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# From Roman *suburbium* to medieval city: zooarchaeological approach to Sotstinent Navarro faunal assemblages (Barcelona, Spain). Caprines and equids as a case study☆

Marina Fernández-Liarte [a,*], Marta Moreno-García [b], Jordi Nadal-Lorenzo [a], Jordi Ramoz-Ruiz [c], Samantha Greeves [c], Matthew von Tersch [d], Jessica Hendy [d], Michelle Alexander [d], Santiago Riera-Mora [a]

[a] SERP. Departament d'Història i Arqueologia. Facultat de Geografia i Història. Universitat de Barcelona. C/ Montalegre, 6-8. 08001, Barcelona, Spain
[b] Centro de Ciencias Humanas y Sociales. CSIC. C/ Albasanz, 26-28. 28037 Madrid, Spain
[c] Serveis Territorials de Cultura a Barcelona. Departament de Cultura. Generalitat de Catalunya. Plaça de Salvador Seguí, 1-9. 08001 Barcelona, Spain
[d] BioArCh, Department of Archaeology, University of York, Heslington YO10 5DD, York, UK

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ABSTRACT

This work examines the interaction between humans and animals in urban environments in north-eastern Iberia from the Roman period to the end of the Middle Ages. We present a zooarchaeological study of the faunal remains found in Sotstinent Navarro, Barcelona, an archaeological site excavated as part of a rescue project. The zooarchaeological evidence presented and analysed here provides insight into the diet and provisioning of the city over time, focussing on three time periods: Late Roman and Late Antiquity (3rd-7th c.), the High Middle Ages (8th-12th c.), and the Late Middle Ages (13th-15th c.). Zooarchaeological data are complemented by biomolecular analyses, both Zooarchaeology by Mass Spectrometry (ZooMS) and stable carbon and nitrogen isotope analyses, focussing on caprines and equids. While equid results are inconclusive, the analysis of caprines provides new insights into sheep and goat livestock management. Caprines, especially sheep, became the predominant taxon, with a specialisation in their management as a meat resource detected, particularly evident in the Late Middle Ages.

## 1. Introduction

The collaboration between the public administration, professional archaeology and the University of Barcelona has materialised in the development of the *PaleoBarcino* project, led by one of the co-authors (Santiago Riera-Mora). In this project, disciplines such as anthracology, carpology, palynology and zooarchaeology complement each other to carry out the paleoenvironmental reconstruction of the Barcelona plain during historic times and to analyse the changes in the occupation and management of the territory and the diversified exploitation of terrestrial and marine natural resources.

The historical and geographical characteristics of a city in constant transformation, such as Barcelona, determine any research approach to its historical and archaeological past. The archaeological work carried out adapts to the city's current reality and its challenges, and is therefore a form of urban archaeology. Various authors have reflected on the concept of urban archaeology (e.g. Quirós, 2005).

Urban archaeology, as practised in cities inhabited since ancient times, faces several challenges (Rainsford & O'Connor, 2016). The continuous use of a site results in a rich archaeological record, with intense stratification that leads to the accumulation, alteration and destruction of layers; however, as this is a living archaeological site, it is impossible to carry out an entirely excavation. The development of programmes for the recovery of urban bioarchaeological heritage is highly variable. In zooarchaeology, the cases of Dublin (Hutton macdonald et al., 1993), York (Rainsford & O'Connor, 2016) and

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* Corresponding author.
*E-mail addresses:* marina_ferli@hotmail.com (M. Fernández-Liarte), marta.moreno@cchs.csic.es (M. Moreno-García), jordinadal@ub.edu (J. Nadal-Lorenzo), ramoselprat@gmail.com (J. Ramoz-Ruiz), sam.greeves@york.ac.uk (S. Greeves), matthew.vontersch@york.ac.uk (M. von Tersch), jessica.hendy@york.ac.uk (J. Hendy), michelle.alexander@york.ac.uk (M. Alexander), rieram@ub.edu (S. Riera-Mora).

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Buenos Aires (Chichkoyan, 2013) are very positive.

In the north-east of the Iberian Peninsula, urban archaeology is essentially a rescue archaeology, which has a long tradition in the city of Barcelona. Generally, rescue urban archaeology pays little attention to bioarchaeological materials. This is evident in our context in the existence of recovery and recording procedures that lack methodological rigour and in the widespread absence of specific studies.

In the case of Barcelona, several zooarchaeological studies have been published. These include sites such as Caserna de Sant Pau (Albizuri canadell and Nadal i lorenzo, 1993; Colominas et al., 2008; Estrada & Nadal, 2008; Lloveras et al., 2014; Nadal, 2016; Saña navarrete, 2016), Avinguda Francesc Cambó (Molinas & Salazar, 2006), Plaça de la Vila de Madrid (Colominas barberà, 2007; Garcia petit, 2007), Conservatori del Liceu (Bordas et al., 2013; Nadal, 2016; Saña navarrete, 2016), Carrer Reina Amàlia (Nadal et al., 2015; Nadal, 2016; Saña navarrete, 2016), El Born (Lloveras roca et al., 2021; Lloveras et al., 2023a) or Reial Monestir de Santa Maria de Pedralbes (Lloveras et al., 2023).

Gathering the statement of an extensive research tradition, the present paper combines zooarchaeological and biochemical approaches, in particular Zooarchaeology by Mass Spectrometry (ZooMS) and stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses.

There are numerous examples of the application of isotopic studies in archaeology, and specifically of stable carbon and nitrogen isotopes in zooarchaeology (Ambrose & DeNiro, 1989; Iacumin et al., 1997; Guiry & Szpak, 2021). In the Iberian Peninsula the zooarchaeological data combined with stable carbon and nitrogen isotope analyses has yielded interesting results, as demonstrated by the cases of Sirignano et al. (2014), Brosa-Planella et al. (2026) or Navarrete et al. (2026).The isotopic composition of the carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) values of collagen in teeth and bones provides valuable information that allows the diet of animals to be characterised (Vogel & van der Merwe, 1977; DeNiro & Epstein, 1978; Ambrose, 1990; Schwarcz, 1991; Hedges et al., 2007).

Furthermore, paleoproteomics is an analytical technique that has seen significant development in recent years (Warinner et al., 2022). In particular, Zooarchaeology by Mass Spectrometry (ZooMS) (Buckley, 2018; Grandal-d'Anglade, 2024), which relies on the method of protein identification via peptide mass fingerprinting (James et al., 1993; Pappin et al., 1993), is of great interest due to the resolution it offers in terms of taxonomic identification (e.g. Buckley & Kansa, 2011; Coutu et al., 2021; Janzen et al., 2021; Culley et al., 2021), since, for example, it resolves the issue of unidentified worked bone materials (e.g. Desmond et al., 2018; Jensen et al., 2020) or facilitates the discrimination of closely related species that are difficult to distinguish using conventional zooarchaeological methods due to their morphological similarity (e.g. Buckley et al., 2010 –*Ovis aries* and *Capra hircus*– and Paladugu et al., 2023 –*Equus caballus* and *Equus asinus*–).

The main aim of the research is to study the dynamics of animal management in an urban context such as the city of Barcelona, from Roman times to the end of the Middle Ages, in a space with changing

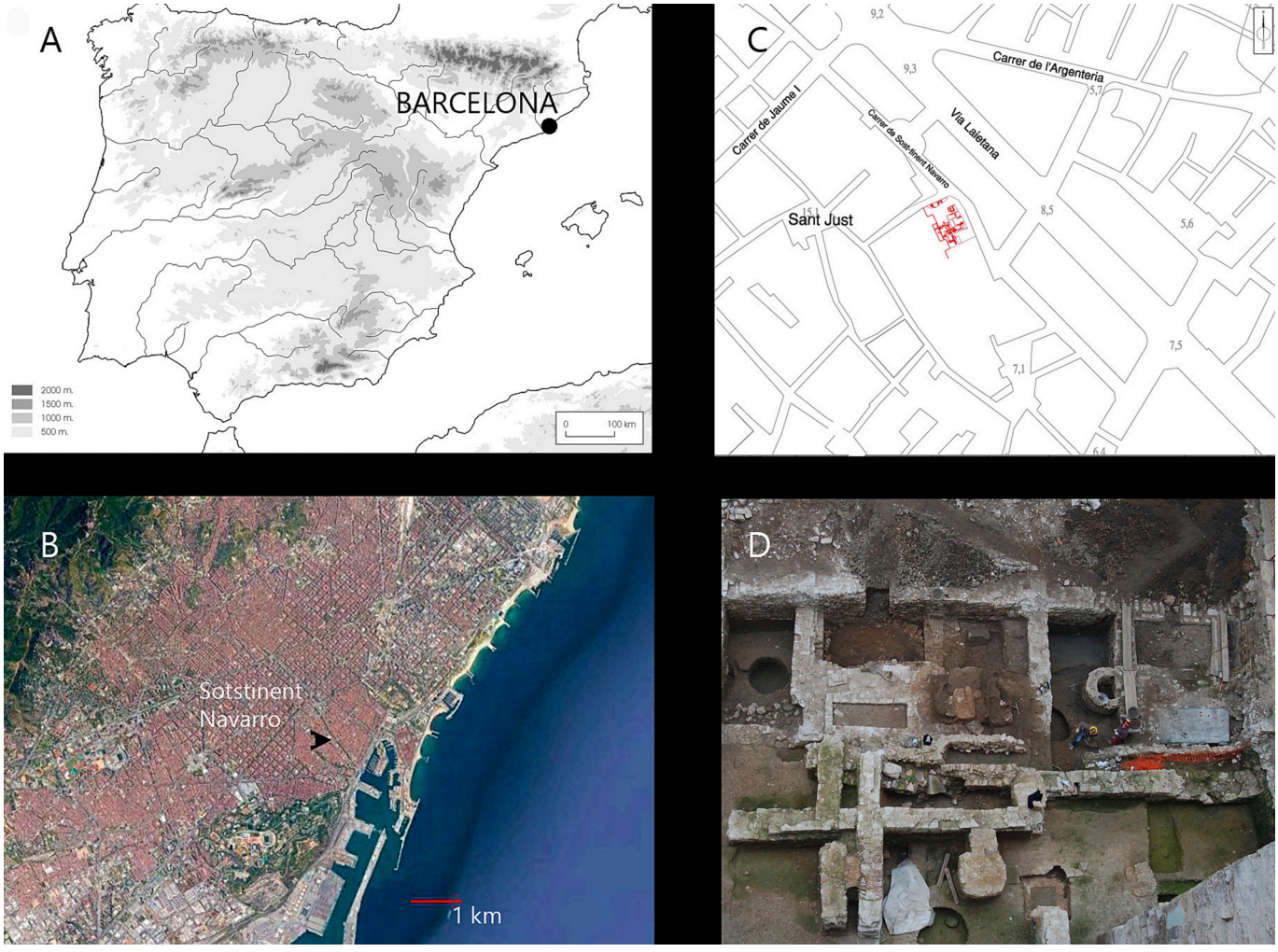



**Fig. 1.** Location of the site. A: Barcelona located in the north-east of the Iberian Peninsula (Catalonia); B-C: Site located in the Gothic Quarter of the city in Sotstinent Navarro Street; D: Aerial view of the excavated area (.
Source: GoogleEarth modified)

uses, using both zooarchaeological data and biochemical analyses. Specifically, we aim to recognise the potential of Zooarchaeology by Mass Spectrometry (ZooMS) and stable carbon and nitrogen isotope analysis in combination with traditional zooarchaeological study, specially to resolve some identification of morphologically close taxa such as sheep and goat and equids.

To achieve the stated aim, we examine the mammal remains found in a rescue excavation carried out in Barcelona, in the so-called Gothic Quarter of the city (Ciutat Vella district). Specifically, the excavation took place in Carrer Sotstinent Navarro (Sotstinent Navarro Street) at the junction with Baixada del Caçador. Sotstinent Navarro is located near the historic centre, on the outer edge of the southeast quadrant of the walled enclosure of the Roman period. The city itself is located in the north-east of the Iberian Peninsula (Catalonia), on a coastal plain next to the Mediterranean Sea (Fig. 1).

