Journal of Food Composition and Analysis 102 (2021) 104019

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Original research article

Nutrient composition of Spanish small ruminants

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ARTICLE INFO

Keywords:
Cholesterol
Fatty acids
Light lamb
Minerals
Proximate composition
Suckling kid
Suckling lamb
Vitamins

ABSTRACT

In order to update the Spanish food composition database, 4 males from each of the following breeds and commercial categories were selected: suckling kids of Murciano-Granadina breed, suckling lambs of Churra and Castellana breeds, and light lambs of Manchega, Merina, Rasa Aragonesa and Segureña breeds. These breeds correspond with the highest census of goats and sheep of Spanish breeds, are located throughout the country, and represent a large proportion of the meat from small ruminants produced in Spain. The shoulder, loin + rack and leg were used. Tissue composition through the dissection of the shoulder was assessed. The edible portion of each joint was obtained to analyze the proximate, fatty acid, cholesterol, mineral and vitamin compositions. For those consumers who want to reduce the intake of fat in their diet, the leg or the shoulder are the recommended joints with a lower fat content than the loin + rack. Meat from Spanish small ruminants is an excellent source of quality nutrients, being high in protein, zinc, pyridoxine and cyanocobalamin, and a source of selenium, phosphorus, potassium and niacin, as well as low in sodium. Therefore, its consumption within a balanced diet guaranties the intake of valuable and essential micronutrients.

1. Introduction

Autochthonous sheep and goat breeds are adapted throughout the world to different environments, which implies several commercial categories according to the breeds, feeding systems or slaughter age. Lamb and goat meat are considered traditional products with scarce development in intensive husbandry systems, although improvements have been assumed in the development of fattening units in Mediterranean areas, in order to obtain a homogenous lamb avoiding the variation in production and fluctuation in price both for producers and consumers (Campo et al., 2016b).

In the case of sheep and goat, the influence that traditional feeding regime associated to local husbandry systems has on fat composition is very strong. Grazing systems are associated to older animals at retail with a larger amount in the meat of *n*-3 polyunsaturated fatty acids and α-tocopherol levels naturally present in the pasture. However, concentrate fed-regimes traditional in Southern Europe are associated to young animals with light carcasses less than 13 kg (EU, 2013, 2017) and a larger composition of *n*-6 polyunsaturated fatty acids in the meat, as a reflection of the composition of the cereals and legumes present in the concentrate-base feeding (Díaz et al., 2005). These concentrate fed animals can be slaughtered with less than 3 months old, whereas grass fed animals will need at least 4 months of age to reach a similar carcass weight (Díaz et al., 2005), which is the main classification criteria at the abattoir. In Mediterranean areas another traditional product is obtained from dairy breeds, both sheep and goats (Guerrero et al., 2018; Sañudo et al., 2013). Animals are slaughtered at a very young age at just under one-month old having received only maternal milk or milk replacers as feed. These suckling animals represent 24 % of the total lamb and 81 % of the total goat production in Spain in terms of number of animals, whereas the light lamb under 13 kg of cold carcass weight represents 46 % of the slaughtered animals in the country (MAPA, 2016). Its meat is highly appreciated by Southern European consumers (Sañudo et al., 2013), being most of them included in Geographical Protected Indication labels under the EU Program, that guarantee the breed, origin and husbandry practices.

The decrease in meat production of small ruminants is especially important over recent years, with a 30 % reduction in value between

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https://doi.org/10.1016/j.jfca.2021.104019
Received 11 January 2021; Received in revised form 14 April 2021; Accepted 1 June 2021
Available online 6 June 2021

2003 and 2018 (MAPA, 2019). On top of the difficulties of the sector such as generational uncertainty or abandonment of farming (Bernués et al., 2011), the decrease in meat consumption in general and that of lamb in particular is a major issue. Consumption in Spain has passed from 2.67 kg per capita of fresh lamb and goat meat in 2003 to 1.33 kg per capita in 2018 (MAPA, 2019). In part this decrease is favoured by recommendations in reducing the consumption of red meat based on fat characteristics (Scollan et al., 2017), even when its regular consumption has been associated to similar metabolic responses compared to the consumption of white meat (Mateo-Gallego et al., 2012; Mesana et al., 2013).

The national databases should reflect the changes in local product composition and be continually updated, since different husbandry practices or even genetic selection can change the composition of the meat (Knight et al., 2020). Nutrient composition of these databases is essential for dietitians, health practitioners or patients with specific nutritional needs. In Spain, we have performed this research with the aim of updating the national database of food composition (BEDCA), using the most common and representative categories of small ruminants in the country (suckling kid, suckling lamb and light lamb) and main cuts (shoulder, loin + rack and leg), focused on nutrients that appear in the database and that are compatible with other databases worldwide. An effort has been made in the selection of the material, in order to make it representative of the large variety of existing breeds and trading labels.

2. Material and methods

2.1. Material

All reagents were HPLC grade (Panreac, Barcelona, Spain). Methyl tridecanoate (C13:0) and 5α- cholestane were used as internal standards (Sigma-Aldrich, Buchs, Switzerland) for fatty acid and cholesterol analyses, respectively. Retinol, α-tocopherol, cholecalciferol and phylloquinone were used as standards for fat soluble vitamin analyses. Ascorbic acid, thiamin, riboflavin, nicotinic acid, nicotinamide, pyridoxin, pyridoxamine, panthothenic acid, biotine, folic acid and cyanocobalamin were used as standards for water soluble vitamin analyses.

