



## Nutrient composition of beef from the pyrenees

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### ABSTRACT

In order to update national beef composition databases, the nutritional composition of beef from different countries in the Pyrenees mountains has been assessed. Entire young bulls, including 25 animals from Pirenaica breed and 7 from Bruna D'Andorra breed, along with 4 oxen and 4 cows from Gasconne breed, were raised and slaughtered under local conditions in the Spanish, Andorran, or French areas of the Pyrenees. Proximate, fatty acid, mineral and vitamin compositions have been assessed in three different commercial cuts: rump cap, loin and flank. Large differences have been found in fatness, with Pirenaica young bulls showing very lean meat, and the loin cut being the fattest. Pyrenean beef is a source of potassium, phosphorus and selenium, high in protein, zinc and vitamin B3, B6 and B12 and low sodium. Young bulls from Pirenaica beef could also be considered as low fat. Gasconne oxen and cows are a source of iron, and some of their cuts are high in selenium. Husbandry practices such as castration or grazing should be available for consumers or dietitians as a source of information due to their influence in the composition of the meat, which can modify nutrition claims and compliance with recommended intakes.

### 1. Introduction

The Pyrenees is a mountain range shared by Spain, Andorra and France with alpine orogeny and several mountain peaks over 3000 m a.s.l. Their climate is characterised with wide temperature oscillations among seasons, with snow covering the peaks and fields at the bottom of the valleys during the end of autumn and the whole winter, and annual pluviometry over 1200 L/m<sup>2</sup> that is mainly due to storms during summer months. These grasslands provide non-marketable benefits to the society such as biodiversity, cultural landscape and recreation experiences, besides high quality products (Teston et al., 2020). This mountain agroecosystem is characterised by traditional livestock farming systems with animals grazing natural feed resources at different altitude throughout the year (Armengol et al., 2021). As an example of sustainability, some traditional management includes transhumance, where the animals move to higher pastures grazing during summer using the bottom of valley's resources during spring and autumn, being indoor in winter when snowfalls are abundant which make animals have silage

or hay as their main feed ingredient during indoor housing.

Even though there is a common environment in the mountain range, there is a variability in the evolution of farming systems over the last 30 years due to land areas, herd's growth and the presence of fattening units (Muñoz-Ulecia et al., 2021). Although farming systems might coincide in the use of grasslands, intended for the mothers and calves until weaning at around 5–6 months old, they can differ from that age onwards using concentrates, silage or fresh pastures as their main feed (Muñoz-Ulecia et al., 2024). Once calves are weaned they can remain in the area or, more likely, travel to different fattening units until they reach between 12 and 14 mo. Animals from this origin are very appreciated in the country due to the compensatory growth that they can experienced once grazing is substitute by concentrates based on cereals and soya. Feed is an important factor influencing the quality of the product, even in ruminants (Wood et al., 2008) where biohydrogenation in the rumen partially modifies the initial composition of the lipids of the diet. Differences can be found in the fatty acid profile when pasture is included in the diet, increasing the content of *n*-3 polyunsaturated fatty

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acids (PUFA) in the muscle, whereas diets based on cereal-based concentrates are associated to lower *n*-3 and higher *n*-6 PUFA content (Wood et al., 2004; 2008).

Because the Pyrenees comprises 3 countries and covers an extensive area that is a source of beef representative of the meat produced in each country, it has been chosen as the focus of this study. An important effort is being undertaken in updating food composition databases in different species across different countries assessing nutritional composition of meat with current production systems (Campo et al., 2021; Lee et al., 2021; Sainsbury et al., 2011). Nutrient composition of these databases is essential for dietitians, health practitioners or patients with specific nutritional needs to create balance diets. This must be a continuous process due to changes that occur in breeding criteria or husbandry systems with time (Knight et al., 2020). Actually, no data from local beef is currently found in the Spanish national food composition database BEDCA, probably due to the high economical cost of nutritional studies. Therefore, the aim of this work was to assess the nutritional composition of beef from the Pyrenees investigating a variety of breeds and products locally produced, in order to update national food composition databases.

## 2. Material and methods

### 2.1. Material

Before chromatographic stages, reagents were of analytical grade (Panreac, Barcelona, Spain) and deionized water, supplied by a Milli-Q Water System (Millipore Corp., Billerica, MA, USA), was used throughout. Chloroform 99.8 %, methanol 99.9 %, KCl 99.5 %, KOH 85 % and hexane 99.0 % were used for fatty acid analysis. Nitric acid 65 % (Merck, Darmstadt, Germany) was employed to digest the samples for mineral analysis and to prepare all standard solutions. Reagents for chromatography were HPLC grade (Panreac, Barcelona, Spain). Methyl tricosanoate 99.5 % and Supelco 37 Component FAME mix were used as standards (Sigma-Aldrich, Buchs, Switzerland) for fatty acid analysis. Retinol 95.0 %,  $\alpha$ -tocopherol 95.5 %, cholecalciferol 98 % and phylloquinone were used as standards for fat soluble vitamin analyses. Ascorbic acid 99.0 %, thiamine 99.0 %, riboflavin, nicotinic acid 98.0 %, nicotinamide 99.5 %, pyridoxine 98.0 %, pyridoxamine 98.0 %, panthothenic acid 98.0 %, biotine 99.0 %, folic acid 97 % and cyanocobalamin 98 % were used as standards for water soluble vitamin analyses.

### 2.2. Animals

All samples were obtained at processing plants after commercial practices were applied to both the rearing and the slaughtering of the animals. Stunning was performed with captive bolt. The Ethics Committee for Animals Experiments at the University of Zaragoza considered that this project was exempted from the scope of the Directive 2010/63/EU (EU, 2010a) and Spanish Policy for Animal Protection RD53/2013 (BOE, 2013) on the protection of animals used for experimental and other scientific purposes.