We focus on stratigraphic levels from the Late Roman period and Late Antiquity (3rd-7th c.), High Middle Ages (8th-12th c.) and Late Middle Ages (13th-15th c.). These chronocultural moments are the result of the city's unique historical distinctive feature. In this sense, the invasions and the reform of the city's defences in the 3rd century, the Muslim presence and the subsequent Carolingian conquest in the 8th century, the accelerated expansion of the city in the 13th century, and the Catalan Civil War and the unification of the kingdoms of Castile and Aragon in the 15th century (Banks, 2003; Beltrán de heredia bercero, 2008) are events that are reflected in the continuities and discontinuities of the archaeological record.

The colony *Iulia Augusta Faventia Paterna Barcino* was founded around 10B.C. by the emperor Augustus (Beltrán de heredia bercero, 2013). Carrer Sotstinent Navarro documents a rich sequence of occupation from the beginning of the 1st century CE to the present day. In the Early Roman period, we find the construction of the Augustan wall and its corresponding moat (Ramos ruiz, 2017). The Early Roman City is a 10-hectare walled enclosure, with a rectangular layout featuring rounded corners and an orthogonal urban planning (Granados, 1984; Mar et al., 2012).

At the end of the 3rd and beginning of the 4th century, the wall was reformed, adding a new wall on the outside of the first one and raising seventy-six towers (Puig & Rodà, 2010; Ravotto, 2014). Public spaces within the city were being taken over. The city's streets in the 3rd century, and particularly in the 4th century, were privatised (Perich roca, 2014). In the northern part of the city, there would have been a Paleochristian Basilica and a baptistery (Bonnet and Beltrán de heredia, 2000), evidence of the existence of a strong Christian community in the 4th century, when *Barcino* was already an episcopal seat (Sales carbonell, 2020). During the 5th and 6th centuries, the city became the royal seat of Visigothic monarchs and usurpers (Gurt esparraguera and godoy fernández, 2000; Ripoll, 2000). The first Christian structures were also identified in the *suburbium* during the 5th and 6th centuries (Beltrán de heredia, 2010). At the same time, during the Late Roman and Late Antiquity periods, the area of Sotstinent Navarro underwent various modifications, although it essentially maintained its extra-urban nature, forming part of the *suburbium* of the colony. In the early 6th century, the area of Sotstinent Navarro was used for agricultural purposes, and evidence of silos has been found (Ramos ruiz et al., 2018, Ramos ruiz et al., 2020). So, was a marginal area outside the walls.

Barcelona remained under the control of Al-Andalus between 714 and 801 (Gibert rebull, 2005). The Franks arrived in the 9th century (Jaspert, 2003), although by the end of the 10th century Count Borrell of Barcelona led the breakaway from the Frankish kingdom (Salrach, 1991). In this context, the structure of the Roman wall was transformed, and from the 10th century onwards, buildings are added, especially for the high-status individuals of the city (Banks, 2021). It was not until the High Middle Ages that the area of Sotstinent Navarro was incorporated into the city proper (Ramos ruiz, 2017). Outside the city, the *suburbium* became urbanised and settlements began to form from the 10th century onwards. During the Middle Ages, *burgi* sprang up around basilicas, convents and monasteries (Banks, 2013). Also, during the second half of the 10th century, suburbs developed alongside the markets. These burghs proliferated along the roads leading into and out of the city (Banks, 2003).

In the 13th century, the medieval wall was built and *burgi* were incorporated into the city (Banks, 2003; Vinyoles I Vidal., 2003). Barcelona thus underwent significant changes from the mid-13th century to the early 15th century (Cubeles i bonet, 2003). In Sotstinent Navarro in the Late Middle Ages, portions of a Gothic mansion are documented. During the Modern Age, the area was used as a warehouse, and finally, at the beginning of the 19th century, the buildings that were demolished before the archaeological work began were built (Ramos ruiz, 2017).

## 2. Materials and methods

As has been mentioned, we present a zooarchaeological analysis of the mammal remains recovered in Carrer Sotstinent Navarro, focusing on caprines and equids. The limitations of traditional archaeozoological methods in the taxonomic identification of these closely related species (sheep and goats, on the one hand, and donkeys and horses, on the other) highlighted the need to use Zooarchaeology by Mass Spectrometry (ZooMS) to take taxonomic discrimination a step further. In this regard, it is essential to apply stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analyses to the previously biochemically identified remains to characterise the diet of these taxa. For this reason, we exclude other species present also in the archaeological record.

Anatomical and taxonomical identifications were carried out with the aid of the reference collection of the University of Barcelona and specialised works such as Boessneck et al. (1964), Boessneck (1980), Prummel and Frisch (1986), Armitage and Chapman (1979), Eisenmann (1981) and Albizuri et al. (2017). Age (Grant, 1982; Payne, 1973, 1987; Schmid, 1972; Silver; 1969) and sex determination and pathological (Fraser, 1993; Harcourt, 1971; Radostits et al., 2010; Smith, 2009), biometric (von den Driesch, 1976; Davis, 1996) and taphonomic analysis (Binford, 1981; Brain, 1981; Liesau, 1998; Shipman et al., 1984; Stiner et al., 1995; Vigne, 1987) were also carried out. The quantification methods applied were the number of specimens (NSP), the number of identified specimens (NISP), the minimum number of elements (MNE), the minimum number of individuals (MNI) and the minimum number of animal units (MAU), in accordance with the proposals used in the literature (Grayson, 1984; Lyman, 1994).

The present zooarchaeological study combines the classical study with Zooarchaeology by Mass Spectrometry (ZooMS) and the analysis of stable isotopes of carbon and nitrogen. Biomolecular analyses were carried out on 50 remains at BioArCh, University of York. They include 40 remains of caprines (32 mandibles and 8 calcanei) and 10 of equids (first phalanges). The extraction of collagen from the bone followed a modified Longin (1971) method with the addition of Ezee filters (Bronk Ramsey et al., 2004). For isotopic measurement by Elemental Analysis-Isotope Ratio Mass Spectrometry (EA-IRMS), 0.4–0.6 mg of collagen was weighed out in duplicate into tin capsules and combusted alongside internal and international standards in a Sercon 20–22 continuous flow isotope ratio mass spectrometer coupled to a Sercon gas solid liquid elemental analyser at BioArCh. Stable carbon and nitrogen isotope ratios were calibrated relative to VPDB and AIR scales using the standard reference materials IsoAnalytical Cane ($\delta^{13}C$ = -11.64‰ ± 0.03), Sigma Methionine ($\delta^{13}C$ = -35.83‰ ± 0.03, $\delta^{15}N$ = -0.76‰ ± 0.05) and IAEA N2 ($\delta^{15}N$ = 20.41‰ ± 0.12). Uncertainty was monitored using the standard reference materials Sigma fish gel ($\delta^{13}C$ = -15.27‰ ± 0.04, $\delta^{15}N$ = 15.21‰ ± 0.13), IsoAnalytical Alanine ($\delta^{13}C$ = -23.33‰ ± 0.10, $\delta^{15}N$ = -5.56‰ ± 0.14) and IsoAnalytical Soy ($\delta^{13}C$ = -25.22‰ ± 0.03, δ15N = 0.99‰ ± 0.07). Precision (u(Rw)) was determined to be ± 0.117‰ for $\delta^{13}C$ and ± 0.120‰ for $\delta^{15}N$ based on repeated measurement of calibration standards, check standards and sample replicates. According to calibration and check standards, measurement precision (ssrm, pooled measured standard deviation of calibration and check

standards) was ± 0.101‰ for $\delta^{13}C$ (df = 67) and ± 0.106‰ for $\delta^{15}N$ (df = 67). All but one sample were analysed in duplicate (98%). The measurement precision specific to samples (srep, pooled standard deviation of sample replicates) was ± 0.084 ‰ for $\delta^{13}C$ (df = 52) and ± 0.079 ‰ for $\delta^{15}N$ (df = 52). Accuracy (u(bias)) was determined to be ± 0.147 ‰ for $\delta^{13}C$ and ± 0.187 ‰ for $\delta^{15}N$ based on the difference between observed and reported δ values (RMSbias) and long-term standard deviations (u(Cref)) of check standards. Total analytical standard uncertainty (uc) was estimated to be ± 0.188 ‰ for $\delta^{13}C$ and ± 0.222 ‰ for $\delta^{15}N$ (Szpak et al., 2017). Statistical comparisons of observed patterns in $\delta^{13}C$ and $\delta^{15}N$ values were carried out using the Kruskal-Wallis test for three groups of data and the Mann-Whitney *U* test for two sets. The PAST software package (Hammer et al., 2001) was used to carry out statistical analysis.

From the extracted collagen, samples were prepared for ZooMS based on the protocol in Buckley et al. (2009) and then analysed using Matrix Assisted Laser Desorption Ionization Time of Flight Mass Spectrometry (MALDI-TOF-MS). In brief approximately 1 mg of extracted freeze-dried collagen was resuspended in 100 μl ammonium bicarbonate (AmBic). The samples were then digested overnight using 1 μl of trypsin, with the digestion being terminated after approximately 18 h with the addition of 1 μl 5% trifluoroacetic acid (TFA). The resulting peptides were purified using C18 ziptips, before being eluted in 100 μl 0.1% TFA in 50% water and 50% acetonitrile. 1 μl of each sample was spotted in triplicate onto a Bruker MALDI plate next to calibrant spots and 1 μl of Matrix (α-Cyano-4-hydroxycinnamic acid) was added to both the samples and the calibration spots. The samples were run on a Bruker UltrafleXtreme MALDI-TOF MS. The resulting spectra were processed using the opensoure software mMass (Strohalm et al., 2010) and marker peaks were identified using reference markers for sheep, goat and equids (Buckley et al., 2009; Welker et al., 2016). All ZooMS data are available via the Zenodo accession: https://doi.org/10.5281/zenodo.17484068.

## 3. Results

### 3.1. Zooarchaeological analysis

#### 3.1.1. Late Roman period and Late Antiquity (3rd-7th c.)

This assemblage is dominated by domestic livestock, with caprines forming the main taxon. Sheep are particularly prevalent, with a sheep-to-goat ratio of 4:1, while cattle, equids and suids make up the remainder. Commensal (dog and cat) and wild species (rabbit and red deer) are secondary (Table 1).

Focusing on caprines, livestock management would prioritise the rearing of sheep over goats. The consumption of animals in the second and third year, once they have reached their optimal meat weight, as well as maintaining senile animals, demonstrates the multi-purpose use of goats and sheep, where both the meat and by-products are valued (Table 2). Keeping goats until a more advanced age, however, could indicate a greater interest in this species' secondary products than in sheep. The slaughter of caprines at different ages suggests a versatile use.

All parts of the skeleton are recognised, with particular importance given to the limbs, some relevance to the cranial skeleton and under-representation of the axial skeleton (Fig. 2). Priority would be given to obtaining cuts of high (girdles and stylopodium) and medium (zeugopodium) meat value from caprines; consequently, a large portion of the sample would consist of consumption waste from the shoulders and legs of these animals. Thus, the processing of the carcasses –including the dismembering, butchering and removing the flesh- confirms the consumption of caprines meat. The butchery waste would be used for other purposes. Once the animals were slaughtered in the slaughterhouses, the presence of skulls and autopodia would be related to the processing of the hides. It was common practice to keep these elements attached to the hide during the tanning process (Serjeantson, 1989). In addition, traces of skinning on the carcasses of caprines demonstrate the craft activities of hide processing.

#### 3.1.2. High Middle Ages (8th-12th c.)

The osteological remains have a mixed origin, with waste derived from food consumption, artisanal or industrial activity, and the disposal of uneaten animals. Caprines continue to be prominent, with more sheep than goats (sheep:goat ratio of 3:1). Dogs, suids, cattle and equids follow. Cats and wild species such as red deer, rabbit, and brown bear are much less abundant (Table 1).