2.2. Animals

All animals used in this study were slaughtered at a EU-licensed abattoir following commercial practices with electrical stunning. Twenty-four hours after slaughter, four male carcasses of each of the following breeds and commercial categories were selected at each processing plant: suckling kid of Murciano-Granadina breed, suckling lamb of Churra and Castellana breeds, and light lamb of Manchega, Merina, Rasa Aragonesa and Segureña breeds. The general characteristics of the commercial categories for each breed, and the specific cold carcass weight of the animals in the study are shown in Table 1. Murciano-Granadina is the most popular autochthonous Spanish goat dairy breed, located throughout the country, and kids were sampled in Granada (Andalucía, South of Spain) for this study. Churra and Castellana breeds are two sheep dairy breeds orientated to the production of cheese, and their suckling lambs were obtained in Zamora (Castilla-León, West of Spain). Manchega's lambs were obtained in Albacete (Castilla-La Mancha, Centre of Spain). Merino is the largest Spanish breed by census, and lambs were obtained in Badajoz (Extremadura, Southwest of Spain). Rasa Aragonesa is the second largest Spanish breed by census, and lambs were obtained in Zaragoza (Aragón, Northeast of Spain). Finally, Segureña lambs were obtained in Jaen (Andalucía, South of Spain). More information about these breeds can be found in MAPA (2020). All animals had been reared under common husbandry practices, fed with maternal milk or milk replacers in suckling animals, and cereal-based concentrates and straw ad libitum, starting before weaning took place, in light lambs (Campo et al., 2016b). They were representative of their breeds and commercial category, being chosen at the abattoir by their respective Farmers associations. These regions contribute to 81.4 % of the Spanish lamb census (MAPA, 2019). Among Spanish goats, 68.9 % of the females are from dairy breeds, and the dairy breed used in this study accounts for 39.8 % of the total goats in Spain (MAPA, 2019). The breeds in this study correspond with the highest census of goats and sheep of Spanish breeds, and are located throughout the country, representing a large proportion of the meat from small ruminants produced in Spain.

2.3. Sampling

At each processing plant, 24 h after slaughter each carcass was longitudinally split. From the left side, the shoulder, leg and loin + rack cuts were obtained, following standardized procedures previously used (Colomer-Rocher et al., 1988) guided by anatomical points (Campo et al., 2016a). After weighing, the bone was separated from the edible portion that comprised muscle and all visible adipose tissues with a knife by a worker at the processing plant. Then, bone and edible tissues were weighed again in order to calculate the percentage in relation to each joint. These edible tissues were ground in a cutter SAMMIC-SK3 (Sammic S.L., Azcoitia, Spain) at 1700 rpm for 30 s. Afterwards, ground samples from each cut and animal were taken, vacuum packaged, immediately frozen and kept at −18 °C until analysed for proximate composition, fatty acid, cholesterol, mineral and vitamin analyses.

2.4. Tissue composition

From the right side carcass, the shoulder was also obtained at the processing plant (Colomer-Rocher et al., 1988), vacuum packaged and kept at −18 °C until analyzed in the lab. After thawing the joint at 4 °C keeping the vacuum, the tissue composition was calculated by dissecting all tissues with a scalpel and weighing the muscle, subcutaneous and intermuscular fats, bone and other tissues in relation to the weight of the thawed shoulder.

Table 1
General characteristics of the animals produced in each breed and commercial category and average cold carcass weight of the animals in the study.

	Suckling kid	Suckling lamb		Light lamb				SEM	*P* breed
	MG	CH	CA	MA	ME	RA	SE		
n	4	4	4	4	4	4	4		
Weaning age *days*	20–25	25–30	25–30	30–40	50–60	45–50	45–50		
Weight at weaning *kg*	8–9	11–12	11–12	10–11	15–16	14–15	14–15		
Age at slaughter *days*	20–25	25–30	25–30	75–85	85–90	85–90	85–90		
Slaughter weight *kg*	8–9	11–12	11–12	26–28	25–26	25–26	25–26		
Cold carcass weight *kg*	5.92 c	6.88 c	6.63 c	12.91 a	11.67 b	12,05 ab	11.36 b	0.54	<0.001

Breeds: MG: Murciano Granadina, CH: Churra, CA: Castellana, MA: Manchega, ME: Merina, RA: Rasa Aragonesa, SE: Segureña.
MSE: Mean Standard Error.
a,b,c: values with different letters differ significantly ($P < 0,05$).

2.5. Proximate composition

After thawing under vacuum conditions, minced samples were subjected to the determination of moisture (ISO, 1997), total fat (ISO, 1973), protein (ISO, 1978) with a conversion factor of 6.25 and total ash (ISO, 1998). All analyses per cut were performed in duplicates.

2.6. Fatty acid analysis

Total lipids were extracted from each minced sample in chloroform: methanol (Bligh and Dyer, 1959). The fatty acid methyl esters (FAMES) were prepared by basic transesterification with KOH (2 N in methanol). FAMES were analyzed by GC-FID (7820A, Agilent Technologies) ISO (1995). A HP-88 column (60 m × 0,25 mm × 0,25 um), Helium was used as a carrier gas and C13:0 as an internal standard. C12:0, C14:0, C14:1, C15:0, C16:1, C17:0, C17:1, C18:0, C18:1 *n*-9, C18:2 *n*-6, C18:3 *n*-3, *c*9*t*11C18:2, C20:4 *n*-6, C20:5 *n*-3 and C22:6 *n*-3 have been quantified. Saturated, monounsaturated and polyunsaturated fatty acids have also been calculated.