In Spain, 25 entire young bulls from Pirenaica breed were used. They were reared in the Sobrarbe region of Aragón, in the Pyrenees, under three husbandry conditions: ecological system, with weaning at 5–7 months old, having pasture, hay and ecological concentrates during winter months afterwards; mixed system with similar weaning and pasture, but finished with concentrates, and fattening units with earlier weaning at around 3–4 months old having concentrates and cereal straw from there onwards without grazing or hay. These three systems are representative of the husbandry conditions of beef production in Spain. Animals were slaughtered at an age of  $13.5 \pm 1.3$  months old with  $343.8 \pm 44.5$  kg cold carcass weight.

In Andorra, 7 entire young bulls from Bruna D'Andorra breed were used. They were reared grazing with the mothers until weaning at

around 6 months old, and then were fed concentrates and hay silage. They were slaughtered at an age of  $12.2 \pm 1.6$  months old with  $337.4 \pm 40.2$  kg cold carcass weight.

In France, four oxen from Gasconne breed were used from Aude Department in Languedoc-Roussillon. They were grazing during 8 months per year and then fed hay and cereals during the cold months of the year. The last four months prior to the slaughter oxen were fed with hay and concentrates ad libitum. They were slaughtered at  $46.3 \pm 1.01$  months old with  $506.9 \pm 30.1$  kg hot carcass weight.

Also four cows from Gasconne breed were used in France from Ariège Department in Midi-Pyrénées. They were fed a mixture of wheat, corn, fava beans and lucerne. Cows were grazing in natural pastures, and then fed a mixture of cereals and hay ad libitum for four months prior to slaughter. They were slaughtered at  $68.2 \pm 18.5$  months old with  $430.4 \pm 61.0$  kg hot carcass weight.

### 2.3. Sampling

Animals were slaughtered in abattoirs near their rearing farms. At each processing plant, 24–48 h after slaughtering three commercial cuts per carcass were obtained for sampling (Fig. 1): Loin (LO) between the fourth and tenth ribs where the *longissimus thoracis* (LT) muscle was

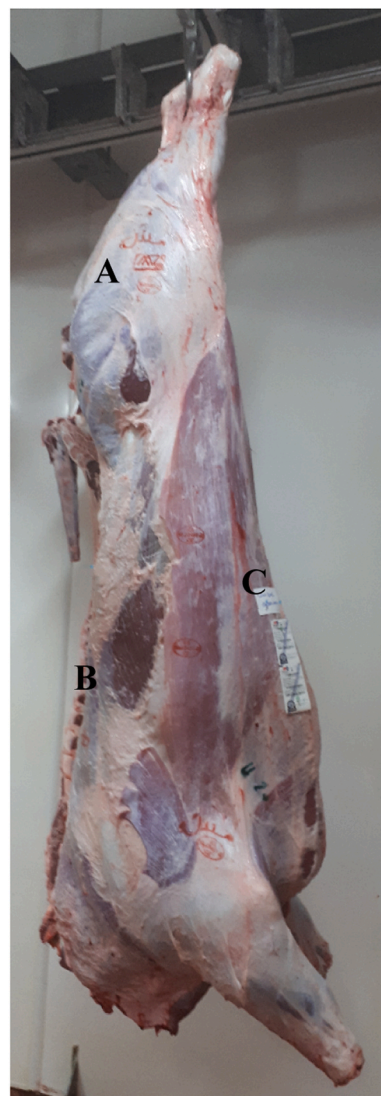


Fig. 1. Location in the carcass of the cuts used in the study: A: Rum cap; B: Loin; C: Flank.

excised, Rump cap (RC) composed of the upper and fore portion of *gluteobiceps* muscle, and Flank (FL) composed of *transversus* and *obliquus* abdominal muscles. All muscles were kept with external fat. Slices of each muscle were vacuum packaged and kept frozen at  $-18^{\circ}\text{C}$  until analyses were performed. Prior to each analysis, thawing at room temperature was done without breaking the vacuum. Description of each analysis and quality control for 2.4, 2.5, 2.6 and 2.7 sections have been previously published (Campo et al., 2021).

#### 2.4. Proximate composition

Dry matter (ISO, 1997), total fat (ISO, 1973), protein (ISO, 1978) with a conversion factor of 6.25 and ashes (ISO, 1998) were assessed. All analyses per cut were performed in duplicates.

#### 2.5. Fatty acid analysis

Total lipids were extracted from each 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 gas chromatography (HP6890, Agilent Technologies, Madrid, Spain), equipped with a flame ionization detector and an automatic injection system (HP 7683), and fitted with a SP 2560 column (100 m x 0.25 mm x 0.20  $\mu\text{m}$ ) with  $\text{N}_2$  as a carrier gas at a constant flow of 0.8 mL/min. C23:0 methyl ester and Supelco 37 Component FAME mix were used as standards (Campo et al., 2016; Carrilho et al., 2009). Saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids have been calculated from those identified fatty acids.

#### 2.6. Mineral composition

After thawing the samples at  $15\text{--}17^{\circ}\text{C}$  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 (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P) and zinc (Zn).

#### 2.7. Vitamin composition

##### 2.7.1. Fat soluble vitamins

After thawing at  $4\text{--}7^{\circ}\text{C}$ , fat soluble vitamins: A (Valls et al., 2007), E (Piironen et al., 1985) and D (Thompson and Plouffe, 1993) were extracted with saponification processes, using pyragallol as an antioxidant. HPLC-DAD (1260 Infinity II, Agilent Technologies) was used to assess vitamins A (ISO, 2000) and D (ISO, 2009). Vitamin E was analyzed by HPLC and fluorescence detection (ISO, 2014).

##### 2.7.2. Water soluble vitamins

After thawing at  $4\text{--}7^{\circ}\text{C}$ , in each mince sample the water soluble vitamins: B1 (thiamin), B2 (riboflavin), B3 (niacin), B5 (panthothenic acid), B6 (pyridoxine), B8 (biotin), B9 (folates and folic acid), B12 (cyanocobalamin) and C (ascorbic acid) were extracted by acid-enzymatic hydrolysis (Barna and Dworschak, 1994; Esteve et al., 1998; Loporati 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 x 2.1 mm x 1.8  $\mu\text{m}$ , Agilent Technologies) for vitamins B2, B5, B8, B9, B12 and C and HILIC column (100 mm x 3 mm x 3  $\mu\text{m}$ , Phenomenex) for vitamins B1, B3 and B6.