Caprines were slaughtered primarily for their meat (Table 3). Mortality of some lambs may be related to obtaining tender meat and milk, while that of sub-adults and young adults (mutton and rams) displays the interest in meat consumption of caprines that have already reached their optimal weight and have reproduced and contributed to the maintenance of the herds. The reduced presence of fully adult and senile animals confirms this pattern. There are no major differences in the

**Table 1**
Taxonomic distribution of mammals remains in number of specimens (NSP), number of identified specimens (NISP) and minimum number of individuals (MNI) in the Late Roman period and Late Antiquity (3rd-7th c.), High Middle Ages (8th-12th c.) and Late Middle Ages (13th-15th c.). In parentheses percentage values.

| Taxa | 3rd-7th c. | | | 8th-12th c. | | | 13th-15th c. | | |
|---|---|---|---|---|---|---|---|---|---|
| | NSP (%) | NISP (%) | MNI (%) | NSP (%) | NISP (%) | MNI (%) | NSP (%) | NISP (%) | MNI (%) |
| *Ovis aries* | 43 (3.1) | 43 (5.4) | / | 90 (3.6) | 90 (5,8) | / | 256 (14) | 256 (18.7) | / |
| *Capra hircus* | 9 (0.7) | 9 (1.1) | / | 25 (1) | 25 (1.6) | / | 10 (0.5) | 10 (0.7) | / |
| *Ovis/Capra* | 354 (25.6) | 354 (44.6) | / | 537 (21.4) | 537 (34.8) | / | 550 (30.1) | 550 (40.2) | / |
| Total caprines | 406 (29.4) | 406 (51.2) | 18 (42.9) | 652 (26) | 652 (42.3) | 26 (38.8) | 816 (44.7) | 816 (59.6) | 105 (72.4) |
| *Bos taurus* | 138 (10) | 138 (17.4) | 7 (16.7) | 213 (8.5) | 213 (13.8) | 8 (11.9) | 147 (8) | 147 (10.7) | 9 (6.2) |
| Bovids | 1 (0.1) | 1 (0.1) | / | 4 (0.2) | 4 (0.3) | / | 0 | 0 | / |
| *Sus* sp. | 67 (4.8) | 67 (8.4) | 5 (11.9) | 219 (8.7) | 219 (14.2) | 12 (17.9) | 243 (13.3) | 243 (17.8) | 10 (6.9) |
| *Equus* sp. | 94 (6.8) | 94 (11.9) | 4 (9.5) | 182 (7.3) | 182 (11.8) | 7 (10.4) | 19 (1) | 19 (1.4) | 2 (1.4) |
| *Canis familiaris* | 77 (5.6) | 77 (9.7) | 3 (7.1) | 240 (9.6) | 240 (15.6) | 7 (10.4) | 70 (3.8) | 70 (5.1) | 5 (3.4) |
| *Felis catus* | 7 (0.5) | 7 (0.9) | 3 (7.1) | 25 (1) | 25 (1.6) | 4 (6) | 51 (2.8) | 51 (3.7) | 8 (5.5) |
| *Cervus elaphus* | 1 (0.1) | 1 (0.1) | 1 (2.4) | 4 (0.2) | 4 (0.3) | 1 (1.5) | 1 (0.1) | 1 (0.1) | 1 (0.7) |
| *Capreolus capreolus* | 0 | 0 | 0 | 0 | 0 | 0 | 7 (0.4) | 7 (0.5) | 1 (0.7) |
| *Ursus arctos* | 0 | 0 | 0 | 1 (0) | 1 (0.1) | 1 (1.5) | 0 | 0 | 0 |
| *Oryctolagus cuniculus* | 2 (0.1) | 2 (0.3) | 1 (2.4) | 3 (0.1) | 3 (0.2) | 1 (1.5) | 14 (0.8) | 14 (1) | 3 (2.1) |
| *Lepus* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 1 (0.1) | 1 (0.1) | 1 (0.7) |
| Determined | 793 (57.4) | 793 (100) | 42 (100) | 1543 (61.5) | 1543 (100) | 67 (100) | 1369 (74.9) | 1369 (100) | 145 (100) |
| Medium-sized | 236 (17.1) | | | 417 (16.6) | | | 253 (13.8) | | |
| Large-sized | 210 (15.2) | | | 384 (15.3) | | | 163 (8.9) | | |
| Unidentified | 143 (10.3) | | | 166 (6.6) | | | 42 (2.3) | | |
| Undetermined | 589 (42.6) | | | 967 (38.5) | | | 458 (25.1) | | |
| Total | 1382 (100) | | | 2510 (100) | | | 1827 (100) | | |

**Table 2**
Bone fusion of caprines and tooth wear stages of sheep and goat in number of identified specimens (NISP) in the Late Roman period and Late Antiquity.

| Bone fusion of caprines | | | | | | | Tooth wear stages of *Ovis aries* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stage | Age | Bone | U | V | F | %JUV | Stage | Age | N | % |
| I | 0–5 months | Distal humerus | 2 | | 9 | 8,57 | A | 0–2 months | 0 | 0 |
| | | Proximal radius | 1 | | 23 | | B | 2–6 months | 0 | 0 |
| | | | | | | | C | 6–12 months | 0 | 0 |
| II | 5–12 months | Scapula | | | 14 | 13,64 | D | 12–24 months | 0 | 0 |
| | | Pelvis | 2 | | | | E | 24–36 months | 1 | 25 |
| | | Proximal first phalanx | 1 | | 5 | | F | 36–48 months | 1 | 25 |
| | | Proximal second phalanx | | | | | G | 48–72 months | 2 | 50 |
| | | | | | | | H | 72–96 months | 0 | 0 |
| III | 12–24 months | Distal tibia | 4 | 2 | 8 | 38,46 | I | 96–120 months | 0 | 0 |
| | | Distal metapodial | 4 | | 8 | | Tooth wear stages of *Capra hircus* | | | |
| | | | | | | | Stage | Age | N | % |
| IV | 24–42 months | Proximal calcaneus | 2 | | 2 | 47,06 | A | 0–2 months | 0 | 0 |
| | | Proximal ulna | 1 | | 3 | | B | 2–6 months | 0 | 0 |
| | | Proximal femur | 3 | | 2 | | C | 6–12 months | 0 | 0 |
| | | Proximal humerus | 3 | | 1 | | D | 12–24 months | 0 | 0 |
| | | Distal radius | 4 | | 4 | | E | 24–36 months | 0 | 0 |
| | | Distal femur | 1 | | 3 | | F | 36–48 months | 0 | 0 |
| | | Proximal tibia | 2 | | 3 | | G | 48–72 months | 1 | 50 |
| | | | | | | | H | 72–96 months | 1 | 50 |
| V | > 42 months | Vertebra | 1 | | 2 | 33,33 | I | 96–120 months | 0 | 0 |

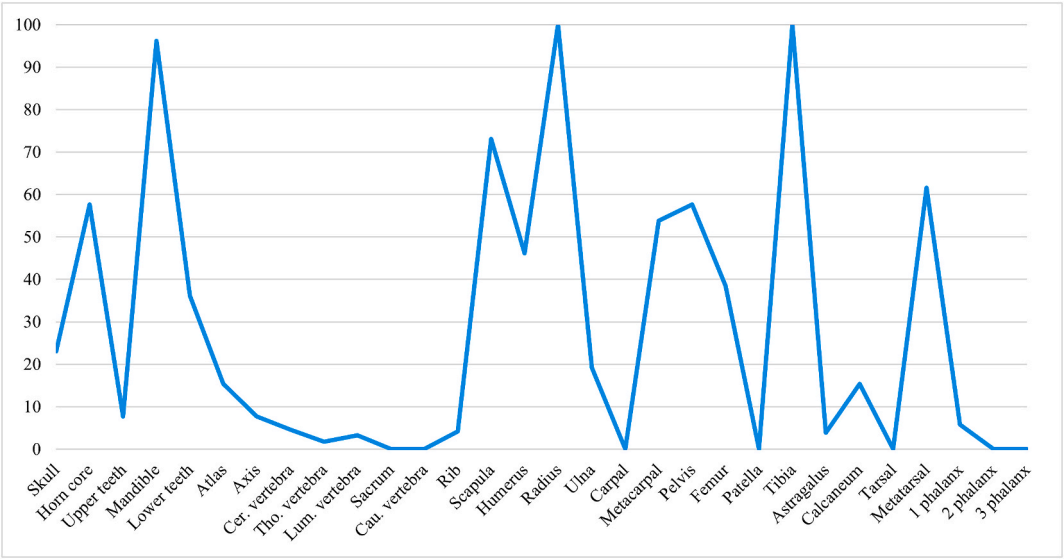



**Fig. 2.** Skeletal representation of caprines in minimum number of animal units (MAU) in the Late Roman period and Late Antiquity (3rd-7th c.).

mortality patterns of sheep and goats. Both taxa are slaughtered at the time of their meat optimum, although secondary resources would also be exploited.

Limbs and head are well represented regions compared to the axial skeleton and the distal appendicular skeleton (Fig. 3). The marks associated with dismembering, butchering and removing the flesh found on girdles, stylopodium and zeugopodium are evidence that the carcasses were processed for meat consumption. Caprines also provided raw materials for artisanal and industrial production. The skins of these species would have been a highly valuable resource as evidenced by the significant number of horn cores bearing chop marks at their base. These cores are primarily from sheep, but also from goats. Similarly, the presence of metapodium and acropodium with chop and cut marks could be a consequence of skin removal. The preservation of these elements (horns with the horn core and autopods) alongside the skinned animal hides would have facilitated their handling in the tannery (Serjeantson, 1989).

### 3.1.3. *Late Middle Ages (13th-15th c.)*

The faunal spectrum remains unchanged from the previous period, but caprine remains now account for more than half of the assemblage. The ratio of sheep to goats (26:1) indicates that sheep are clearly dominant. Suids and cattle occupy a secondary position, followed by a small number of dogs, cats, equids and wild taxa (cervids and leporids) (Table 1).

The slaughter of caprines would also be primarily for meat (Table 4). Among caprines, the first peak in slaughtering occurs before the age of 5 months, suggesting the consumption of lamb. Occasionally, meat from animals aged between 5 months and 1 year would also be consumed. From the age of 1 year, coinciding with the optimum meat quality, butchering activity would intensify up to the age of 4 years. The contribution of older animals is lower, but this indicates the use of secondary products, such as milk or wool. As the predominant animal, sheep were mainly exploited for meat consumption.

The cranial skeleton stands out, especially horn cores, the appendicular skeleton is well represented, except for the basipodium and acropodium, and the axial skeleton is minor (Fig. 4). From the 13th

**Table 3**
Bone fusion of caprines and tooth wear stages of sheep and goat in number of identified specimens (NISP) in the High Middle Ages.

| Bone fusion of caprines | | | | | | | Tooth wear stages of *Ovis aries* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stage | Age | Bone | U | V | F | %JUV | Stage | Age | N | % |
| I | 0–5 months | Distal humerus | 3 | | 12 | 11,63 | A | 0–2 months | 0 | 0 |
| | | Proximal radius | 2 | | 26 | | B | 2–6 months | 0 | 0 |
| | | | | | | | C | 6–12 months | 0 | 0 |
| II | 5–12 months | Scapula | | | 12 | 15 | D | 12–24 months | 0 | 0 |
| | | Pelvis | 3 | | | | E | 24–36 months | 1 | 33,33 |
| | | Proximal first phalanx | | | 5 | | F | 36–48 months | 1 | 33,33 |
| | | Proximal second phalanx | | | | | G | 48–72 months | 1 | 33,33 |
| | | | | | | | H | 72–96 months | 0 | 0 |
| III | 12–24 months | Distal tibia | 5 | 1 | 13 | 40 | I | 96–120 months | 0 | 0 |
| | | Distal metapodial | 9 | 1 | 11 | | Tooth wear stages of *Capra hircus* | | | |
| | | | | | | | Stage | Age | N | % |
| IV | 24–42 months | Proximal calcaneus | 1 | | 2 | 60,38 | A | 0–2 months | 0 | 0 |
| | | Proximal ulna | 2 | | 3 | | B | 2–6 months | 0 | 0 |
| | | Proximal femur | 3 | | 2 | | C | 6–12 months | 0 | 0 |
| | | Proximal humerus | 2 | 1 | 1 | | D | 12–24 months | 0 | 0 |
| | | Distal radius | 12 | | 7 | | E | 24–36 months | 1 | 33,33 |
| | | Distal femur | 3 | | 3 | | F | 36–48 months | 1 | 33,33 |
| | | Proximal tibia | 6 | 2 | 3 | | G | 48–72 months | 0 | 0 |
| | | | | | | | H | 72–96 months | 1 | 33,33 |
| V | > 42 months | Vertebra | | | 1 | 0 | I | 96–120 months | 0 | 0 |