2.7. Cholesterol analysis

From the extracted lipids by Bligh and Dyer method (1959), 100 mg of fat were saponified. From the unsaponified fraction the cholesterol was derivatized with BSTFA (N,O-Bis(trimethylsilyl)trifluoroacetamide) and analyzed by GC-FID (7820A, Agilent Technologies) (Guardiola et al., 1994). A HP-5 (5% phenyl-95 % dimethyl polysiloxane) column, with He as a carrier as and 5α- cholestane as an internal standard were used.

2.8. Mineral composition

After thawing the samples at 15−17 °C during 30′, each mince sample was hydrolysed with nitric acid (Türkmen and Ciminli, 2007). Detection and quantification was performed by ICP-MS (PerkinElmer Elan DRC-e) in the case of selenium, and ICP-OES (Thermo Elemental IRIS Intrepid) in the case of calcium, iron, potassium, magnesium, sodium, phosphorus and zinc.

2.9. Vitamin composition

2.9.1. Fat soluble vitamins

After thawing at 4−7 °C, in each mince sample the fat soluble vitamins A (Valls et al., 2007), E (Piironen et al., 1985) and D (Thompson et al., 1993) were extracted with saponification processes, using pyragallol as an antioxidant. The vitamin K was extracted by solid-liquid extraction (Elder et al., 2006). HPLC-DAD (1260 Infinity II, Agilent Technologies) was used to assess vitamins A (ISO, 2000), D (ISO (2009), and K (Mata-Granados et al., 2004). Vitamin E was analyzed by HPLC and fluorescence detection (ISO, 2014).

2.9.2. Water soluble vitamins

After thawing at 4−7 °C, in each mince sample the water soluble vitamins: B1 (thiamin), B2 (riboflavin), B3 (niacin), B5 (panthotenic acid), B6 (pyridoxine), B8 (biotin), B9 (folates and folic acid), B12 (cyanocobalamin) and C (ascorbic acid) were extracted by acid-enzymatic hydrolysis according to Esteve et al. (1998); Barna and Dworschak (1994), and Leporati et al. (2005). Detection and quantification were performed by LC–MS (1290 Infinity II UHPLC and 6470 triple quadrupole MS detector, Agilent Technologies). Two columns were used, Zorbax C18 column (100 mm × 2,1 mm × 1,8 um, Agilent Technologies) for vitamins B2, B5, B8, B9, B12 and C and HILIC column (100 mm × 3 mm × 3um, Phenomenex) for vitamins B1, B3 and B6.

2.10. Quality control

Reproducibility of measurements for proximate analyses were performed through intercomparative tests across batches, following ISO 9001 (2015) certification procedures. The methods were also validated through participation in an accredited laboratory proficiency test organized by the Food Analysis Performance Assessment Scheme (FAPAS).

For fatty acid analysis, a food-based reference material was used from ASICI (Zafra, Badajoz, Spain). Standard mixtures of known concentration were added to the matrix, and all the extraction procedures were undertaken. Z-scores and recovery were calculated. Blank samples with hexane were run together in each batch. Individual FAMEs were identified by comparing their retention time with those of standards for all fatty acids analysed supplied by Sigma Aldrich (Sigma-Aldrich, Buchs, Switzerland). The same procedure was applied for cholesterol analyses, using 5α- cholestane with increased concentrations to the matrix.

For verification of precision and accuracy in minerals, TMDA 64.3 and TM 15.3 (Environmental and Climate Change Canada, Ottawa, Canada) matrix were used as certified reference materials in ICP-OES and ICP-MS, respectively. Linearity was assessed with 5 samples of a standard of known concentration.

For vitamin assessments, precision and accuracy were assessed using recovered standards added to the matrix. Additionally, Z-scores were calculated.

2.11. Data management

Commercial category includes those breeds associated to each product. A General Lineal Model (GLM) was used with SPSS 26.0 to assess differences in carcass weight due to the breed or in tissue composition of the shoulder due to the commercial category. A GLM was also used to assess differences in proximate, fatty acid, cholesterol, mineral and vitamin composition, considering commercial category (suckling kid, suckling lamb and light lamb) and cut (shoulder, loin + rack and leg) as fixed effects, together with their interactions. A Tukey test has been applied to find differences between mean values considering the breed (for cold carcass weight), the commercial category, the cut or the interaction between commercial category and cut.

3. Results

3.1. Carcass weight and joint composition

Suckling animals, both kids and lambs, showed lighter carcasses than light lambs ($P < 0.001$, Table 1). Within light lambs, Manchega carcasses were heavier than Merino and Segureña carcasses.

One third of the whole carcass corresponds to the leg, independently of the species and commercial type (Table 2). The shoulder varies in average between 18.2 % in the suckling lamb to 22.0 % of the whole carcass in the suckling kid. The loin + rack is the joint with the largest variation in relation to the whole carcass, with values between 21.3 % in the suckling kid and 29.5 % in the suckling lamb.

Large differences in edible tissues have been found in the different commercial cuts ($P < 0.001$) and products ($P = 0.002$). In terms of edible portion (Table 2), the loin + rack shows the highest percentage of bone ranging from 32.3 % in light lamb to 39.2 % in suckling lamb. The shoulder and the leg have a similar percentage of edible tissues in light lamb, but the leg has 0.7 percentage points less of muscle + visible fat tissues in the suckling kid and 1.5 points less in the suckling lamb than the shoulder.

3.2. Tissue composition

Muscle is the most abundant tissue in the shoulder and, therefore, in

Table 2
Percentage of commercial cuts (in relation to the half carcass), muscle + visible fat and bone of Spanish small ruminants.