#### 2.8. Data management

Mean values per type of beef and cut, and mean standard error per variable are shown. A GLM was applied to assess differences in

nutritional composition, considering the commercial type of beef as the combination of breed, sex and age (Pirenaica young bull, Bruna D'Andorra young bull, Gasconne oxen and Gasconne cow) and the cut (RC, LO and FL) as fixed effects, together with their interactions, using SPSS 26.0. A Tukey test has been used to find differences between mean values considering the interaction between the beef type and cut.

### 3. Results and discussion

#### 3.1. Proximate composition

There are large differences in moisture composition between commercial cuts and types of beef ( $P < 0.001$ , Table 1). The flank of Pirenaica young bulls contains 6.9 g more of water per 100 g than the loin of Gasconne oxen, being the loin the cut with the lowest content of moisture, especially in older animals. These differences are not related to the amount of protein, which is a nutrient that was significantly affected by the cut ( $P = 0.021$ ) but not by the type of beef ( $P = 0.093$ ). Mean values for the flank showed less protein content (23.2 g/100 g) than the rump cap or the loin (23.8 and 24.0 g/100 g, respectively). The main differences in composition were due to the fat content ( $P < 0.001$ ), with very lean meat in young bulls, especially of Pirenaica breed, ranging between 1.75 and 2.28 g/100 g depending on the cut in this breed. Older animals (Gasconne oxen and cows) have showed the fattest meat, especially in the loin (9.27 and 6.51 g/100 g, respectively). This is a late deposition tissue that mostly defines the moment of slaughtering of the animals within a commercial category. Bovines within the EU are divided for statistical and commercial purposes according to the sex and age of the animal, among others, into calves (less than 8 months old), young cattle (between 8 and 12 mo), bulls (entire males over 12 mo), bullocks (castrated males older than 12 mo), heifers (females that have not yet calved older than 12 mo), or cows (females that have calved) (EU, 2008). At retail, when the consumer inquires for beef in Spain most of the times males and females are not distinguished in the most consumed category which is yearling (animals around one-year old), although this separation by sex is compulsory at the abattoir in animals older than 12 months old. Nevertheless, the European consumer chooses between cows or oxen in animals older than 24 mo supported by an idea of quality associated with beef from older animals, especially if they are castrated (Moloney et al., 2022). The demand for meat from older animals in Spain is mainly associated with specialized restaurants.

Fatness increases with weight which is also related to the age of the animal, reducing energy and feed efficiency (Honig et al., 2022) and increasing production costs. Therefore, young animals are slaughtered when they obtain a certain fatness before rearing costs increase too much. Breed is not compulsory to appear in the label at purchase; however, fatness highly depends on the precociousness of the breed (Eriksson et al., 2020). Double-muscle cattle with a mutation in the myostatin protein have lower intramuscular fat (IMF) (even less than 1 g fat/100 g in the LT muscle) than other beef breeds (Campo et al., 1999). Male yearlings of Pirenaica breed have shown 1.78 g/100 g of IMF in the LT muscle when slaughtered slightly younger than in our study with 310 kg of cold carcass weight (Campo et al., 1999). This IMF is lower than the current value of 2.27 g/100 g found in the same cut without trimming surrounding adipose tissue, which is how beef is mainly consumed. Nevertheless, these values can be considered fairly close to each other. In other breeds such as Brown Swiss (nowadays named in Spain 'Parda de Montaña') or Bruna dels Pirineus, (similar breeds to Bruna D'Andorra) data from young bulls of 3.03 g IMF /100 g (Campo et al., 1999) or 2.43 g IMF /100 g (Xerra et al., 2004) have been found in comparison with the 4.23 g/100 found in our study. Parda de Montaña, Bruna dels Pirineus or Bruna D'Andorra originally were considered dual purpose breeds because they had an interesting milk production and higher than pure beef breeds. Pirenaica is considered a fast growth breed, therefore, leaner than breeds less efficient in terms of meat production or from dairy origin. Friesian, the most popular dairy breed, can

Table 1

Proximate composition [g/100 g of edible portion (muscle + visible fat)] of commercial cuts from Pyrenean beef.

n	Pirenaica young bull			Bruna D'Andorra young bull			Gasconne ox			Gasconne cow			MSE	P Beef	P Cut	P BxC
	Rump cap 25	Loin 25	Flank 25	Rump cap 7	Loin 7	Flank 7	Rump cap 4	Loin 4	Flank 4	Rump cap 4	Loin 4	Flank 4				
Moisture	72.9 ab	72.4 abc	73.8 a	71.4 abcd	70.3 bcde	70.9 bcde	69.4 def	66.9 f	69.9 cde	71.4 abcd	68.6 ef	71.4 abcd	0.196	<0.001	<0.001	0.084
Protein	23.6 abc	24.1 ab	23.2 abc	24.2 ab	24.4 a	23.5 abc	23.6 abc	22.8 d	23.1 bc	24.0 abc	23.9 abc	22.8 cd	0.090	0.093	0.021	0.444
Fat	2.28 de	2.27 de	1.75 e	3.14 cde	4.23 bcde	4.53 bcde	5.74 bc	9.27 a	5.75 bc	3.40 cde	6.51 ab	4.74 bcd	0.209	<0.001	<0.001	0.005
Ash	1.21	1.20	1.20	1.23	1.16	1.13	1.23	1.05	1.25	1.20	1.07	1.11	0.022	0.756	0.391	0.921

Rump cap: composed of gluteobiceps muscle; Loin: composed of longissimus thoracis muscle; Flank: composed of transversus and obliquus abdominal muscles.