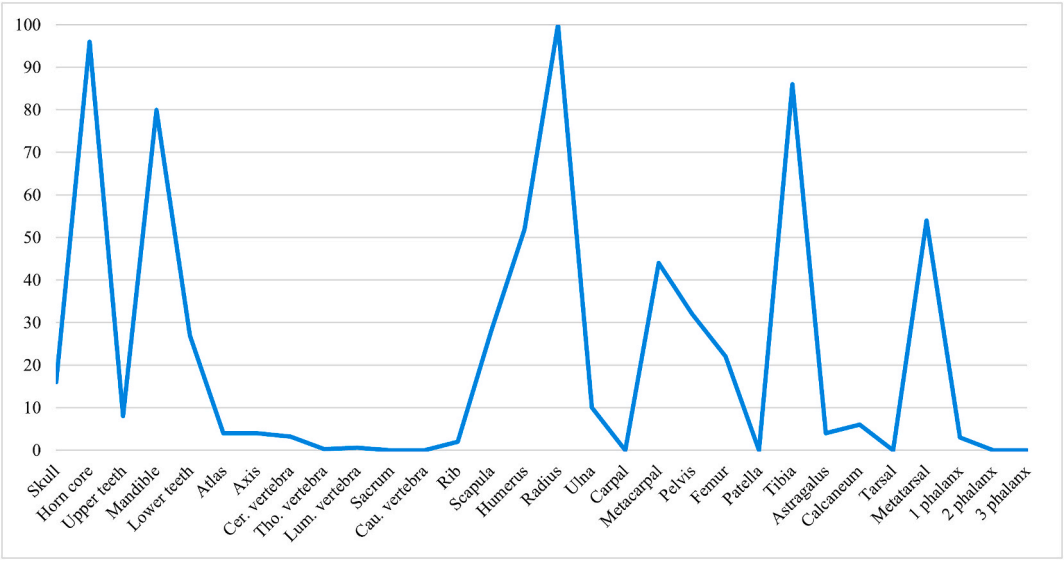



**Fig. 3.** Skeletal representation of caprines in minimum number of animal units (MAU) in the High Middle Ages (8th-12th c.).

century onwards the acquisition of higher-value meat cuts (shoulders and legs) intensifies, with numerous marks associated with the processes of dismembering, butchering and removing the flesh of carcasses. The waste from the butchering process would have been used in the hide industry, as suggested by the skinning marks on the carcasses of caprines. Thus, the large number of modified horn cores made of caprines, and especially sheep, would appear to be the byproduct of the leather-tanning process at a nearby tannery.

### 3.2. Biomolecular analyses

#### 3.2.1. Taxonomical identification by Zooarchaeology by Mass Spectrometry (ZooMS)

*3.2.1.1. Equids.* Tryptic digestion of the 10 equids samples confirmed the identification at the genus level (Table 5), while experimentation with the enzyme chymotrypsin, following the proposal of Paladugu et al. (2023), was unsuccessful. Unfortunately, the peptide marker needed to differentiate between horse and donkey was not present in any spectra and we are unable to make more specific taxonomic assignments.

*3.2.1.2. Caprines.* The 40 caprines samples revealed the presence of 32 sheep (Table 6) and 8 goats (Table 7). Specifically, 10 sheep specimens and 3 goat specimens were identified in the Late Roman period and Late Antiquity; in the High Middle Ages 6 specimens were sheep and 5 goat; and the 16 Late Middle Ages specimens were all sheep. Of the 8 calcanei analysed, 5 were previously identified, according to their morphological and biometrical characteristics, as goat (1 in the High Middle Ages) and sheep (2 in the Late Roman period and Late Antiquity, 1 in the High Middle Ages and 1 in the Late Middle Ages). The identification of these 5 calcanei has been confirmed, so ZooMS has contributed to assess the reliability of morphological and biometrical criteria, as well as confirming the general predominance of sheep over goat.

In short, we have demonstrated in the case of the calcaneus how the ZooMS technique can address the lack of specific identifications for caprines, especially when it is particularly difficult to identify them based on morphological characteristics. Although these criteria are widely accepted by the research community and are commonly used,

**Table 4**
Bone fusion of caprines and tooth wear stages of sheep in number of identified specimens (NISP) in the Late Middle Ages.

| Bone fusion of caprines | | | | | | | Tooth wear stages of *Ovis aries* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stage | Age | Bone | U | V | F | %JUV | Stage | Age | N | % |
| I | 0–5 months | Distal humerus | 5 | | 26 | 17,39 | A | 0–2 months | 0 | 0 |
| | | Proximal radius | 3 | | 12 | | B | 2–6 months | 0 | 0 |
| | | | | | | | C | 6–12 months | 0 | 0 |
| II | 5–12 months | Scapula | 2 | | 38 | 4,44 | D | 12–24 months | 3 | 25 |
| | | Pelvis | | | | | E | 24–36 months | 4 | 33,33 |
| | | Proximal first phalanx | | | 5 | | F | 36–48 months | 2 | 16,67 |
| | | Proximal second phalanx | | | | | G | 48–72 months | 2 | 16,67 |
| | | | | | | | H | 72–96 months | 0 | 0 |
| III | 12–24 months | Distal tibia | 4 | 2 | 19 | 30,77 | I | 96–120 months | 1 | 8,33 |
| | | Distal metapodial | 4 | 2 | 8 | | | | | |
| IV | 24–42 months | Proximal calcaneus | 2 | | | 74,71 | | | | |
| | | Proximal ulna | 8 | | 1 | | | | | |
| | | Proximal femur | 5 | 3 | | | | | | |
| | | Proximal humerus | 9 | 1 | 4 | | | | | |
| | | Distal radius | 10 | 1 | 9 | | | | | |
| | | Distal femur | 12 | 2 | 3 | | | | | |
| | | Proximal tibia | 11 | 1 | 5 | | | | | |
| V | > 42 months | Vertebra | 1 | 2 | 1 | 75 | | | | |

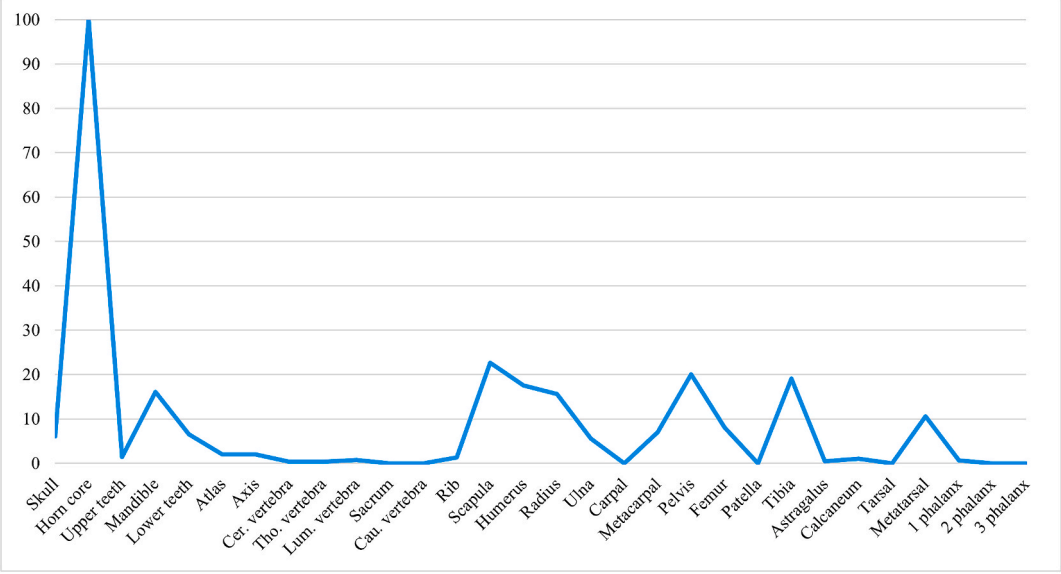



**Fig. 4.** Skeletal representation of caprines in minimum number of animal units (MAU) in the Late Middle Ages (13th-15th c.).

there is always a small degree of uncertainty. Intraspecific morphological variability within a single bone, as well as the skill or experience of the zooarchaeological analysis, influence the ability to apply the guidelines set forth in specialized studies (e.g., Boessneck et al., 1964; Boessneck, 1980; Prummel & Frisch, 1986). Thus, the use of ZooMS solves the sense of subjectivity, while confirming the validity (at least in the case of the calcaneus) of the physical attributes.

### 3.2.2. Stable isotope analysis

*3.2.2.1. Collagen preservation.* The isotopic analysis included 48 collagen samples from the 50 cases studied (Tables 8–10), as two first phalanges of high medieval equids did not provide valid results. Regarding the quality of the collagen, the yield ranged between 0.7% and 20.5%, with four samples below 1.5%. The %C ranges from 14.6% to 44.6% and the %N from 5.1% to 16.5%, with concentrations higher than the 13% and 4.8% indicated as acceptable collagen by Ambrose (1990). The C/N ratio ranges between 2.9 and 3.4, between the values of 2.9 and 3.6 indicated by DeNiro (1985).

*3.2.2.2. $\delta^{13}C$ and $\delta^{15}N$ values.* In the Late Roman period and Late Antiquity, the mean $\delta^{13}C$ values were $-19.9 \pm 1.1$‰ for sheep (n = 10), $-19.6 \pm 0.3$‰ for goat (n = 3), and $-20.8 \pm 0.0$‰ for *Equus* sp. (n = 2) (Tables 8 and 11; Fig. 5). Statistically, there were no significant differences between taxonomic groups ($p = 0.1664$), although sheep showed greater variability (−20.9 to −17.2‰) than goats (−19.8 to −19.4‰) and equids (range of 0.1‰). No significant differences were detected between sheep and goat ($p = 0.4469$), despite the documented ranges (3.7‰ and 0.4‰, respectively). The mean $\delta^{15}N$ values were $5.6 \pm 1.5$‰ in sheep, $4.4 \pm 1.0$‰ in goat, and $6.0 \pm 1.4$‰ in *Equus* sp. (Table 12). There were no significant differences between the three taxa ($p = 0.2439$), although the data for sheep ranged from 4.1 to 8.4‰, those for goats from 3.6 to 5.6‰, and those for equids from 5.0 to 7.0‰. Although diversity is greater in sheep (range of 4.3‰) than in goats (range of 1.9‰), the differences are not statistically significant ($p = 0.1508$). In short, the values for goats and equids are narrow, while sheep has a greater range of dispersion, with one sample standing out with a $\delta^{13}C$ value (−17.2‰).