	Suckling kid			Suckling lamb			Light lamb			MSE	Product	Cut	PxC
	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg				
n	*4*	*4*	*4*	*8*	*8*	*8*	*16*	*16*	*16*				
% over carcass	22.6 de	21.3 e	35.4 a	18.2 e	29.5 bc	32.8 ab	19.5 e	26.9 cd	33.6 ab	0.72	0.936	<0.001	0.983
% muscle + visible fat	73.6 a	66.7 ab	72.9 a	67.1 ab	60.8 b	65.6 ab	75.7 a	67.7 ab	76.0 a	1.04	<0.001	0.002	0.946
% bone	26.3 b	33.3 ab	27.1 b	32.0 ab	39.2 a	34.5ab	24.3	32.3 ab	24.0 b	0.62	<0.001	0.002	0.946

MSE: Mean Standard Error.
a,b,c, d, e: values with different letters differ significantly ($P < 0,05$).

the carcass (Table 3). The smallest percentage of muscle appears in the suckling lamb (57.6 %) and the largest in the suckling kid (61.6 %, $P < 0.01$). Light lamb shows the smallest percentage of bone (21.8 %) associated to the largest total fat (16.2 %), both due to the higher percentages of subcutaneous (9.27 %) and intermuscular (6.92 %) fat depots ($P < 0.01$). Suckling lambs had the lowest subcutaneous fat percentage (6.99 %) and suckling kids the lowest intermuscular fat (4.85 %).

3.3. Proximate composition

Moisture content is very homogenous in suckling lamb in each joint (67.1–67.4 g/100 g), but is lower in the loin + rack than in the leg and shoulder in light lamb (Table 4). This is related to the higher fat content in the loin + rack in light lamb (18.5 g/100 g) in comparison with the leg (12.1 g/100 g). All ash content is fairly constant between 0.9–1−1 g/100 g in each joint and animal type, with higher values in the leg of suckling lamb and lower in the loin + rack of both suckling kid and light lamb.

3.4. Fatty acid composition

The highest differences in the amount of fatty acids appeared due to the commercial category, especially because of oleic acid content ($P < 0.001$, Table 4) which contributed to the large differences in monounsaturated fatty acids (MUFA) content. The leg as the leanest joint in each product showed the lowest amount of MUFA in the edible tissues, together with the shoulder in suckling lamb.

Saturated fatty acids ranged between 4.54 and 6.39 g/100 g in the loin + rack and leg in light lamb, respectively, and 4.14 and 5.47 g/100 g in suckling lamb, with suckling kids showing intermediate values. MUFA, from which oleic acid was the most abundant fatty acid in the whole profile, ranged between 4.38 and 6.17 g/100 g in light lamb and 4.03 and 5.29 g/100 g in suckling lamb. Polyunsaturated fatty acids (PUFA) ranged between 0.62 and 0.88 g/100 g in light lamb and 0.56 and 0.75 g/100 g in suckling lamb, showing the lowest fatty acids variation between animal types. *n*-3 PUFA did not show a significant contribution to the fatty acid profile, with very low values even in the case of α-linolenic acid, which provoked a ratio *n*-6 PUFA/ *n*-3 PUFA fairly constant between joints and products ranging between 7.20 and 7.65.

Table 3
Tissue composition (g/100 g) of the shoulder of three different commercial categories of Spanish small ruminants.

	Suckling kid	Suckling lamb	Light lamb	MSE	*P* Product
n	*4*	*8*	*16*		
Muscle	61.6 a	57.6 b	60.7 a	0.48	0.003
Subcutaneous fat	9.26 a	6.99 b	9.27 a	0.32	0.003
Intermuscular fat	4.85 b	5.94 ab	6.92 a	0.25	0.006
Total fat	14.1 ab	12.9 b	16.2 a	0.45	0.002
Bone	23.1 b	27.6 a	21.8 b	0.61	<0.001
Other tissues[1]	1.19 b	1.84 a	1.37 b	0.07	<0.001

MSE: Mean Standard Error.
a,b: values with different letters differ significantly ($P < 0,05$).
[1] Veins, lymph nodes, etc.

3.5. Cholesterol

The amount of cholesterol was species dependent and was not fully related to the amount of fat (Table 4). Although the leg was the joint with the highest cholesterol content in each commercial category, suckling lamb showed the highest amount of cholesterol in each joint, varying from 75.0 mg/100 g in the shoulder to 76.5 mg/100 g in the leg. Suckling kid and light lamb showed similar composition in the loin + rack (64.4 mg/100 g), while suckling kid had the lowest content of all commercial types in the shoulder (61.8 mg/100 g) and in the leg (65.8 mg/100 g).

3.6. Mineral composition

Mineral composition is indicated in Table 5. The most abundant mineral was potassium (ranging between 249 and 324 mg/100 g), followed by phosphorus (157−213 mg/100 g), sodium (64.1–89.1 mg/100 g), magnesium (15.8–21.4 mg/100 g) and calcium (7.27–13.7 mg/100 g). This tendency in mineral abundance was similar for all commercial categories and joints.

Light lamb showed the highest amount of iron (1.11−1.24 mg/100 g), zinc (3.08–3.68 mg/100 g) and selenium (11.7–12.5 ng/100 g) among the commercial categories. Selenium was the most variable mineral, with suckling lambs showing the lowest values at each joint (6.54–8.07 ng/100 g).