MSE: Mean Standard Error

a,b,c,d,e: values with different letters differ significantly ( $P < 0.05$ )

reach 2.5–3.0 g IMF/100 g in the LT muscle as veal with only 215 kg of cold carcass weight (Partida et al., 2007a; 2007b). When males are castrated (such as the Gasconne oxen in our study), the deposition of IMF increases, reaching between 4.34 and 6.26 g IMF/100 g in the LT in 11.8 months old Frisian animals with 230 kg of cold carcass weight (Prado et al., 2014). Therefore, the large differences in muscle fatness due to the breed found at retail could support the idea of including the breed as a factor besides the commercial category when assessing meat composition.

In other species such as lamb, differences in fatness are very evident among different cuts (Campo et al., 2016; 2021). In the beef types that we have analyzed, no significant differences have been found among the cuts in young bulls, independently of the breed. Differences have been found when animals are older, so that the loin is the fattest cut and the rump cap the leanest, especially in cows. Independently of the quality grade, cuts derived from the loin have also shown higher fat content that cuts from the hind limb when a large number of steers were used (Acheson et al., 2015). No differentiation between cuts in terms of fat content should be done if beef is consumed from yearlings, but special care should be taken if beef originates from older or castrated animals. Consumers preferences of fatness also evolves with time in terms of beef acceptability (Ngapo and Dransfield, 2006), since fat is an essential aspect of juiciness and flavour (O'Quinn et al., 2024) and decisive in purchasing decisions (Liu et al., 2022). Therefore, this is a crucial aspect not only related with health but also with eating quality and satisfaction.

No significant differences have been found in ashes between cuts or beef types.

Nutrition claims identify foods that are a source or rich in specific nutrients, helping consumers to choose healthier foods (EU, 2010b). All beef types and cuts analysed could be labelled as 'high in protein'. Young bulls from Pirenaica beef could also be considered as 'low fat' since this meat does not reach 3 g of fat/100 g in any cut (EU, 2006; 2012). In a population of 40–49 years old citizens with normal activities, the consumption of 150 g of this meat (Moreiras et al., 2016) could provide between 6 % and 12 % and 62–89 % of the recommended intake (RI) in total energy and protein, respectively.

### 3.2. Fatty acid composition

Due to the large differences in fat content, fatty acids are shown in relation to total fatty acids, since those animals with higher fat content always showed significantly higher fatty acid content. Large differences have been found in almost all assessed individual and groups of fatty acids due to the type of beef ( $P < 0.001$ ), and in most of them due to the cut (Table 2). Nevertheless, the percentage of MUFA and the ratio  $n-6$  PUFA/ $n-3$  PUFA have not been affected by the cut ( $P > 0.05$ ). In the case of MUFA, this was due to the lack of differences in oleic acid between the different cuts. Values of C18:1  $n-9$  ranged between 29.9 and 34.4 g/100 g of total fatty acids in Pirenaica and Bruna D'Andorra young bulls, 36.4 and 37.4 g/100 g in Gasconne cows and 40.7 and 42.6 g/100 g in

Gasconne oxen. SFA have been found in higher percentage in the loin in all beef types influenced by the higher composition in both palmitic and stearic acids, whereas MUFA percentage was higher in older animals (oxen and cows) than in young bulls in all cuts ( $P < 0.001$ ). The age of the animals, castration, breed and the diet are essential factors that highly influences fatty acid composition (Wood et al., 2004; 2008), even in ruminants. Ruminants experience biohydrogenation in the rumen due to microbial activity, and therefore most of the dietary fat is absorbed in a more saturated form. This higher SFA percentage in the loin has been responsible for the lower ratio SFA/PUFA in relation to the other cuts. FL and RC of Pirenaica yearlings were the cuts with the highest SFA/PUFA ratio (0.542 and 0.545, respectively), although not significantly different from the loin or the same cuts in Bruna D'Andorra animals.

Levels of SFA of young bulls were comparable to those found in Charolais or Limousin crossbreeds (Vázquez-Mosquera et al., 2023) or in Blonde D'Aquitaine steers (Castro et al., 2016), all of them considered meat beef breeds. Nevertheless, the level of MUFA was higher in older animals, especially in oxen that are castrated, than in young bulls. This lower composition of MUFA in entire young males was complemented with a higher composition of PUFA. As a result, higher and more desirable PUFA/SFA ratio (DHSS, 1994) has been found in young bulls than in oxen, being lower than 0.4 in the loin of all breed types. Sex hormones can affect lipid metabolism through the modification of enzymes activity (Du et al., 2009). Castrated males have been associated with higher IMF and MUFA and lower PUFA than entire males in the *longissimus dorsi* muscle due to a lower elongase activity (Santiago et al., 2023). In fact, oxen showed around 1/3 higher oleic acid than Pirenaica or Bruna D'Andorra young bulls probably influenced by a higher  $\Delta^9$  desaturase activity (Santiago et al., 2023; Terevinto et al., 2020).

Among PUFA, linoleic acid was higher in young bulls (6.81–13.8 g/100 g) than in cows (3.13–6.41 g/100 g) or oxen (2.32–4.47 g/100 g), showing the loin cut the lowest percentage in each beef type. On the contrary,  $\alpha$ -linolenic acid showed the opposite tendency with older animals, especially cows (0.844–1.254 g/100 g) having greater values than young bulls (0.326–0.436 g/100 g). As a result of their age and the husbandry system, yearlings showed a higher  $n-6$  PUFA/ $n-3$  PUFA (10.5–14.6) than oxen (3.41–3.82) and cows (2.56–2.80) ( $P < 0.001$ ). The low  $n-6$ / $n-3$  PUFA ratio are characteristic of animals that have been grazing most of their lives. Even with the supplementation of grain during four months prior to slaughter, oxen and cows had a desirable ratio (DHSS, 1994; Wood et al., 2004) below 4 (even lower than 3 in the case of cows) that can be obtained with grazing, which is characteristic in mountainous pastures such as those in the Pyrenees. The finishing period cannot fully change the fatty acid profile acquired during previous husbandry conditions (Guerrero et al., 2013), especially if  $n-3$  PUFA have been previously incorporated into the membrane, since their turnover will be slow. This is why cows and oxen showed such a low  $n-6$ / $n-3$  PUFA ratio, even when they were finished with cereals in the diet prior to slaughter, after spending most of the year grazing. On the contrary, young bulls showed a  $n-6$ / $n-3$  PUFA ratio higher than 10, far