In the High Middle Ages, the mean $\delta^{13}C$ was $-20.2 \pm 0.8$‰ for sheep (n = 6), $-19.7 \pm 0.6$‰ for goat (n = 5), and $-20.3 \pm 1.5$‰ for the genus

**Table 5**
Peptides with taxonomic value identified in the spectra of the 10 first phalanges of *Equus* sp.

| Phase | Sample | α1 508 | α2 978 | α2 978 (+Hyp) | α2 484 | α2 502 | α2 292 | α2 793 | α2 454 | α1 586 | α1 586 (+Hyp) | α2 757 | α2 757 (+16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3rd-7th c. | 702 F17 | 1105.55 | 1182.57 | – | 1427.68 | 1550.69 | – | 2145.09 | 2821.43 | 2883.52 | 2899.52 | 2984.68 | 2999.66 |
| 3rd-7th c. | 3021 F16 | 1105.61 | – | – | 1427.78 | 1550.81 | – | 2145.15 | 2820.31 | 2883.37 | – | 2983.46 | 2999.46 |
| 8th-12th c. | 450 F3 | 1105.62 | 1182.67 | – | 1427.8 | 1550.83 | 1649.87 | 2145.18 | 2820.35 | 2883.42 | 2899.4 | 2983.51 | 2999.5 |
| 8th-12th c. | 581 F90 | 1105.65 | – | – | 1427.83 | 1550.86 | 1649.89 | 2145.2 | 2820.38 | 2883.45 | 2899.44 | 2983.53 | 2999.53 |
| 8th-12th c. | 597 F15 | 1105.57 | 1182.61 | – | 1427.71 | 1550.74 | 1649.8 | 2145.13 | 2820.5 | 2883.6 | – | – | 2999.72 |
| 8th-12th c. | 598 F1 | 1105.62 | – | – | 1427.8 | 1550.82 | – | 2145.18 | 2820.33 | 2883.4 | 2899.38 | 2983.49 | 2999.49 |
| 8th-12th c. | 3004 F88 | 1105.59 | – | – | 1427.73 | 1550.76 | – | 2145.17 | 2820.48 | 2883.57 | – | 2983.72 | 2999.7 |
| 8th-12th c. | 3016 F19 | 1105.56 | 1182.59 | – | 1427.7 | 1550.71 | – | 2145.12 | 2820.45 | 2883.55 | 2899.54 | 2983.7 | 2999.68 |
| 13th-15th c. | 261 F31 | 1105.36 | – | – | 1427.62 | – | – | 2145.13 | 2820.34 | 2883.41 | – | 2983.5 | 2999.5 |
| 13th-15th c. | 4075 F29 | 1105.58 | 1182.6 | – | 1427.73 | – | – | 2145.17 | 2820.49 | 2883.58 | – | 2983.73 | 2999.71 |

*Equus* (n = 4) (Tables 9 and 11; Fig. 6). No significant differences ($p$ = 0.3634) were found between taxa, but variability was more pronounced in equids (−21.6 to −18.2‰), among which a higher $\delta^{13}C$ value (−18.2‰) was noted. Among caprines, sheep showed different ranges in isotopic values (−21.5 to −19.1‰) than goats (−20.1 to −18.7‰), but these differences were not statistically significant ($p$ = 0.4102). The mean $\delta^{15}N$ is 7.5 ± 4.1‰ for sheep, 5.1 ± 1.6‰ for goat and 6.2 ± 1.3 for *Equus* (Table 12). These differences are not statistically significant ($p$ = 0.5884), despite the range of values for sheep (3.6 to 14.6‰), compared to goats (2.9 to 6.6‰) and equids (5.1 to 8.0‰). Although no significant differences are documented among caprines (p = 0.4113), the range in sheep is 11.0‰, while in goat it is 3.7‰. Therefore, goat presents more homogeneous values compared to the dispersion of sheep, in which a rather high value in $\delta^{15}N$ (14.6‰) stands out.

In the Late Middle Ages, mean $\delta^{13}C$ values ranged from −19.9 ± 0.7‰ in sheep (n = 16) to −20.2 ± 0.2‰ in equids (n = 2) (Tables 10 and 11; Fig. 7). Although no significant differences were found between taxa ($p$ = 0.4397), variability was evident in sheep (−21.0 to −18.0‰), in contrast to that in *Equus* (−20.3 to −20.1‰). The mean $\delta^{15}N$ was 5.5 ± 2.3‰ for sheep and 7.2 ± 2.4‰ for the genus *Equus* (Table 12). These values do not express significant differences ($p$ = 0.2324), although again the diversity is greater in sheep (3.1 to 10.5‰) than in equids (5.4 to 8.9‰).

At the diachronic level, the average $\delta^{13}C$ of the species sheep fluctuates between −19.9 ± 1.1‰ in the first phase, −20.2 ± 0.8‰ in the High Middle Ages and −19.9 ± 0.7‰ in the Late Middle Ages. The High Medieval period marks the lower limit and the Late Roman period and Late Antiquity the upper one, the period with the greatest amplitude of variation. However, these differences are not statistically significant ($p$ = 0.8028). Regarding the average $\delta^{15}N$, the values oscillate between 5.6 ± 1.5‰ between the 3rd and 7th centuries, 7.5 ± 4.1‰ in the second stage and 5.5 ± 2.3‰ at the last stage. Although the lowest value is recorded in the Late Middle Ages and the highest value and greatest variability are documented in the High Middle Ages, the differences are not statistically significant ($p$ = 0.429). Therefore, the species exhibits less variability in the Late Roman period and Late Antiquity, except for the sample with the highest $\delta^{13}C$ value (−17.2‰), while diversity increases in the medieval centuries.

In relation to goat, the mean $\delta^{13}C$ is set at −19.6 ± 0.3‰ between the 3rd and 7th centuries and −19.7 ± 0.6‰ between the 8th and 12th centuries, differences that are not statistically significant ($p$ = 0.5486). The High Middle Ages is the phase that presents the minimum and maximum values and the greatest range of variability. The average $\delta^{15}N$ is set at 4.4 ± 1.0‰ initially and 5.1 ± 1.6‰ later, but the differences are not significant ($p$ = 0.551). Again, the High Middle Ages offers greater variability. Thus, the values remain quite concentrated throughout the centuries, showing less variability than sheep.

Regarding *Equus*, the mean $\delta^{13}C$ values are −20.8 ± 0.0‰ in the Late Roman period and Late Antiquity, −20.3 ± 1.5‰ in the High Middle Ages, −20.2 ± 0.2‰ in the Late Middle Ages, being statistically indistinguishable ($p$ = 0.3998). The High Middle Ages is the most notable moment, offering the lowest and upper limit and the greatest amplitude of variation. In $\delta^{15}N$ the average for the 3rd and 7th centuries is 6.0 ± 1.4‰, for the 8th and 12th centuries it is 6.2 ± 1.3‰ and for the 13th and 15th centuries it is 7.2 ± 2.4‰, with no significant differences ($p$ = 0.5698). The minimum value is documented in the Late Roman period and Late Antiquity, while the maximum is documented in the Late Middle Ages, when there is also a wider range of data.

## 4. Discussion

The taxonomic composition is dominated by species exploited for food, which at the same time provided other resources, such as labor or raw materials for artisanal industries. The dynamics of livestock management do not appear to have undergone many changes between the 3rd and 15th centuries. This continuity is particularly evident in cattle and suids −with no conclusive data for equids-, while there does appear to be a trend towards specialisation in caprine consumption.

Caprines were the main taxon throughout the entire occupation sequence. From the 3rd century onwards, a certain pattern can be observed in sacrifices between the first months of life and 4 years of age. The slaughter of a small proportion of animals under 5 months of age could be related to the consumption of suckling lambs or lambs born in the previous year. In general, the rate of slaughter would increase between 5 months and 1 year of age, at which point mortality increases, coinciding with the optimum age for meat production. Thus, it is especially between 2 and 4 years of age. The decrease in deaths from 4 to 10 years of age shows that some adults were kept for the use of secondary resources such as wool or milk.

This dynamic is common between the 3rd and 15th centuries, but parallel to the increase in the importance of caprines as the occupation sequence progresses, a specialisation of this resource can be detected. Thus, in the Late Roman period and Late Antiquity, there is evidence of continuous and balanced animal slaughter from the first year up to 10 years of age. In the High Middle Ages, there was a drastic change, with a reduction in deaths from the age of 4 onwards. And in the Late Middle

**Table 6**
Peptides with taxonomic value identified in the spectra of *Ovis aries* samples.

| Phase | Sample | Bone | α1 508 | α2 978 | α2 978 (+Hyp) | α2 484 | α2 502 | α2 292 | α2 793 | α2 454 | α1 586 | α1 586 (+Hyp) | α2 757 | α2 757 (+16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3rd-7th c. | 145 F89 | Mandible | 1105.57 | – | – | 1427.7 | 1580.74 | 1648.8 | 2131.12 | 2793.41 | 2883.53 | 2899.55 | 3017.68 | 3033.67 |
| 3rd-7th c. | 322 F26 | Mandible | 1105.51 | – | – | 1427.66 | – | 1648.76 | 2131.03 | 2793.31 | 2884.44 | – | – | 3034.66 |
| 3rd-7th c. | 402 F18 | Mandible | 1105.62 | – | – | 1427.78 | 1580.82 | 1648.88 | 2131.13 | 2792.26 | 2883.36 | 2899.35 | 3017.43 | 3033.43 |
| 3rd-7th c. | 508 F1 | Mandible | 1105.64 | – | – | 1427.8 | 1580.84 | 1648.89 | 2131.15 | 2792.31 | 2883.41 | 2899.4 | 3017.49 | 3033.49 |
| 3rd-7th c. | 572 F1 | Mandible | 1105.59 | 1180.64 | 1196.64 | 1427.73 | 1580.77 | 1648.84 | 2131.15 | 2792.46 | 2883.58 | 2899.58 | 3017.71 | 3033.71 |
| 3rd-7th c. | 4098 F2 | Mandible | 1105.4 | – | – | 1427.53 | 1580.45 | 1648.6 | 2130.69 | 2792.58 | 2882.68 | 2898.66 | 3017.66 | 3033.68 |
| 3rd-7th c. | 322 F123 | Calcaneus | 1105.57 | – | – | 1427.7 | 1580.73 | 1648.8 | 2131.11 | 2792.43 | 2883.54 | 2899.55 | 3017.75 | 3033.68 |
| 3rd-7th c. | 343 F11 | Calcaneus | 1105.59 | – | – | 1427.73 | 1580.76 | 1648.82 | 2131.15 | 2792.45 | 2883.57 | 2899.59 | 3017.74 | 3033.72 |
| 3rd-7th c. | 345 F1 | Calcaneus | 1105.56 | – | – | 1427.69 | 1580.72 | 1648.79 | 2131.11 | 2792.42 | 2883.54 | 2899.56 | 3017.69 | 3033.69 |
| 3rd-7th c. | 572 F2 | Calcaneus | 1105.67 | – | – | – | – | 1648.93 | 2131.22 | – | 2883.52 | 2899.51 | 3017.61 | 3033.58 |
| 8th-12th c. | 409 F4 | Mandible | – | – | – | 1427.78 | – | 1648.88 | 2131.13 | 2792.26 | 2883.35 | – | 3017.4 | 3033.42 |
| 8th-12th c. | 706 F1 | Mandible | 1105.37 | – | – | 1427.63 | 1580.73 | 1648.79 | 2131.14 | 2792.33 | 2883.43 | 2899.42 | 3017.51 | 3033.51 |
| 8th-12th c. | 3004 F3 | Mandible | 1105.61 | – | – | 1427.75 | 1580.79 | 1648.85 | 2131.19 | 2792.51 | 2883.64 | 2899.65 | 3018.84 | 3034.85 |
| 8th-12th c. | 4077 F2 | Mandible | 1105.54 | – | – | 1427.7 | – | 1648.81 | 2131.14 | – | 2883.59 | – | 3018.71 | 3033.83 |
| 8th-12th c. | 4096 F3 | Mandible | 1105.58 | – | – | 1427.72 | – | 1648.83 | 2131.15 | 2793.45 | 2884.58 | 2900.61 | – | 3034.76 |
| 8th-12th c. | 201 F28 | Calcaneus | 1105.58 | – | – | 1427.71 | 1580.75 | 1648.81 | 2131.12 | 2792.4 | 2883.53 | 2899.53 | 3017.64 | 3033.66 |
| 13th-15th c. | 187 F14 | Mandible | – | – | – | 1427.64 | – | 1648.74 | 2131.02 | 2792.24 | 2883.36 | – | 3017.46 | 3033.47 |
| 13th-15th c. | 187 F16 | Mandible | 1105.55 | – | – | 1427.68 | – | 1648.77 | 2131.04 | 2792.31 | 2883.41 | 2899.43 | 3017.55 | 3033.5 |
| 13th-15th c. | 211 F1 | Mandible | 1105.6 | – | – | 1427.73 | 1580.78 | 1648.84 | 2131.17 | 2793.54 | 2884.7 | 2900.73 | 3018.88 | 3034.89 |
| 13th-15th c. | 261 F139 | Mandible | 1105.55 | – | – | 1427.7 | – | 1648.81 | 2131.04 | 2792.24 | 2883.34 | – | 3017.46 | 3033.47 |
| 13th-15th c. | 701 F1 | Mandible | 1105.54 | – | – | 1427.69 | – | 1648.78 | 2131.05 | 2793.18 | 2883.3 | 2900.28 | – | 3034.44 |
| 13th-15th c. | 3003 F84 | Mandible | 1105.44 | – | – | 1427.56 | – | 1648.64 | 2130.67 | 2792.57 | 2883.62 | 2899.63 | 3017.69 | 3033.68 |
| 13th-15th c. | 3003 F85 | Mandible | 1105.58 | – | – | 1427.74 | 1580.8 | 1648.84 | 2131.12 | 2793.24 | – | – | 3019.44 | 3034.53 |
| 13th-15th c. | 4002 F123 | Mandible | 1105.67 | – | – | 1427.86 | 1580.9 | 1648.96 | 2131.23 | 2792.4 | 2883.51 | 2899.5 | 3017.51 | 3033.57 |
| 13th-15th c. | 4002 F125 | Mandible | 1105.57 | – | – | 1427.7 | 1580.74 | 1648.8 | 2131.11 | 2792.38 | 2883.5 | 2899.5 | 3018.62 | 3033.6 |
| 13th-15th c. | 4002 F127 | Mandible | 1105.52 | – | – | 1427.66 | – | 1648.77 | 2131.05 | 2793.25 | 2883.38 | 2900.36 | – | 3034.58 |
| 13th-15th c. | 4070 F21 | Mandible | 1105.59 | – | – | 1427.72 | – | 1648.83 | 2131.16 | 2792.51 | 2883.65 | 2900.64 | 3018.75 | 3034.08 |
| 13th-15th c. | 4070 F23 | Mandible | 1105.58 | – | – | 1427.76 | 1580.8 | 1648.86 | 2131.16 | 2793.3 | – | – | 3018.01 | 3034.97 |
| 13th-15th c. | 4075 F11 | Mandible | 1105.58 | – | – | 1427.71 | 1580.75 | 1648.81 | 2131.13 | 2792.46 | 2883.58 | 2899.59 | 3017.73 | 3033.72 |
| 13th-15th c. | 4075 F12 | Mandible | 1105.54 | – | – | 1427.68 | 1580.7 | 1648.77 | 2131.09 | 2792.41 | 2883.54 | 2899.54 | 3017.66 | 3033.68 |
| 13th-15th c. | 4002 F10 | Calcaneus | 1105.56 | – | – | 1427.69 | – | 1648.78 | 2131.1 | 2792.46 | 2883.55 | 2900.58 | 3018.69 | 3033.69 |
| 13th-15th c. | 4062 F12 | Calcaneus | 1105.59 | – | – | 1427.73 | 1580.77 | 1648.82 | 2131.14 | 2792.44 | 2883.56 | 2899.57 | 3017.71 | 3033.71 |