3.7. Vitamin composition

Data of vitamin A, B7, C and K are not shown since their abundance was lower than the detection level of the techniques used (0.03 mg/100 g, 4.0 μg/100 g, 0.02 mg/100 g and 0.05 mg/100 g, respectively). The most abundant vitamin was niacin, ranging between 2.63 and 4.34 mg/100 g, followed by pyridoxine (0.53−0.83 mg/100 g). α-tocopherol was lower in suckling lamb (0.12−0.17 mg/100 g), showing almost half the amount present in suckling kid and light lamb (0.23−0.31 mg/100 g). Folate varied between 3.44 and 4.67 μg/100 g, and cyanocobalamin between 1.61 and 2.62 μg/100 g.

4. Discussion

4.1. Joint composition

The differences in cold carcass weight between the commercial categories are a reflection of their slaughter age, below 30 days old in the

Table 4
Proximate (g), fatty acid (g) and cholesterol (mg) composition [/100 g of edible portion (muscle + visible fat)] of the three main commercial cuts of three different commercial categories of Spanish small ruminants.

	Suckling kid			Suckling lamb			Light lamb			MSE	*P* Product	*P* Cut	*P* PxC
	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg				
n	*4*	*4*	*4*	*8*	*8*	*8*	*16*	*16*	*16*				
Proximate composition													
Moisture	65.8ab	64.5b	67.4a	67.1a	67.4a	67.4a	66.9a	63.4b	68.0a	0.35	0.214	0.022	0.099
Protein	18.6 abcd	17.1 d	18.8 abcd	19.5 a	18.5 abcd	19.2 ab	17.6 bcd	17.3 cd	19.0abc	0.14	<0.001	<0.001	0.099
Fat	14.6 ab	17.5 ab	12.8 ab	12.4 b	13.1 ab	12.3 b	14.5 ab	18.5 a	12.1 b	0.43	0.016	0.001	0.120
Ash	0.97 ab	0.91 b	1.03 ab	1.08 ab	1.04 ab	1.11 a	0.93 ab	0.92 b	0.99 ab	0.01	<0.001	0.027	0.947
Fatty acid composition													
C12:0	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.04	0.974	0.844	0.916
C14:0	0.38	0.43	0.31	0.32	0.39	0.29	0.38	0.46	0.33	0.23	0.897	0.970	0.951
C14:1	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.201	0.585	0.780
C15:0	0.09	0.79	0.08	0.08	0.81	0.07	0.10	0.79	0.08	0.05	0.583	0.532	0.979
C16:0	2.63	3.07	2.21	2.29	2.77	2.09	2.69	3.22	2.29	0.61	0.354	0.787	0.977
C16:1	0.17	0.18	0.14	0.14	0.16	0.13	0.16	0.20	0.14	0.20	0.837	0.858	0.873
C17:0	0.33	0.41	0.28	0.29	0.34	0.27	0.34	0.41	0.29	0.25	0.951	0.747	0.912
C17:1	0.21	0.23	0.17	0.18	0.20	0.16	0.20	0.24	0.17	0.17	0.773	0.649	0.939
C18:0	1.72	2.03	1.44	1.50	1.81	1.36	1.77	2.11	1.50	0.29	0.619	0.749	0.987
C18:1 *n*-9	4.76 b	5.64 a	3.99 c	4.04 c	4.86 b	3.70 c	4.76 b	5.66 a	4.02 c	0.68	<0.001	0.685	0.876
C18:2 *n*-6	0.49	0.57	0.41	0.42	0.50	0.38	0.50	0.59	0.41	0.11	0.560	0.330	0.952
C18:3 *n*-3	0.05	0.05	0.03	0.04	0.05	0.04	0.05	0.06	0.04	0.05	0.618	0.846	0.948
CLA	0.07	0.07	0.05	0.06	0.07	0.05	0.07	0.08	0.06	0.08	0.826	0.817	0.869
C20:4 *n*-6	0.06	0.06	0.05	0.05	0.06	0.04	0.05	0.07	0.05	0.04	0.310	0.786	0.670
C20:5 *n*-3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.933	0.989	0.997
C22:6 *n*-3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.746	0.638	0.581
SFA	5.20	6.12	4.37	4.54	5.47	4.14	5.34	6.39	4.54	0.75	0.285	0.655	0.967
MUFA	5.19 b	6.12 a	4.34 c	4.41 c	5.29 b	4.03 c	5.17 b	6.17 a	4.38 c	0.70	<0.001	0.629	0.934
PUFA	0.73	0.84	0.60	0.62	0.75	0.56	0.74	0.88	0.62	0.14	0.544	0.340	0.700
PUFA/SFA	0.14	0.14	0.14	0.14	0.14	0.13	0.14	0.14	0.14	0.003	0.152	0.210	0.824
n-6 /*n*-3[1]	7.55	7.50	7.65	7.38	7.43	7.30	7.30	7.38	7.20	0.64	0.448	0.970	0.980
Cholesterol composition													
	61.8 c	64.3 c	65.8 c	75.0 ab	75.1 ab	76.5 a	65.7 c	64.4 c	68.0 bc	6.39	<0.001	0.151	0.816

MSE: Mean Standard Error.
CLA: conjugated linoleic acid *c9t11*C18:2.
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.
a,b,c, d: values with different letters differ significantly ($P < 0,05$).
[1] *n*-6 PUFA/*n*-3 PUFA.

suckling animals and over 70 days old in light lambs. Animals older than 3 months old would produce carcasses considered as ‘heavy lamb’ characteristic in other husbandry systems with grazing (Fowler et al., 2019). The commercial cuts used in this study represent approximately 73 % of the whole carcass in light lambs as previously found in Rasa Aragonesa breed (Campo et al., 2016a). This value is lower than 78 % found in Canaria breed (Camacho et al., 2015), which has been assigned to a different morphology with a higher shoulder development and not to a specific production aptitude (Canaria breed is a dairy breed whereas Rasa Aragonesa breed is an unimproved breed more orientated towards lamb production). Other authors have identified different percentages of different cuts in different breeds at different slaughter weights (Badiani et al., 1998; Sheridan et al., 2003), that makes indispensable the analysis of local products (Campo et al., 2016a).