**Table 2**  
Fatty acid composition [g/100 g of total fatty acids of the edible portion (muscle + visible fat)] of commercial cuts from Pyrenean beef.

n	Pirenaica young bull			Bruna D'Andorra young bull			Gasconne ox			Gasconne cow			MSE	P Beef	P Cut	P BxC
	Rump cap 25	Loin 25	Flank 25	Rump cap 7	Loin 7	Flank 7	Rump cap 4	Loin 4	Flank 4	Rump cap 4	Loin 4	Flank 4				
C12:0	0.042 bc	0.048 abc	0.041 c	0.045 abc	0.060 a	0.050 abc	0.051 abc	0.058 ab	0.054 abc	0.043 abc	0.053 abc	0.054 abc	0.001	<0.001	0.001	0.828
C14:0	1.80 b	2.07 ab	1.71 b	1.70 b	2.21 ab	1.66 b	1.98 ab	2.72 a	2.30 ab	1.78 b	2.32 ab	2.22 ab	0.040	<0.001	<0.001	0.415
C14:1	0.428 abcd	0.293 d	0.417 abcd	0.427 abcd	0.362 bcd	0.502 abcd	0.632 a	0.570 ab	0.547 abc	0.477 abcd	0.317 cd	0.403 abcd	0.013	<0.001	0.008	0.345
C15:0	0.342 ab	0.364 ab	0.296 ab	0.308 ab	0.358 ab	0.267 b	0.360 ab	0.458 a	0.390 ab	0.327 ab	0.386 ab	0.324 ab	0.008	0.026	0.009	0.577
C16:0	21.0 bc	22.2 abc	20.3 c	22.2 abc	23.7 abc	21.7 abc	22.1 abc	25.4 a	23.7 abc	22.2 abc	25.4 a	24.7 ab	0.214	<0.001	<0.001	0.861
C16:1	2.77 de	2.19 e	2.88 de	2.96 cde	2.65 de	3.41 bcd	4.79 a	3.62 bcd	4.07 abc	4.15 ab	3.01 cde	3.28 bcde	0.075	<0.001	<0.001	0.250
C17:0	0.955 abc	1.04 abc	0.885 bc	0.835 bc	0.972 abc	0.739 c	1.02 abc	1.32 a	1.17 ab	0.918 abc	1.16 ab	1.01 abc	0.021	0.001	0.004	0.106
C17:1	0.702 bc	0.529 c	0.693 bc	0.601 c	0.515 c	0.596 c	1.10 ab	0.914 abc	1.20 a	0.658 bc	0.637 c	0.691 bc	0.025	<0.001	0.079	0.713
C18:0	13.4 cde	17.5 ab	13.5 cde	13.6 cde	17.8 a	13.2 de	9.47 f	13.5 cde	11.8 def	10.4 ef	16.8 abc	14.1 bcd	0.258	<0.001	<0.001	0.927
C18:1 n-9	30.0 d	29.9 d	31.5 cd	32.5 cd	34.1 bcd	34.4 bcd	42.4 a	40.7 ab	42.6 a	36.4 abc	37.0 abcd	37.4 abcd	0.474	<0.001	0.517	0.969
C18:2 n-6	13.4 a	11.1 abc	13.8 a	11.9 ab	6.81 bcd	11.5 ab	4.47 d	2.32 d	3.05 d	6.41 bcd	3.13 d	4.65 cd	0.454	<0.001	0.004	0.745
C18:3 n-3	0.436 de	0.403 de	0.434 de	0.409 de	0.326 e	0.407 de	0.660 cd	0.472 de	0.489 de	1.254 a	0.844 bc	1.054 ab	0.022	<0.001	<0.001	0.025
CLA	0.447 ab	0.396 b	0.457 ab	0.389 b	0.384 b	0.435 ab	0.719 a	0.524 ab	0.531 ab	0.719 a	0.522 ab	0.473 ab	0.015	<0.001	0.023	0.191
C20:4 n-6	3.66 a	1.97 abcde	3.35 ab	2.98 abc	1.03 de	3.04 abc	1.45 bcde	0.314 e	0.666 e	2.87 abcd	0.705 e	1.30 cde	0.130	<0.001	<0.001	0.381
C20:5 n-3	0.293 bc	0.111 c	0.237 bc	0.321 bc	0.082 c	0.267 bc	0.410 bc	0.083 c	0.171 bc	1.21 a	0.263 bc	0.478 b	0.024	<0.001	<0.001	<0.001
C22:5 n-3	0.647 b	0.399 b	0.585 b	0.654 b	0.224 b	0.573 b	0.691 b	0.185 b	0.329 b	1.33 a	0.451 b	0.723 b	0.031	0.001	<0.001	0.068
C22:6 n-3	0.062 b	0.026 b	0.046 b	0.072 b	0.023 b	0.053 b	0.060 b	0.035 b	0.028 b	0.158 a	0.048 b	0.063 b	0.003	<0.001	<0.001	0.008
SFA	37.9 def	43.6 abcd	37.0 ef	38.9 cdef	45.5 ab	37.9 def	35.3 f	43.7 abc	39.7 bcdef	36.0 f	46.5 a	42.7 abcde	0.401	0.053	<0.001	0.013
MUFA	40.1 d	39.6 d	41.4 cd	40.3 d	43.2 cd	42.8 cd	53.1 a	49.7 abc	52.3 ab	45.6 abcd	44.7 bcd	45.2 abcd	0.495	<0.001	0.653	0.853
PUFA	19.8 a	15.0 abcd	19.8 a	17.5 ab	9.24 bcde	17.2 ab	9.16 bcde	4.21 e	5.67 de	15.1 abc	6.44 cde	9.50 bcde	0.610	<0.001	<0.001	0.511
n-6 PUFA	17.9 a	13.6 abc	18.0 a	15.6 ab	8.17 bcd	15.3 a	6.56 cd	2.87 d	4.08 d	10.3 abcd	4.23 d	6.62 cd	0.590	<0.001	<0.001	0.657
n-3 PUFA	1.49 bcd	0.976 cd	1.36 bcd	1.52 bcd	0.689 d	1.39 bcd	1.88 bc	0.815 cd	1.07 cd	4.07 a	1.68 bcd	2.41 b	0.075	<0.001	<0.001	0.001
PUFA/SFA	0.525 a	0.348 abc	0.542 a	0.461 ab	0.207 bc	0.457 ab	0.268 abc	0.096 c	0.144 c	0.442 ab	0.143 c	0.225 bc	0.018	<0.001	<0.001	0.275
n-6 /n-3 <sup>1</sup>	12.5 a	14.6 a	13.5 a	10.5 a	12.0 a	11.1 a	3.41 b	3.57 b	3.82 b	2.56 b	2.64 b	2.80 b	0.433	<0.001	0.313	0.847