**Table 7**
Peptides with taxonomic value identified in the spectra of *Capra hircus* samples.

| Phase | Sample | Bone | α1 508 | α2 978 | α2 978 (+Hyp) | α2 484 | α2 502 | α2 292 | α2 793 | α2 454 | α1 586 | α1 586 (+Hyp) | α2 757 | α2 757 (+16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3rd-7th c. | 343 F31 | Mandible | 1105.36 | – | – | 1427.5 | – | 1648.57 | 2130.8 | – | 2882.76 | – | 3077.75 | 3093.59 |
| 3rd-7th c. | 402 F22 | Mandible | 1105.51 | – | – | 1427.68 | – | 1648.78 | 2131.04 | – | – | – | 3078.83 | 3094.76 |
| 3rd-7th c. | 3021 F2 | Mandible | 1105.59 | – | – | 1427.72 | – | 1648.82 | 2131.15 | 2792.46 | 2883.58 | 2900.58 | 3077.74 | 3093.73 |
| 8th-12th c. | 450 F1 | Mandible | 1105.53 | – | – | 1427.69 | 1580.73 | 1648.78 | 2131.06 | 2792.25 | 2883.38 | 2899.35 | 3077.53 | 3093.53 |
| 8th-12th c. | 570 F1 | Mandible | 1105.58 | – | – | 1427.71 | – | 1648.81 | 2131.13 | 2792.44 | 2883.54 | 2900.55 | 3077.72 | 3093.72 |
| 8th-12th c. | 706 F2 | Mandible | 1105.62 | – | – | 1427.78 | – | 1648.89 | 2131.13 | 2792.26 | 2883.35 | – | 3077.42 | 3093.42 |
| 8th-12th c. | 3004 F4 | Mandible | 1105.54 | – | – | 1427.66 | – | 1648.75 | 2131.02 | 2793.23 | 2883.36 | 2900.35 | 3077.5 | 3093.51 |
| 8th-12th c. | 718 F15 | Calcaneus | 1105.59 | – | – | 1427.73 | 1580.76 | 1648.83 | 2131.15 | 2792.47 | 2883.59 | 2899.59 | 3077.76 | 3093.74 |

**Table 8**
Results of the isotopic analysis of the Late Roman period and Late Antiquity samples.

| Sample | Age | ZooMS | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | %C | %N | C/N | % Col. |
|---|---|---|---|---|---|---|---|---|
| 345 F1 | > 36 months | *Ovis aries* | −20.7 | 4.6 | 41.4 | 14.8 | 3.3 | 4.2 |
| 322 F123 | > 36 months | *Ovis aries* | −20.6 | 4.9 | 38.9 | 14.7 | 3.1 | 10.3 |
| 4098 F2 | 36–48 months | *Ovis aries* | −19.3 | 6.6 | 29.1 | 10.6 | 3.2 | 3.9 |
| 145 F89 | 24–36 months | *Ovis aries* | −20.5 | 4.6 | 44.3 | 15.8 | 3.3 | 12.2 |
| 322 F26 | / | *Ovis aries* | −19.9 | 6.1 | 42.4 | 15.0 | 3.3 | 11.3 |
| 402 F18 | 48–72 months | *Ovis aries* | −19.5 | 4.5 | 24.8 | 8.9 | 3.2 | 1.5 |
| 572 F1 | 48–72 months | *Ovis aries* | −17.2 | 7.6 | 20.6 | 7.8 | 3.1 | 0.7 |
| 572 F2 | < 36 months | *Ovis aries* | −19.6 | 5.0 | 33.6 | 11.7 | 3.4 | 2.2 |
| 343 F11 | < 36 months | *Ovis aries* | −20.8 | 4.1 | 37.7 | 13.2 | 3.3 | 8.8 |
| 508 F1 | / | *Ovis aries* | −20.9 | 8.4 | 37.3 | 13.2 | 3.3 | 3.8 |
| 402 F22 | / | *Capra hircus* | −19.4 | 5.6 | 42.1 | 14.9 | 3.3 | 13.2 |
| 3021 F2 | 48–72 months | *Capra hircus* | −19.8 | 3.6 | 38.2 | 15.4 | 2.9 | 0.7 |
| 343 F31 | 72–96 months | *Capra hircus* | −19.8 | 4.1 | 43.1 | 15.4 | 3.3 | 10.0 |
| 3021 F16 | > 12–15 months | *Equus* sp. | −20.8 | 5.0 | 32.2 | 11.4 | 3.3 | 2.5 |
| 702 F17 | > 12–15 months | *Equus* sp. | −20.8 | 7.0 | 36.8 | 14.4 | 3.0 | 0.9 |

**Table 9**
Results of the isotopic analysis of the High Middle Ages samples.

| Sample | Age | ZooMS | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | %C | %N | C/N | % Col. |
|---|---|---|---|---|---|---|---|---|
| 201 F28 | > 36 months | *Ovis aries* | −21.5 | 8.8 | 40.1 | 15.1 | 3.1 | 12.2 |
| 4077 F2 | 24–36 months | *Ovis aries* | −20.4 | 8.8 | 43.7 | 15.5 | 3.3 | 13.5 |
| 409 F4 | 36–48 months | *Ovis aries* | −19.1 | 5.4 | 43.0 | 14.9 | 3.4 | 4.1 |
| 3004 F3 | / | *Ovis aries* | −20.0 | 3.6 | 42.7 | 15.3 | 3.3 | 17.3 |
| 706 F1 | 48–72 months | *Ovis aries* | −20.1 | 4.0 | 40.9 | 14.6 | 3.3 | 6.0 |
| 4096 F3 | / | *Ovis aries* | −20.1 | 14.6 | 41.7 | 14.8 | 3.3 | 15.2 |
| 718 F15 | > 36 months | *Capra hircus* | −20.1 | 2.9 | 42.9 | 15.5 | 3.2 | 17.5 |
| 450 F1 | 36–48 months | *Capra hircus* | −20.1 | 6.5 | 43.9 | 15.4 | 3.3 | 7.7 |
| 570 F1 | 72–96 months | *Capra hircus* | −19.7 | 5.3 | 44.0 | 16.3 | 3.2 | 14.5 |
| 3004 F4 | 24–36 months | *Capra hircus* | −19.9 | 4.1 | 41.1 | 14.5 | 3.3 | 12.3 |
| 706 F2 | / | *Capra hircus* | −18.7 | 6.6 | 42.5 | 15.2 | 3.3 | 14.1 |
| 3016 F19 | > 12–15 months | *Equus* sp. | −21.6 | 5.4 | 36.8 | 14.1 | 3.0 | 7.1 |
| 450 F3 | > 12–15 months | *Equus* sp. | −20.7 | 5.1 | 39.4 | 13.6 | 3.4 | 4.7 |
| 581 F90 | > 12–15 months | *Equus* sp. | −18.2 | 8.0 | 14.6 | 5.1 | 3.3 | 0.8 |
| 598 F1 | > 12–15 months | *Equus* sp. | −20.9 | 6.1 | 35.6 | 12.7 | 3.3 | 2.4 |

Ages, slaughter was clearly focused on animals between 1 and 4 years of age. Furthermore, in this latter phase, the mortality rate of animals between 5 and 12 months of age is very low, so there may have been a preference for the consumption of suckling lambs or young lambs and animals between 1 and 4 years of age. In general, sheep were used for a variety of purposes between the 3rd and 15th centuries. The scarce information available on goats suggests that they were exploited for secondary products during the Late Roman period and Late Antiquity and

**Table 10**
Results of the isotopic analysis of the Late Middle Ages samples.

| Sample | Age | ZooMS | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) | %C | %N | C/N | % Col. |
|---|---|---|---|---|---|---|---|---|
| 4002 F10 | < 36 months | *Ovis aries* | −20.6 | 4.4 | 42.2 | 15.4 | 3.2 | 11.5 |
| 4075 F11 | 12–24 months | *Ovis aries* | −21.0 | 8.0 | 44.0 | 15.6 | 3.3 | 12.0 |
| 4075 F12 | 96–120 months | *Ovis aries* | −20.5 | 10.5 | 43.8 | 16.5 | 3.1 | 17.2 |
| 187 F14 | 48–72 months | *Ovis aries* | −19.9 | 4.5 | 43.2 | 15.4 | 3.3 | 14.1 |
| 187 F16 | 36–48 months | *Ovis aries* | −18.6 | 5.1 | 43.5 | 15.5 | 3.3 | 7.7 |
| 701 F1 | 24–36 months | *Ovis aries* | −20.2 | 8.0 | 42.6 | 15.2 | 3.3 | 14.5 |
| 3003 F84 | / | *Ovis aries* | −19.8 | 3.2 | 43.5 | 15.7 | 3.2 | 18.0 |
| 3003 F85 | 48–72 months | *Ovis aries* | −20.0 | 3.1 | 43.4 | 15.5 | 3.3 | 16.8 |
| 4002 F123 | 24–36 months | *Ovis aries* | −19.8 | 3.6 | 38.2 | 13.3 | 3.4 | 1.7 |
| 4002 F125 | 12–24 months | *Ovis aries* | −18.0 | 9.3 | 40.9 | 14.5 | 3.3 | 14.6 |
| 4002 F127 | 12–24 months | *Ovis aries* | −20.5 | 3.4 | 43.1 | 15.3 | 3.3 | 17.0 |
| 4070 F21 | 24–36 months | *Ovis aries* | −19.9 | 5.2 | 42.1 | 15.1 | 3.3 | 18.0 |
| 4070 F23 | / | *Ovis aries* | −20.0 | 4.4 | 42.4 | 14.9 | 3.3 | 13.2 |
| 211 F1 | 36–48 months | *Ovis aries* | −19.9 | 7.5 | 39.3 | 13.5 | 3.4 | 6.6 |
| 261 F139 | 24–36 months | *Ovis aries* | −20.2 | 5.0 | 41.2 | 14.7 | 3.3 | 17.0 |
| 4062 F12 | < 36 months | *Ovis aries* | −20.0 | 3.6 | 43.3 | 15.8 | 3.2 | 3.8 |
| 4075 F29 | > 12–15 months | *Equus* sp. | −20.1 | 5.4 | 44.6 | 16.3 | 3.2 | 20.5 |
| 261 F31 | > 12–15 months | *Equus* sp. | −20.3 | 8.9 | 38.7 | 13.8 | 3.3 | 4.1 |

**Table 11**
Summary of isotopic data of $\delta^{13}C$ (‰) values.

| Phase | ZooMS | n | Min | Max | Range | Mean ± 1σ |
|---|---|---|---|---|---|---|
| 3rd-7th c. | *Ovis aries* | 10 | −20.9 | −17.2 | 3.7 | −19.9 ± 1.1 |
| 3rd-7th c. | *Capra hircus* | 3 | −19.8 | −19.4 | 0.4 | −19.6 ± 0.3 |
| 3rd-7th c. | *Equus* sp. | 2 | −20.8 | −20.8 | 0.1 | −20.8 ± 0.0 |
| 8th-12th c. | *Ovis aries* | 6 | −21.5 | −19.1 | 2.4 | −20.2 ± 0.8 |
| 8th-12th c. | *Capra hircus* | 5 | −20.1 | −18.7 | 1.4 | −19.7 ± 0.6 |
| 8th-12th c. | *Equus* sp. | 4 | −21.6 | −18.2 | 3.5 | −20.3 ± 1.5 |
| 13th-15th c. | *Ovis aries* | 16 | −21.0 | −18.0 | 3.0 | −19.9 ± 0.7 |
| 13th-15th c. | *Equus* sp. | 2 | −20.3 | −20.1 | 0.3 | −20.2 ± 0.2 |

for a variety of purposes in the High Middle Ages.