The heavier the weight of the animal, the larger amount of muscle and fat in relation to the amount of bone that appears in each joint. This is very clear in lamb, with values in light lamb that exceeds in 8.6 percentage points in the shoulder and 10.4 percentage points in the leg those values of the suckling lamb. These are related to the development of the body as the animal grows, since the posterior part of the animal is later at maturing in relation to the front part, meaning that the rear of the animal will incorporate fat at a slower rate and later than that found in the shoulder. However, this is also species dependent where with similar husbandry practices, even though a few days younger, suckling kids have edible proportions intermediate between light lambs and suckling lambs, showing a faster development of these edible tissues than lamb at these initial live stages. In fact, goats are more precocious than sheep also at the reproductive level (Abecia et al., 2016; Chasles et al., 2019).

4.2. Tissue composition

The tissue composition of the shoulder is considered representative of the tissue composition of the whole carcass. Therefore, with the effort of dissecting just one joint, the whole carcass tissue composition can be calculated at a cheaper economical and labour cost. This applies to lamb and goat (Camacho et al., 2015; Santos et al., 2017), because in beef a rib is used (McEvers et al., 2018; Robelin and Geay, 1975). Bone percentage did not coincide exactly between the values obtained at the processing plant in the left shoulder, and at the lab in the right shoulder. The dissection with a scalpel is more precise than the dissection at the processing plant with knives, which causes leftovers of muscle that remains attached to the bone at the processing plant, increasing the value of non-edible tissues. This happens as well at a commercial level when deboned joints are sold.

Adipose tissue is the most variable tissue in farm animals at slaughter weights because it grows faster as age increases (Abdullah and Qudsieh, 2009). Although the shoulder of suckling kids showed similar subcutaneous fat percentage than light lambs, kids were much younger and showed the smallest percentage of intermuscular fat, even lower than suckling lambs. This relates to the late fat deposition of intermuscular fat depot in relation to subcutaneous fat, and the tendency in goats of

Table 5
Mineral and vitamin composition [mg[1], μg[2], ng[3]/ 100 g of edible portion (muscle + visible fat)] of the three main commercial cuts of three different commercial categories of Spanish small ruminants.

	Suckling kid			Suckling lamb			Light lamb			MSE	*P* Product	*P* Cut	*P* PxC
	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg	Shoulder	Loin + Rack	Leg				
n	*4*	*4*	*4*	*8*	*8*	*8*	*16*	*16*	*16*				
Mineral composition													
Calcium[1]	13.7	9.56	9.94	8.09	10.7	11.2	8.16	13.3	7.27	0.58	0.664	0.531	0.060
Iron[1]	0.81 ab	0.57 b	0.63 b	0.78 ab	0.86 ab	0.98 ab	1.12 ab	1.11 ab	1.24 a	0.04	<0.001	0.602	0.740
Potassium[1]	288 ab	249 b	296 ab	289 ab	292 ab	324 a	285 ab	265 b	301 ab	4.00	0.056	0.002	0.646
Magnesium[1]	18.8	15.8	18.7	17.9	19.7	21.4	18.9	18.9	20.8	0.44	0.344	0.200	0.731
Sodium[1]	85.1 ab	64.1 b	71.4 ab	81.4 ab	89.1 a	81.6 ab	77.2 ab	75.7 ab	67.5 ab	1.57	0.006	0.171	0.144
Phosphorus[1]	188 ab	157 b	191 ab	178 ab	192 ab	213 a	175 ab	172 ab	193 ab	3.36	0.120	0.019	0.476
Selenium[3]	10.6 ab	7.79 b	9.10 ab	6.54 b	6.63 b	8.07 ab	12.5 a	11.7 ab	12.3 a	0.41	<0.001	0.395	0.740
Zinc[1]	3.15 ab	2.24 b	2.53 ab	3.16 ab	2.69 ab	3.11 ab	3.68 a	3.35 ab	3.08 ab	0.11	0.037	0.136	0.702
Vitamin composition													
Thiamine (B1)[1]	0.13	0.11	0.14	0.14	0.13	0.15	0.14	0.13	0.14	0.04	0.460	0.057	0.482
Riboflavin (B2)[1]	0.10 bc	0.14 a	0.11 ab	0.08 bc	0.09 bc	0.08 c	0.07 c	0.08 c	0.07 c	0.03	<0.001	0.046	0.542
Niacin Vit (B3)[1]	2.63 b	2.72 b	3.40 ab	2.91 ab	2.97 ab	3.46 ab	3.40 ab	4.34 a	3.32 ab	1.00	0.040	0.328	0.656
Pantothenic acid (B5)[1]	0.04	0.06	0.09	0.11	0.16	0.11	0.09	0.12	0.11	0.09	<0.001	0.004	0.002
Pyridoxine (B6)[1]	0.77 ab	0.83 a	0.53 abc	0.51 b	0.54 bc	0.61 abc	0.53 b	0.63abc	0.54 bc	0.15	<0.001	0.320	0.053
Folate (B9)[2]	3.44	4.30	4.61	5.18	4.19	4.67	4.61	4.46	4.16	0.96	0.096	0.111	0.003
Cyanocobalamin (B12)[2]	2.28 ab	1.61 b	2.06 ab	2.45 a	1.82 ab	2.62 a	2.06 ab	1.98 ab	2.53 a	0.56	0.726	<0.001	0.311
α-tocopherol (E)[1]	0.27 a	0.24 a	0.23 a	0.15 b	0.12 b	0.17 b	0.27 a	0.25 a	0.31 a	0.11	0.001	0.538	0.898