Rump cap: composed of gluteobiceps muscle; Loin: composed of longissimus thoracis muscle; Flank: composed of transversus and obliquus abdominal muscles.

a,b,c,d,e, f: values with different letters differ significantly ( $P<0.05$ ); MSE: Mean Standard Error; CLA: conjugated linoleic acid c9t11C18:2

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; <sup>1</sup> n-6 PUFA/n-3 PUFA

away from recommended values of 4 in terms of healthy consumption (DHSS, 1994). These high values have been previously described in systems when young animals are reared on concentrates (Mateo et al., 2023; Partida et al., 2007b) which are rich in n-6 PUFA instead of grass, which is higher in n-3 PUFA.

Commercial cuts in other ruminants such as lamb or goat have not shown differences in groups of fatty acids when assessed together muscle and edible fat (Campo et al., 2016; 2021). However, beef behaves differently since the loin showed the highest SFA content, as it has been previously found in other breeds (Vázquez-Mosquera et al., 2023). Since beef is usually slaughtered older than small ruminants, differences might appear in different muscles that cannot be evident in younger animals. The loin has the function of supporting posture whereas the rump cap is involved in motion (Wolf et al., 2018). Differences in fibre type has also been found between muscles with different glycolytic activity (Gangnat et al., 2016) and, therefore, muscles can differ in metabolism and energy demand affecting lipid composition (Wolf et al., 2018). Terevinto et al. (2020) found differences in lipid enzyme activity between fore limb and hind limb muscles in Aberdeen Angus steers. Independently of the diet, higher SFA and lower PUFA content have been found in the LT muscle in relation to other muscles in heifers (Wolf et al., 2018), supporting the findings of a more saturated fat in the loin.

In terms of nutrition claims, the fatty acid composition of the beef analysed does not match the requirements for consideration as a source of omega 3, monounsaturated or polyunsaturated fatty acids (EU, 2006).

### 3.3. Mineral composition

Trace elements are less available for ruminants than for non ruminants due to processes that occur in the rumen (Spears, 2003). Therefore, their content in the diet would affect the incorporation to different tissues (Taylor et al., 2008) being one of the most variable elements in the plants (Reiné et al., 2020). This is one of the reasons why interest in updating national databases is constant and trace elements are the focus of many researchers over recent years (Silva et al., 2022), since meat is a source of trace elements in the human diet. Due to differences in muscle composition, data for different retail cuts should be obtained for nutritional aims (Yung et al., 2016).

Potassium and phosphorus have been the only assessed minerals that were not affected either by the beef type or the cut. Their content (352–404 mg K/100 g; 163–188 mg P/100 g) was similar to those found (325 mg K/100 g; 181 mg P/100 g) in New Zealand beef

(Purchas et al., 2014).

The type of beef has showed an effect on the composition of calcium, iron, sodium ( $P < 0.001$ ), magnesium and selenium ( $P < 0.01$ ), whereas the cut only showed an effect on sodium and zinc ( $P < 0.001$ ), with significant interactions between beef type and cut (Table 3). Oxen and cows showed the highest amount of calcium (5.59–8.46 mg/100 g) and iron (2.09–2.68 mg/100 g), whereas the loin showed the lowest amount of sodium and the highest of zinc. The FL of Gasconne cows had higher content of magnesium (27.3 mg/100 g) than the LO of Bruna D’Andorra yearlings (20.8 mg/100 g). The RC of the cows showed the lowest content of selenium (10.5 ng/100 g) whereas the LO of oxen showed the highest (17.3 ng/100 g).

Zinc levels have not been affected by the beef type but for the cut. Piston et al. (2020) also found differences in different cuts in Uruguayan beef, associating lower levels in those muscles with lower collagen content. Nevertheless, their values were 2–4 fold depending on the muscle than those found in Pyrenean beef, probably associated to differences in the pasture composition where animals were grazing until harvesting at 36 months old. However, pasture finished steers in New Zealand in a muscle composite (Purchas et al., 2014) have shown similar levels of Zn (3.69 mg/100 g) than those found in the Pyrenees in the RC or the FL of young bulls, but not in the LO that was higher (4.89–5.28 mg/100 g) as was the content in older Pyrenean animals.

Iron content has been associated to the age of the animals in other species such as lamb, so that older animals have increased levels in the muscle (Campo et al., 2021). This has also been found in Pyrenean beef, where young bulls from Pirenaica or Bruna D’Andorra breeds had 25–48 % less iron than Gasconne oxen or cows. Steers in New Zealand that were older than young bulls but younger than oxen showed 1.91 mg Fe/100 g of muscle (Purchas et al., 2014), values that are in between of the content of the previously described animals. The same tendency was observed in calcium levels, with young bulls showing clearly lower content than older animals, and very similar to those of New Zealand steers.