Likewise, the specialisation can also be observed in the anatomical distributions and butchery marks of caprines. The processing of meat and the selection of cuts show a continuation until the High Middle Ages. Thus, between the 3rd and 12th centuries the parts of lesser meat value predominate. Whereas, in the context of a privileged late medieval residence, pieces of higher meat value were consumed, as corroborated by butcher patterns, which show a preference for high meat value regions. The increase in caprines would be associated with the gradual demographic and political growth of the city, since *Barcino* gained importance from the Late Roman period onwards, with the new wall and the reform and construction of *domus* within the city (Perich roca, 2014).

**Table 12**
Summary of isotopic data of $\delta^{15}N$ (‰) values.

| Phase | ZooMS | n | Min | Max | Range | Mean ± 1σ |
|---|---|---|---|---|---|---|
| 3rd-7th c. | *Ovis aries* | 10 | 4.1 | 8.4 | 4.3 | 5.6 ± 1.5 |
| 3rd-7th c. | *Capra hircus* | 3 | 3.6 | 5.6 | 1.9 | 4.4 ± 1.0 |
| 3rd-7th c. | *Equus* sp. | 2 | 5.0 | 7.0 | 2.0 | 6.0 ± 1.4 |
| 8th-12th c. | *Ovis aries* | 6 | 3.6 | 14.6 | 11.0 | 7.5 ± 4.1 |
| 8th-12th c. | *Capra hircus* | 5 | 2.9 | 6.6 | 3.7 | 5.1 ± 1.6 |
| 8th-12th c. | *Equus* sp. | 4 | 5.1 | 8.0 | 2.9 | 6.2 ± 1.3 |
| 13th-15th c. | *Ovis aries* | 16 | 3.1 | 10.5 | 7.4 | 5.5 ± 2.3 |
| 13th-15th c. | *Equus* sp. | 2 | 5.4 | 8.9 | 3.5 | 7.2 ± 2.4 |

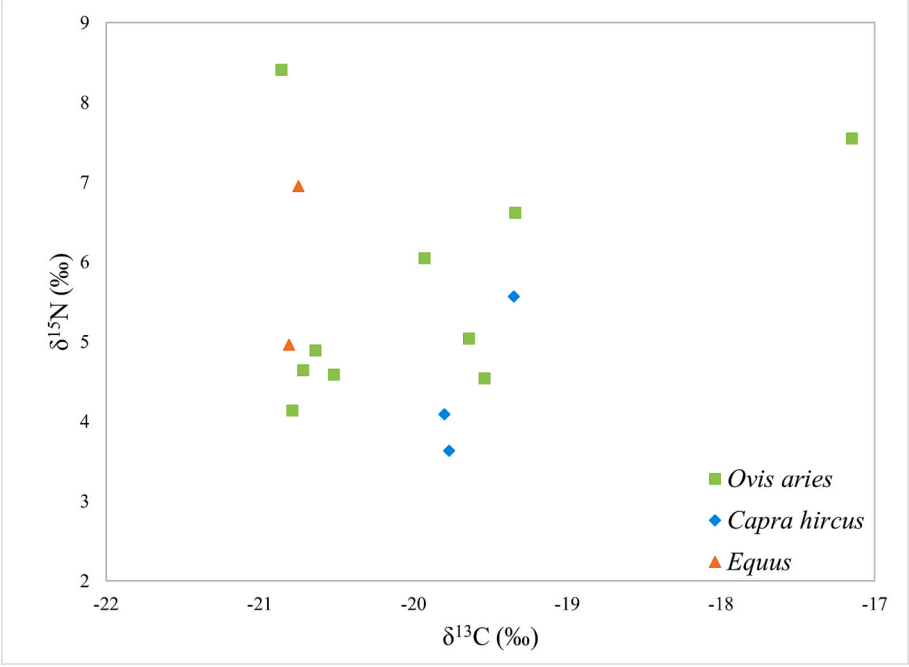



**Fig. 5.** $\delta^{13}C$ (‰) and $\delta^{15}N$ (‰) values of the Late Roman period and Late Antiquity (3rd-7th c.) samples.

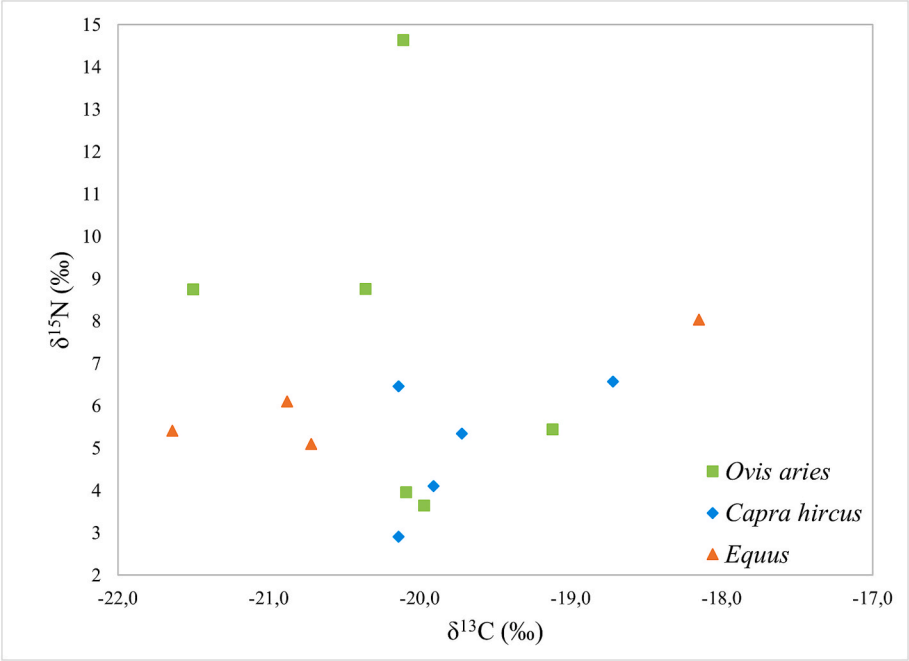



**Fig. 6.** $\delta^{13}C$ (‰) and $\delta^{15}N$ (‰) values of the High Middle Ages (8th-12th c.) samples.

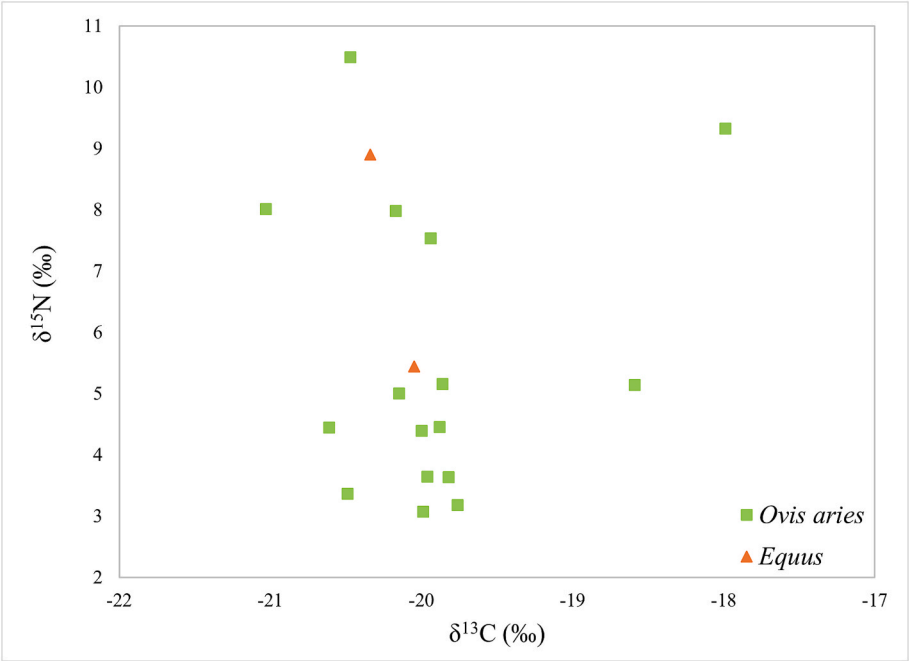



**Fig. 7.** $\delta^{13}C$ (‰) and $\delta^{15}N$ (‰) values of the Late Middle Ages (13th-15th c.) samples.

The population boom meant that the city would no longer be self-sufficient in meat production, requiring the importation of animals through the arrival of flocks, most likely caprines, primarily *Ovis aries*, due to their greater manageability and mobility. The predominance of caprines continued throughout the Middle Ages, in line with the growing food and craft needs of the population, leading to a specialisation in the management and consumption of caprines, and especially sheep, linked to an atmosphere of greater wealth in late medieval Barcelona. The importance of caprines, and specifically sheep, is also documented in other parts of Barcelona and in later chronologies, such as in the late Medieval and Modern levels of the Casa Corrales (El Born) or the Royal Monastery of Santa Maria de Pedralbes (Lloveras et al., 2023c).

In addition, the late Medieval documentation available for Barcelona demonstrates a taste for mutton, influenced by the purchasing power of different social classes. This meat was part of the daily diet of the upper social classes and ordinary days of the clergy and was the most consumed type of meat among the upper middle classes. For the middle and lower classes, mutton was reserved for special occasions, with goat and ewes being preferred, as they were less select and less expensive (Banegas lópez, 2016). This demand would be met by importing flocks from production centres to cover the food needs of a highly populated urban centre.

The $\delta^{13}C$ and $\delta^{15}N$ values from Sotstinent Navarro help clarify the origin of the flocks. Isotopic data show that the diet of caprines and equids was based on $C_3$ plants, although the higher values around −18‰ and above (Ganzarolli et al., 2018) indicates that $C_4$ plants contributed to the diet of some individuals. $\delta^{15}N$ values ranged from 2.9 to 14.6‰, although 94% of the sample did not exceed 8.9‰, and three samples of sheep had higher values (4096 F3 samples from the high Medieval period and 4002 F125 and 4075 F12 samples from the late Medieval period). Beyond diet, factors such as the use of manure as fertilizer on crops (Bogaard et al., 2007) can contribute to increase $\delta^{15}N$.