MSE: Mean Standard Error.
a,b,c: values with different letters differ significantly ($P < 0,05$).

accumulating fat at other levels than inside the muscle. The effect of age and weight at slaughter is very clear within species, since light lamb shows much higher muscle and fat percentages, both at subcutaneous and intermuscular levels, than suckling lambs (Camacho et al., 2015), and also at the intramuscular level (Martínez-Cerezo et al., 2005). This indicates the relative importance in bone composition, decreased in light lambs, having more edible components than in younger animals.

4.3. Proximate composition

Most studies in the literature focus on a single muscle, mainly the *Longissimus dorsi*, which is commonly used in meat quality studies due to its size. However, this manuscript focuses on edible content, and there are other muscles in each joint, together with subcutaneous and intermuscular fat, that can be consumed. Therefore, the composition does not coincide with most published data, whose fat content can vary between 1.28–2.79 % (Martínez-Cerezo et al., 2005) in similar breeds and at similar or even larger weights than the current study. Miguélez et al. (2008) found higher fat content (17.3 %) in suckling lambs from Churra, Castellana and Ojalada breeds, than the suckling lambs from Churra and Castellana breeds of our study, in smaller animals (5.5 kg cold carcass weight). The inclusion of all joints in their analysis might have increased those values, since the fattiest joints of the carcass are the breast and the flank [42.1 and 20.8 % fat in the edible tissues, respectively, in light lamb (Campo et al., 2016a)], which were included in the sampling of Miguélez et al. (2008) and that highly increased the fat percentage of the whole carcass. This also supports the separation of intake recommendations by the joint, and not only by the species. Lamb is an example of a large difference in fatness composition in the different cuts. Data in light lamb, however, are similar to those previously found in Rasa Aragonesa breed (Campo et al., 2016a).

Intake of fat should be moderate, below 35 % of the total energy in the diet (EFSA, 2010). In this sense, the fat from the intake of 100 g of edible tissues would contribute between 5.45 % in the case of the leg and 8.33 % in the loin + rack in suckling lamb to the total dietary energy in a diet of 2000 kcal/d. Considering the content of bone of each joint, the fresh product that corresponds to this 100 g of edible tissue would be 132 g and 140 g of leg and loin + rack, respectively. Attending to nutritional claims (EU, 2006), every joint of these commercial categories could be labelled as 'High in protein' since at least 20 % of the energy value is provided by protein. The minimum value would be 30.1 % of the energy coming from protein in the edible portion of loin + rack of light lambs.

4.4. Fatty acid composition

The recommendations in the reduction of meat intake in the diet are partially supported because it is a source of fat, especially of saturated fatty acids in the case of ruminants (Wood et al., 2004). EFSA (2010) recommends a diet as low in saturated fat as possible within a nutritionally adequate diet but also recommends an intake of linoleic acid (*n*-6 essential PUFA) that contributes to 4% of the energy in the diet. In this sense, the amount of linoleic acid would contribute between 0.17 % and 0.27 % to the total energy of the diet (in the case of the leg of suckling lamb and loin + rack of light lamb, respectively). The recommendations of dietary intake around 250 mg of long chain *n*-3 PUFA, mainly eicosapentanoic and docosahexanoic acids, cannot be achieved with the consumption of small ruminants, without compromising the intake of other fats exceeding daily intake recommendations.

The observed ratio *n*-6 PUFA/ *n*-3 PUFA is characteristic of animals that do not graze and have a diet based in cereals and legumes (Wood et al., 2004). This is typical in Mediterranean husbandry systems of small ruminants. In the case of suckling animals, both lambs and kids would reflect in their meat the composition of the milk from the mothers as a result of their diet (Manso et al., 2011). The lack of differences in PUFA/SFA and *n*-6 PUFA/ *n*-3 PUFA between joints supports the previously reported idea that the relative fatty acid composition, considering all edible tissues together, is very similar throughout the animal body (Campo et al., 2016a). Only differences in the amount of fat will make clear differences among joints in the amount of fatty acids at consumption. Data reported in this work are similar to the composition in Rasa Aragonesa lambs (Campo et al., 2016a), with higher oleic acid content, probably due to the effort of producers of incorporating this fatty acid through feed sources high in oleic acid, such as certain varieties of sunflower.

4.5. Cholesterol composition

Previously reported levels in suckling lambs are higher (91.2 mg/100 g, Miguélez et al., 2008) than the current data. This is related to their higher findings in fat content, as a result of the analysis of the total fat of the carcass, including the fattest joints. The presence of other adipose tissues than intramuscular fat increases the content of cholesterol (Napolitano et al., 2002) although most of it is associated to the membranes, and these are present in the muscle in higher number rather than in other adipose tissues. Data in light lambs are similar to those found in other countries in animals of similar commercial characteristics (Van Heerden and Strydom, 2017) and higher than values in mutton (Sainsbury et al., 2011; Van Heerden and Strydom, 2017), that have lower fat content.