Sodium levels were lower in the loin than in the other cuts, and lower in Pirenaica young bulls than in the other beef types. This mineral presents significant variability in pastures (Reiné et al., 2020). It is an important component of mineral supplementation fed to grazing animals, usually administered in the form of licking blocks. Therefore, its incorporation into the muscle will be highly linked to the supplementation that animals receive in the pasture. The same applies to selenium content, which is added in the diet due to its implication in antioxidant

**Table 3**  
Mineral composition [mg<sup>1</sup>, ng<sup>2</sup>/ 100 g of edible portion (muscle + visible fat)] of commercial cuts from Pyrenean beef.

	Pirenaica young bull			Bruna D’Andorra young bull			Gasconne ox			Gasconne cow			MSE	P Beef	P Cut	P BxC
	Rump cap	Loin	Flank	Rump cap	Loin	Flank	Rump cap	Loin	Flank	Rump cap	Loin	Flank				
<i>n</i>	25	25	25	7	7	7	4	4	4	4	4	4				
Calcium <sup>1</sup>	4.73	4.39	4.97	4.17	4.72	3.72	6.71	7.72	7.75	5.96	5.59	8.46	0.165	<0.001	0.160	0.117
	cd	cd	bcd	cd	cd	d	abc	ab	ab	abcd	abcd	a				
Iron <sup>1</sup>	1.51	1.39	1.55	1.73	1.76	1.76	2.35	2.68	2.53	2.09	2.59	2.55	0.051	<0.001	0.220	0.410
	d	d	d	cd	bcd	bcd	abc	a	abc	abcd	a	ab				
Potassium <sup>1</sup>	357	367	375	396	390	391	354	404	352	360	371	395	4.15	0.201	0.435	0.590
Magnesium <sup>1</sup>	22.8	21.3	23.4	22.6	20.8	24.9	25.5	26.5	24.	23.5	22.8	27.3	0.320	0.010	0.302	0.456
	abcd	cd	abcd	bcd	d	abcd	abc	ab	abcd	abcd	abcd	a				
Sodium <sup>1</sup>	47.3	40.4	49.7	60.8	56.1	64.8	65.4	54.9	60.3	50.4	45.6	72.6	1.09	<0.001	<0.001	0.049
	cd	d	bcd	abc	abcd	ab	ab	abcd	abc	bcd	cd	a				
Phosphorus <sup>1</sup>	170	163	176	184	169	182	186	186	164	163	164	188	1.99	0.284	0.501	0.246
Zinc <sup>1</sup>	3.83	5.28	3.91	3.53	4.89	3.27	4.10	6.52	4.02	3.38	5.33	4.55	0.158	0.440	<0.001	0.907
	ab	ab	ab	ab	ab	b	ab	a	ab	ab	ab	ab				
Selenium <sup>2</sup>	12.0	12.5	11.7	13.3	12.3	11.8	13.7	17.3	13.1	10.5	11.6	16.3	0.258	0.012	0.358	0.007
	bc	abc	bc	abc	abc	bc	abc	a	abc	c	bc	ab				

Rump cap: composed of gluteobiceps muscle; Loin: composed of longissimus thoracis muscle; Flank: composed of transversus and obliquus abdominal muscles.

MSE: Mean Standard Error

a,b,c,d: values with different letters differ significantly ( $P < 0.05$ )

activities, increasing meat shelf life. Large variations have been found in the literature due to different levels in the diet (Cabrera et al., 2010; Purchas et al., 2014; Taylor et al., 2008) that support the necessity of updating databases in different countries throughout the time.

According to EU (2006); (2012), nutrition claims could be considered in different minerals: oxen and cows from Gasconne breed are ‘a source of iron’, all beef types and cuts from the Pyrenees are ‘a source of potassium, phosphorus and selenium’ and ‘high in zinc’ and ‘low sodium’. Besides, the loin of Gasconne oxen and the rump cap of Gasconne cows are ‘high in selenium’. The consumption of 150 g of such beef could contribute between 12 % and 40 % Fe, 15–17 % K, 9–12 % Mg, 3–5.4 %Na, 35–40 % P, 34–65 % Zn and 22–47 % of selenium (Se) to the RI of individuals from a population aged 40–49 with normal activity (Moreiras et al., 2016).

### 3.4. Vitamin composition

Data of vitamin A, B7 and C 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 and 0.02 mg/100 g, respectively). Vitamins D and E have not been detected in all cuts or beef types, with fairly low levels, therefore no statistical analyses have been performed although detected values are shown (Table 4).

The type of beef had a significant effect on the content of vitamins B1 ( $P<0.01$ ), B2, B5 and B12 ( $P<0.001$ ), whereas the cut had an effect on the content of vitamins B2 ( $P<0.05$ ), B1, B5 and B12 ( $P<0.001$ ), with a significant interaction between beef type and cut in B2 ( $P<0.01$ ), B5 ( $P<0.05$ ) and B12 ( $P<0.001$ ). Vitamins B3, B6 and B9 were not affected by these effects, ranging between 5.49 and 7.47, 0.479–0.883 and 5.00–7.48 mg/100 g, respectively.

Cooking can reduce the content of water-soluble vitamins, due to water losses during the process (Lombardi-Boccia et al., 2005). Even with animals of different ages, the levels of vitamin B3, B6 and B12 found in our raw samples have been superior to those found by Roseland et al. (2018) in cooked meat. Nevertheless, raw meat from steers in New Zealand in a composite sample of several muscles showed lower levels of vitamins B1, B2, B3, B6 and B12, but higher of vitamin B5 than Pyrenean beef (Purchas et al., 2104), whereas Italian beef showed lower vitamin B1 and similar vitamin B2 and B3 content than Pyrenean beef (Lombardi-Boccia et al., 2005). In Norwegian Red Cattle bulls and cows (Egelandstal et al., 2020), similar vitamin B12 levels were found to those from Pirenaica beef, as well as similar vitamin B2, B5 and D content, but lower vitamin B1, B3, B6, B9 and higher vitamin E levels were obtained.