When comparing the $\delta^{13}C$ and $\delta^{15}N$ values from Sotstinent Navarro with isotopic data from other studies on the Iberian Peninsula, most of the samples match the published cases (Tables 13 and 14). However, samples with higher $\delta^{13}C$ and $\delta^{15}N$ values in the current dataset are distinct. In Sotstinent Navarro, goats are generally more homogeneous in their isotopic values than sheep. The variability of isotopic values here could be possible evidence of the diversity of grazing areas or the movement of flocks (Vaiglova et al., 2014; Zavodny et al., 2014). Thus, it is interpreted that lesser dispersion could perhaps be due to a more geographically constrained feeding area, while greater diversity could be linked to the existence of different grazing areas and, consequently, the more diverse origin of the animals.

The variability of *Ovis aries* could be related to the sourcing of this species from different production centres for the city's meat supply, while *Capra hircus* could have a more restricted origin. In diachronic terms, the variability of sheep's diets increased, and therefore, the breeding areas might have become more diverse. In the Middle Ages, the growing demand for meat, and for the textile and craft sectors (wool and leather), in a context of urban expansion and Barcelona's status as the capital, explains the specialization in sheep breeding in different parts of the Crown of Aragon and the need to acquire these flocks. According to written sources, in the Late Middle Ages, sheep were mainly supplied from four areas: the western zone (*Urgell*, *Segrià*, the western Pyrenees, the central area of *Aragón* and *Penedès*), the northern area (*Cerdanya*, *Ripollès* and *Capcir*), the southern area (*València*, *Teruel* and *Baix Ebre*) and two marginal areas (*Empordà* and *Menorca*) (Banegas lópez, 2016). These zones match to the three major transhumance areas in Catalonia (Rovira & Miralles, 1999).

**Table 13**
$\delta^{13}C$ (‰) and $\delta^{15}N$ (‰) values from local and regional sites of Ample 1 (Rissech et al., 2016), Vila de Madrid (Salazar-García et al., 2022), Santa Caterina (Castells et al., 2022), Sant Pere de Terrassa (Jordana et al., 2019) and Balaguer (Olivé-Busom & López-Costas, 2024).

| Site | Location | Phase | Taxa | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) |
|---|---|---|---|---|---|
| Ample 1 | Barcelona | 1st-4th c. | Caprine | −20.3 | 6.2 |
| Ample 1 | Barcelona | 1st-4th c. | Caprine | −20.6 | 3.9 |
| Vila de Madrid | Barcelona | 2nd-3rd c. | Goat | −20.2 | 3.5 |
| Vila de Madrid | Barcelona | 2nd-3rd c. | Sheep | −19.3 | 4.0 |
| Vila de Madrid | Barcelona | 2nd-3rd c. | Sheep | −20.7 | 7.0 |
| Vila de Madrid | Barcelona | 2nd-3rd c. | Sheep | −18.7 | 5.9 |
| Vila de Madrid | Barcelona | 2nd-3rd c. | Sheep | −20.3 | 4.3 |
| Santa Caterina | Barcelona | 4th-6th c. | Caprine | −19.6 | 7.9 |
| Santa Caterina | Barcelona | 4th-6th c. | Caprine | −19.3 | 6.7 |
| Santa Caterina | Barcelona | 4th-6th c. | Goat | −20.1 | 3.8 |
| Sant Pere de Terrassa | Terrassa | 5th-8th c. | Caprine | −20.8 | 6.7 |
| Sant Pere de Terrassa | Terrassa | 5th-8th c. | Caprine | −19.8 | 4.6 |
| Sant Pere de Terrassa | Terrassa | 5th-8th c. | Caprine | −19.6 | 4.8 |
| Sant Pere de Terrassa | Terrassa | 9th-10th c. | Caprine | −20.2 | 2.9 |
| Sant Pere de Terrassa | Terrassa | 9th-10th c. | Caprine | −20.8 | 5.0 |
| Sant Pere de Terrassa | Terrassa | 9th-10th c. | Caprine | −20.6 | 4.1 |
| Sant Pere de Terrassa | Terrassa | 9th-10th c. | Caprine | −19.8 | 4.9 |
| Balaguer | Balaguer | 11th c. | Caprine | −19.72 | 6.24 |
| Balaguer | Balaguer | 11th c. | Caprine | −19.77 | 5.26 |

**Table 14**
$\delta^{13}C$ (‰) and $\delta^{15}N$ (‰) values from insular and peninsular sites of 33 Bartomeu Vicent Ramon (Dury et al., 2019), Gózquez (García-Collado, 2016), Las Gobas (Guede et al., 2018), Aistra (Sirignano et al., 2014), Treviño (Sirignano et al., 2014), Dulantzi (Sirignano et al., 2014), Zaballa (Sirignano et al., 2014), Zornoztegi (Sirignano et al., 2014) and Camino Viejo de las Sepulturas (Sarabia-Bautista et al., 2022).

| Site | Location | Phase | Taxa | $\delta^{13}C$ (‰) | $\delta^{15}N$ (‰) |
|---|---|---|---|---|---|
| 33 Bartomeu Vicent Ramon | Ibiza | 10th-12th c. | Caprine | −20.4 | 5.1 |
| Gózquez | Madrid | 6th-8th c. | Caprine | −19.5 | 8.7 |
| Gózquez | Madrid | 6th-8th c. | Caprine | −19.3 | 8.2 |
| Gózquez | Madrid | 6th-8th c. | Goat | −18.1 | 7.8 |
| Gózquez | Madrid | 6th-8th c. | Sheep | −19.8 | 6.8 |
| Gózquez | Madrid | 6th-8th c. | Caprine | −20.3 | 8.4 |
| Las Gobas | Burgos | 9th-10th c. | Caprine | −20.57 | 4.11 |
| Las Gobas | Burgos | 10th c. | Caprine | −20.43 | 4.31 |
| Las Gobas | Burgos | 7th c. | Caprine | −20.62 | 4.91 |
| Las Gobas | Burgos | 6th-7th c. | Caprine | −21.27 | 4.8 |
| Las Gobas | Burgos | 8th c. | Caprine | −21.06 | 5.41 |
| Las Gobas | Burgos | 8th c. | Caprine | −20.34 | 5.47 |
| Aistra | Álava | 10th c. | Sheep | −21.5 | 4.6 |
| Aistra | Álava | 7th c. | Sheep | −21.3 | 4.7 |
| Aistra | Álava | 7th-8th c. | Sheep | –22,0 | 2.3 |
| Treviño | Burgos | 10th-13th c. | Sheep | −19.8 | 5.9 |
| Treviño | Burgos | 10th-13th c. | Sheep | −21.3 | 3.0 |
| Dulantzi | Álava | 6th-7th c. | Goat | −20.9 | 5.5 |
| Dulantzi | Álava | 6th-7th c. | Sheep | −21.2 | 6.3 |
| Dulantzi | Álava | 8th-9th c. | Sheep | −21.1 | 9.8 |
| Dulantzi | Álava | 6th-9th c. | Sheep | −20.6 | 8.0 |
| Dulantzi | Álava | 6th-7th c. | Caprine | −19.8 | 7.7 |
| Zaballa | Álava | 10th c. | Sheep | −20.6 | 4.7 |
| Zornoztegi | Álava | 10th-11th c. | Sheep | −19.6 | 4.0 |
| Zornoztegi | Álava | 13th-14th c. | Sheep | −20.9 | 6.1 |
| Zornoztegi | Álava | 8th-10th c. | Sheep | −19.5 | 5.6 |
| Camino Viejo Sepulturas | Albacete | 4th-5th c. | Caprine | −20.3 | 5.1 |
| Camino Viejo Sepulturas | Albacete | 4th-5th c. | Caprine | −20.0 | 6.7 |
| Camino Viejo Sepulturas | Albacete | 4th-5th c. | Caprine | −19.3 | 8.5 |

In short, over the course of the centuries, different evidence suggests an increase in the specialisation of caprine production and consumption (relative frequencies, productive orientations, livestock provisioning) which is also reflected in butchery techniques and in the selection of pieces of meat. It was in the Late Middle Ages that this increase in complexity became apparent, with greater processing of carcasses and a more professional practice. On a general level, this could be the result of the historical moment, urban expansion and the need to supply an important urban centre such as Barcelona with the demand of a growing population, as well as the professionalisation of the meat sector, as suggested by all the regulations imposed by the late medieval municipal authorities in relation to its sale. While the acquisition of pieces of greater meat value, such as hindquarters, would refer to the atmosphere of a certain opulence of the Gothic palace.

In contrast to the growing economic importance of caprines, cattle played a more secondary role. Late medieval records indicate that meat from oxen, cow or calf was considered inferior to that of sheep (Banegas lópez, 2016). Thus, the progressive specialization of meat production and consumption in caprines leaves cattle as a complementary meat source, following their amortisation as draft animals and perhaps as

dairy producers. Similarly, suids remain in a secondary position and exhibit a similar pattern throughout the occupation sequence at Sotstinent Navarro, meaning they were always a minor source of meat. We assume that most of the remains belong to pigs, and only the sporadic presence of wild boar is confirmed in the High Middle Ages. This suggests that pig has always been a marginal but stable component of the urban meat diet. On the other hand, horses and donkeys are not considered food animals; they are used as working animals. In addition, game animals were occasionally consumed. The presence of bear in the High Middle Ages and roe deer in the Late Middle Ages is particularly interesting in the context of urban growth, during which the wealthier classes enjoyed both big game (deer and wild boar) and small game (rabbit and hare) (Riera I melis, 1994). Evidence from Sotstinent Navarro suggests that the residents of the high and late medieval mansion consumed high-quality meats in an environment of a certain luxury, opulence exhibited through the presence of a peacock (Fernández et al., 2023).

In conclusion, between the 3rd and 7th centuries, Sotstinent Navarro was an active area outside the city walls. Much of the mammals consists of food waste, although some caprines remains suggest the existence of a craft or industrial sector, and certain domestic animals or wild species would have found their natural habitat in these contexts, with no clear link to human activity. In the High Middle Ages, this area was used for farming and habitation, featuring a manor house or small palace built between the 11th and 12th centuries. The faunal composition, mortality patterns, incidence of pathologies, and taphonomic alterations suggest that the origin of the osteological remains is mixed, with waste derived from food consumption, artisanal or industrial activity, and the disposal of unconsumed animals. In the Late Middle Ages, when the medieval wall was built and burghs were incorporated into the city of Barcelona, Sotstinent Navarro was an active habitation area, with the extension of the high medieval housing. This historical dynamic generates a palimpsest of materials, including consumption waste, residues from artisanal or industrial activities, the disposal of uneaten animals, and some wild species, suggesting an environment of a certain opulence.

## 5. Conclusions

Combining biomolecular analysis with traditional archaeozoological studies has proved to be a useful way of extracting information from osteological remains. Given the existing limitations, applying ZooMS alongside stable carbon and nitrogen isotope analysis to a selected subsample was useful for making inferences about sheep and goat management.

Since the Late Roman period, *Barcino* grew in importance, although Sotstinent Navarro was a marginal area outside the walls, where residue from food consumption and, to a lesser extent, of craft activities in the surrounding area accumulate. With the medieval urban expansion, Sotstinent Navarro was integrated into the urban network, following the incorporation of the burghs into the city and the construction of a new wall. Barcelona's location on the Mediterranean defined its typically Mediterranean economy, in which caprines were the main taxon of livestock. In the High Middle Ages, our results show an intensification in the use of caprine meat and skins. In the Late Middle Ages, Barcelona was a consumption centre that was supplied by herds from different production areas to guarantee the meat market and the tanning of hides, two closely related sectors. Thus, sheep became the dominant species and specialisation in their management as a meat resource was particularly evident in the Late Middle Ages. The presence of high-quality cuts of mutton suggests a late medieval wealthy class that lived in the luxurious and ostentatious atmosphere of the Gothic palace built here.

## CRediT authorship contribution statement

**Marina Fernández-Liarte:** Writing – original draft, Investigation. **Marta Moreno-García:** Writing – review & editing, Supervision. **Jordi Nadal-Lorenzo:** Writing – review & editing, Supervision. **Jordi Ramoz-Ruiz:** Writing – review & editing. **Samantha Greeves:** Writing – review & editing. **Matthew von Tersch:** Writing – review & editing. **Jessica Hendy:** Writing – review & editing, Supervision. **Michelle Alexander:** Writing – review & editing, Supervision. **Santiago Riera-Mora:** Writing – review & editing, Supervision, Funding acquisition.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

Data will be made available on request.

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