds when carcass weight was used as a covariate.

The AI can be considered a suitable measure of the atherogenicity of foods (Ulbricht & Southgate, 1991). In general, ranges of 0.5 to 1 in meat fats have been reported (Turan *et al.*, 2007), while values less than 0.5 have been described in vegetables oils. In this work, the AI was in the range described for meat (0.70-0.75). Significant differences in the AI between breeds were not observed. This finding suggests that in small ruminants this ratio is not influenced by genetics factors or differences in fat deposition. However, Sinanoglou *et al.* (2013) reported significant differences in the hypercholesterolemic index (sum of C14:0 and C16: 0) in the IMF between kids and lambs. According to these authors, these differences are mainly associated with genetic factors.

Desirable fatty acids can be considered as a good indicator of the relative nutritional meat values of different animal species (Huerta-Leidenz *et al.*, 1991). This index includes MUFA + PUFA and C18:0. These fatty acids, that represent the majority of muscle fat,

have favourable implications on consumers' health. In fact, it has been reported that C18:1*n*-9*c* decreases blood cholesterol content (Binkoski *et al.,* 2005). The average percentage of desirable fatty acids of IMF in kids and lambs was greater than 68%. Other authors reported similar results in other goat breeds (range 67-70%; Mushi *et al.*, 2010), while somewhat lower values have been reported on Manchego lambs (66.3%; Cañeque *et al.*, 2005). No significant differences in the composition of desirable fatty acids among the four breeds of goats and Ch lambs were observed (Table 2), indicating that genetic factors might not influence the desirable fat content in suckling small ruminant.

Conjugated linoleic acid isomers (CLA) have received much attention due to their health promoting effects. In fact, a putative anti-atherogenic effect of CLA 9*c*,11*t* has been considered (Pariza *et al.,* 2001). IMF from meat kids (BC, Mo and NS) showed a higher ($p < 0.05$) percentage of CLA than dairy kids (MG) and Ch lambs. While, in KKF highest CLA 9*c*,11*t* content was observed in Ch lambs (Table 2). Hence, in young small ruminants, the effects of purpose, breed or species on CLA content is not clear and other factors such as the composition of mother milk or differences in desaturase activity of fatty acids from IMF and KKF should be considered.

Principal component analysis

Two principal components analyses (PCA), including the main ratios obtained from the fatty acid profile of IMF and KKF were performed. In the PCA of the IMF, Ch lambs were located with MG kids on the left side, close to PUFA (Fig. 1a). In the opposite side, SFA content was closer to the Mo and BC kid breeds. This result would show the differences in the fatty acid composition between fatter carcasses (MG and Ch) and leaner carcasses (BC and Mo). This observation is in agreement with results reported by Horcada *et al.* (2012) from various Spanish goat breeds. On the other hand, Ch lambs appeared clearly distinguished in a different quadrant (lower left) from goat breeds. The PCA including various fatty acid ratios and indices of KKF (Fig. 1b) shows a clear separation between Ch lambs and all kid breeds according to Function 1. Ch lambs were located on the right side of the Fig. 2 close to CLA and MUFA, in agreement with their higher values for MUFA and CLA 9*c*,11*t* in KKF depot (Table 2).

In a recent work using various lipid quality indices from Greek breeds, Sinanoglou *et al*. (2013) showed that PCA analysis is an efficient tool for the classification of small ruminant breeds and species because each one has their own characteristic lipid profile. This observation can be reported for commercial carcasses of Spanish kids and lambs when lipid quality indices of IMF and KKF depots are included in PCA analysis.

In conclusion, the most evident differences in fatty acid profiles in tissues were observed between meat goat breeds and lambs, whilst similarities between the dairy goat breed and lambs were detected. The use of intramuscular and kidney knob fat depots to discriminate commercial suckling kids and lambs according to their fatty acid profiles could be suggested. The fact that intramuscular fat from suckling kid and lamb meat show an appropriate lipid indices associated with low fat content, indicates that moderate consumption of suckling kid and lamb meat may contribute to an overall balanced diet for humans.

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