Analyzing the different cuts, thiamine was more abundant in the RC of young bulls (more than 0.13 mg/100 g) in relation with the LO of cows (0.073 mg/100 g). Riboflavin was in higher amount in the flank of Bruna D’Andorra animals or oxen (0.200–0.205 mg/100 g) in relation with the FL and the LO of Pirenaica young bulls (0.115–0.112 mg/100 g). Vitamin B5 was also higher in the FL of oxen (0.280 mg/100 g) especially in relation with the LO of Pirenaica young bulls (0.106 mg/100 g). Vitamin B12 was in lower amount in the edible portion of the cuts of Pirenaica animals (2.98–3.86 µg/100 g) and the LO of oxen (3.35 µg/100 g) and cows (2.60 µg/100 g) than in the rest of cuts and beef types (6.28–8.20 µg/100 g) ( $P<0.001$ ). Significant differences between muscles have been previously found in the content of cobalamins (Czerwonka et al., 2014) associated to the type of fibre, since white fibres have less cobalamins than red-type muscles (Choi and Kim, 2009). The significant interactions observed in the study may indicate a correlation between the physical activity of animals in their natural habitat and the development of various types of muscle fibres towards a more oxidative profile.

According to EU (2006; 2012), nutrition claims could be made in Pyrenean beef, since all beef types and cuts are ‘high in vitamin B3, B6 and B12’. The consumption of 150 g of this beef could contribute between 43 % and 80 % B3, 39–83 % B6 and 195–615 % B12 to the RI of

**Table 4**  
Vitamin composition [mg, µg, µg<sup>2</sup>/100 g of edible portion (muscle + visible fat)] of commercial cuts from Pyrenean beef.

n	Pirenaica young bull			Bruna D’Andorra young bull			Gasconne ox			Gasconne cow			MSE	P Beef	P Cut	P BxC
	Rump cap	Loin	Flank	Rump cap	Loin	Flank	Rump cap	Loin	Flank	Rump cap	Loin	Flank				
Thiamine (B1) <sup>1</sup>	0.138	0.114	0.121	0.134	0.096	0.123	0.133	0.110	0.118	0.118	0.073	0.085	0.003	0.007	0.001	0.913
Riboflavin (B2) <sup>1</sup>	0.136	0.112	0.115	0.170	0.163	0.205	0.125	0.163	0.200	0.200	0.145	0.163	0.004	<0.001	0.025	0.009
Niacin Vit (B3) <sup>1</sup>	6.98	6.10	6.83	6.19	7.19	7.47	5.49	6.59	6.94	6.94	6.78	5.98	0.126	0.679	0.782	0.077
Pantothenic acid (B5) <sup>1</sup>	0.167	0.106	0.154	0.213	0.136	0.258	0.173	0.160	0.280	0.280	0.143	0.245	0.006	<0.001	<0.001	0.036
Pyridoxine (B6) <sup>1</sup>	0.771	0.672	0.877	0.756	0.479	0.685	0.883	0.665	0.655	0.655	0.493	0.670	0.035	0.263	0.088	0.894
Folate (B9) <sup>2</sup>	6.42	6.52	6.08	6.86	6.60	7.03	5.00	6.40	7.38	7.38	7.48	6.88	0.131	0.412	0.193	0.249
Cyanocobalamin (B12) <sup>2</sup>	2.98	3.29	3.86	7.39	7.30	6.53	7.63	3.35	6.28	6.28	2.60	8.20	0.198	<0.001	<0.001	<0.001
Vitamin D	0.058	0.067	0.068	0.059	0.057	0.060	0.06	-	0.060	0.060	-	0.045	-	-	-	-
α-tocopherol (E) <sup>1</sup>	0.070	0.072	0.060	-	-	0.050	0.090	-	0.070	0.070	-	0.067	-	-	-	-

Rump cap: composed of gluteobiceps muscle; Loin: composed of longissimus thoracis muscle; Flank: composed of transversus and obliquus abdominal muscles.

MSE: Mean Standard Error

a,b,c,d: values with different letters differ significantly ( $P<0.05$ )

individuals from a population aged 40–49 with normal activity (Mor-eiras et al., 2016).

#### 4. Conclusions

In mountainous systems such as the Pyrenees, different beef products are obtained from husbandry practices that can be considered traditional. These systems combine together the breed, the feeding, the sex and the age of slaughter, which provokes differences in the nutritional composition of different cuts. The oxen, cows and young bulls assessed in this study from the Pyrenees differ greatly among them in fatness and in several mineral and vitamins. But even with the variations, nutrition claims can be performed to be included in the label at retail. Pyrenean beef is a source of potassium, phosphorus and selenium, high in protein, zinc and vitamin B3, B6 and B12 and low sodium. Young bulls from Pirenaica beef could also be considered as low fat. Oxen and cows from Gasconne breed are a source of iron, and some of their cuts are high in selenium. Therefore, husbandry practices such as castration or grazing should be available for consumers or dietitians as a source of information due to their influence in the composition of the meat, which can affect their purchase decision due to differences in sensory quality and dietary guidelines. When funding is available, further analysis of other cuts should be taken into consideration in order to update current databases, but also periodically analyses should be performed due to possible changes in husbandry practices influenced by new regulations or climate change that might modify the feeding or the pastures that are typical in this husbandry systems.

#### Declaration of Competing Interest

In the manuscript **Nutrient composition of beef from the Pyrenees** by Campo, M.M., Romero, J.V., Guerrero, A., Bouzaida, M.D., Resconi, V.C., Tesniere, G., Santolaria, P., Olleta, J.L., submitted to the Journal of Food Composition and Analysis, authors declare no conflict of interest. The funding source has been acknowledged in the manuscript, but has not been implied in the collection of samples, analysis, interpretation of data or the writing of the manuscript.

#### Data availability

Data will be made available on request.

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