4.6. Mineral composition

Minerals are essential nutrients for humans that support many biochemical functions. Differences in minerals are associated to the age of the animals which relates to different fibre development (Pannier et al., 2014) and the mineral composition of their diets. This is why mutton animals (Sainsbury et al., 2011) show higher levels of both zinc and especially iron in relation to light lambs, having higher levels than suckling animals that are two months younger on average. Milk is a low iron feeding source, and the accumulation in the myoglobin increases with age as well as with oxidative fibres, which are less abundant when animals are selected for muscle deposition (Ponnampalam et al., 2019). Spanish breeds have poorer conformation and higher intramuscular fat than meat purpose breeds, such as Texel (Blasco et al., 2019), where this derives in higher oxidative fibres and iron content. Iron content in the leg was identical but zinc was higher than values previously found in Rasa Aragonesa breed (Campo et al., 2013). Within commercial category, the shoulder showed higher zinc content than the loin + rack, coincidentally with previous findings in older animals reared in extensive systems where forequarters cuts showed higher zinc levels (Fowler et al., 2019).

Minerals in suckling lambs were similar to those previously found (Miguélez et al., 2008). Levels in light lamb show less magnesium and sodium and more potassium than levels in South Africa (Sainsbury et al., 2011) or Australia (Ponnampalam et al., 2019) for local products. However, in the same country the levels can vary depending on the husbandry system (Fowler et al., 2019). Therefore, each national database of food composition should be updated with local products' composition. Attending to nutritional claims (EU, 2006), the leg of lambs (either suckling or light lambs) are a source of potassium, having the rest of its joints fairly close to the minimum limit of 300 mg/100 g. All joints of Spanish small ruminants are low in sodium, and can be considered a source of phosphorus and even high in phosphorus in the case of the leg of suckling lamb, that contains higher levels than 210 mg P/100 g which is the limit to be 'high in P'. Light lamb is a source of selenium, as well as the shoulder and leg of suckling kids, all of them over the limit of 8.25 ng/100 g. Light lamb is high in zinc, as well as the shoulder of any animal and the leg of suckling lambs, with values over 3 mg/100 g, being the rest of joints a source of this mineral.

4.7. Vitamin composition

Researchers have focused mainly in α-tocopherol composition due to its implication in animal development in difficult ambient conditions or in meat quality preventing oxidation throughout display. Much data is available on this subject (Bellés et al., 2019), but focused in muscle composition, not on the edible portions. Supplementation with vitamin E increases its content in the muscle. Therefore, it is obvious that suckling lambs have not been supplemented, since they show half of the content than suckling kids or light lambs. However, these values are higher than those found in *semimembranosus* muscle in Lecce lambs (D'Alessandro et al., 2019). In any case, the composition of vitamin E in Spanish small ruminant's edible portion is lower than that found in animals that have grazed or fed higher supranutritional levels in the diet (Wood et al., 2004).

Data found in light lambs are higher in B1, B2 and B6, lower in B3 and similar in B12 vitamins than those found in South African mutton (Sainsbury et al., 2011). According to nutritional claims (EU, 2006), Spanish small ruminants are a source of niacin, with values above 2.4 mg/100 g, and are high in vitamin B6, with values above 0.42 mg/100 g and, especially, high in vitamin B12, with values largely exceeding the limit of 0.75 mg/100 g.

5. Conclusions

The majority of meat from small ruminants produced in Spain come from suckling kids, suckling lambs and light lambs. Their particular husbandry conditions make essential the nutritional analysis of different joints in order to update the national food composition database. Around one fourth of the shoulder and leg, and one third of the loin + rack are bones, which should be taken into account when calculating the real meat consumption. The fat content is at least 12.1 % of the edible portion, but for those consumers who want to reduce the intake of fat in their diet, the leg or the shoulder are recommended joints with less fat content than the loin + rack, The composition of fatty acids is representative of animals whose mothers or they themselves have been fed with cereal-based diets, showing *n*-6 PUFA/*n*-3 PUFA above 7, independently of the joint. Suckling lambs show higher cholesterol content than suckling kids or light lambs. According to nutritional claims, meat from Spanish small ruminants is an excellent source of quality nutrients, being high in protein, zinc, pyridoxine and cyanocobalamin, and a source of selenium, phosphorus, potassium and niacin, as well as low in sodium. Therefore, its consumption within a balanced diet guaranties the intake of valuable and essential micronutrients.

Author statement

Authors' individual contributions to the paper are the following:

Maria del Mar Campo: Conceptualization, Data curation; Funding acquisition; Investigation; Project administration, Resources, Supervision, Visualization, Roles/Writing - original draft.

Antonio Silva: Conceptualization, Data curation; Formal analysis; Methodology, Project administration, Resources, Supervision.

Ana Guerrero: Investigation, Methodology, Validation, Writing - review & editing.

Luis Gustavo Castro: Investigation, Methodology.

José Luis Olleta: Investigation, Methodology, Writing - review & editing.

Noelia Martin: Investigation, Validation.

Carlos Fernández: Investigation, Validation.

Fermín López: Conceptualization; Funding acquisition; Investigation.

Declaration of Competing Interest

The authors report no declarations of interest.

Acknowledgements

Authors want to thank Carlos Sañudo for his help and guidance in the development of this project, Julia Pomed for her technical support, the Organización Interprofesional Agroalimentaria del Ovino y Caprino (Interovic) for financial support, the Cooperative Societies Oviso SCL, Cosegur SCA, Manchacor SL and Oviaragon SC in light lamb, Asovino SCL in suckling lamb and Cosegur SCA in suckling kid, for their help in selecting their respective animals, and the provisioning of their processing plants while obtaining the carcasses, and would like to acknowledge the use of Servicio General de Apoyo a la Investigación-SAI, Universidad de Zaragoza.

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