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Livestock feeding strategies and socio-economic dynamics during the sixth to fourth centuries BC in the north-eastern Iberian Peninsula and southern France. A review of animal palaeodietary studies

Estratègies d'alimentació ramadera i dinàmica socioeconòmica en els segles VI-IV aC al nord-est de la península Ibèrica i el sud de França. Una revisió d'estudis de paleodieta animal

Estrategias de alimentación ganadera y dinámica socioeconómica durante los siglos VI-IV a. C. en el noreste de la península ibérica y el sur de Francia. Una revisión de estudios de paleodieta animal

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This paper presents a review of published studies on livestock palaeodiets conducted on sites dated from the sixth to fourth centuries BC in the north-eastern Iberian Peninsula and southern France. The aim is to provide a preliminary overview of the relationship between animal feeding strategies and socio-economic dynamics. It also seeks to highlight current limitations and propose future research directions, particularly regarding geographical, chronological and animal-species representativeness. The analysis of data from 11 archaeological sites revealed that socio-economic dynamics played a major role in shaping animal feeding strategies, and that the latter were adapted to a series of constraints imposed by historical contexts. We also observed that not all regions are equally represented, and that sheep and goats are the best-represented animal species. Future research should aim to address these gaps, by broadening the scope of studies to other regions, earlier chronologies and underrepresented species, such as pigs and cattle.

KEYWORDS
ZOOARCHAEOLOGY, HUSBANDRY PRACTICES, ANIMAL PALAEODIET, PROTOHISTORY, CATALONIA, LANGUEDOC

En aquest article es presenta una revisió dels estudis publicats sobre paleodietes ramaderes realitzats en jaciments que daten als segles VI al IV aC al nord-est de la península Ibèrica i el sud de França. L'objectiu és proporcionar una visió preliminar de la relació entre les estratègies d'alimentació animal i la dinàmica socioeconòmica. Es busca també destacar les limitacions actuals i proposar futures línies de recerca, en particular pel que fa a la representativitat geogràfica, cronològica i de les espècies animals estudiades. L'anàlisi de dades d'11 jaciments arqueològics va revelar que la dinàmica socioeconòmica va tenir un paper important en la configuració de les estratègies d'alimentació animal i que aquestes darreres es van adaptar a una sèrie de restriccions imposades pels contextos històrics. També observem que no totes les regions estan igualment representades, i que les ovelles i les cabres són les espècies més ben representades. La investigació futura hauria d'abordar aquestes llacunes i ampliar l'abast dels estudis a altres regions, cronologies anteriors i espècies subrepresentades, com ara els porcs i el bestiar boví.

PARAULES CLAU
ARQUEOZOOLOGIA, PRÀCTIQUES RAMADERES, PALEODIETA ANIMAL, PROTOHISTÒRIA, CATALUNYA, LLENGUADOC

En este artículo se presenta una revisión de los estudios publicados sobre paleodietas ganaderas realizados en yacimientos que datan en los siglos VI al IV a. C. en el noreste de la península ibérica y el sur de Francia. El objetivo es proporcionar una visión preliminar de la relación entre las estrategias de alimentación animal y la dinámica socioeconómica. Se busca también destacar las limitaciones actuales y proponer futuras líneas de investigación, en particular con respecto a la representatividad geográfica, cronológica y de las especies animales estudiadas. El análisis de datos de 11 yacimientos arqueológicos reveló que la dinámica socioeconómica jugó un papel importante en la configuración de las estrategias de alimentación animal, y que estas últimas se adaptaron a una serie de restricciones impuestas por los contextos históricos. También observamos que no todas las regiones están igualmente representadas, y que las ovejas y las cabras son las especies mejor representadas. La investigación futura debería abordar estas lagunas, ampliando el alcance de los estudios a otras regiones, cronologías anteriores y especies subrepresentadas, como los cerdos y el ganado vacuno.

PALABRAS CLAVE
ARQUEOZOOLOGÍA, PRÁCTICAS GANADERAS, PALEODIETA ANIMAL, PROTOHISTORIA, CATALUÑA, LANGUEDOC

1. Introduction

Societies in the north-eastern Iberian Peninsula and southern France during the Iron Age (seventh to second centuries BC) underwent a series of progressive transformations affecting their economic, social and political structures. This period saw the consolidation of hierarchical systems and territorial organization controlled by aristocratic elites (Py, 1993; Asensio *et al*., 1998, 2002; Sanmartí and Belarte, 2001; Sanmartí, 2001, 2004; Gailledrat, 2014; Garcia, 2014). On both sides of the Pyrenees, these elites resided in fortified settlements that served defensive purposes and acted as displays of power (Py and Garcia, 1993; Py and Roure, 2002; Gailledrat, 2013). In this way, aristocratic elites could accumulate and redistribute surplus agricultural production, and control trade networks, engendering competition for access to exchangeable goods.

Between the sixth and fourth centuries BC, archaeological evidence shows an increase in these trends. From the fifth century BC onwards, fewer individuals were interred in necropolises, which were exclusively reserved for elites, attesting to social buried. Grave goods, including weaponry, highlight the warrior identity of elites. Throughout this period, the territory was organised into large and fortified settlements, but archaeological evidence also attests to the presence of small settlements and specialised sites, such as silo pits or centres focused on metallurgical activities (Asensio *et al*., 1998; Asensio and Martin, 2004). Technologically, the appearance of iron marked an important shift in production, leading to major changes in the economic system, notably in agriculture.

In the sixth century BC, Greek colonies such as *Massalia* (Marseille, France) and *Emporion* (Empúries, Spain) were established, alongside *Agathé* (Agde, France) in the fifth century BC (Sanmartí, 2009). Paradoxically, by the sixth century BC, we observe a drastic reduction in ceramic imports (Asensio, 1996; Asensio *et al*., 2002). This has been interpreted as an indication of a more self-sufficient society, with imports kept to a minimum. Moreover, it has been suggested that only the aristocratic elites would have had access to these imported goods. The number of importations increased during the middle of the fourth century BC.

These transformations had an impact on the environment, as suggested by palynological, anthracological, geoarchaeological and carpological analyses (Riera and Esteban, 1994; Alonso, 2000; Piqué, 2002; Chabal, 2007; Ponel and Rocq, 2007; Jorda *et al*., 2008; Bagan *et al*., 2010; Montaner *et al*., 2014; Ejarque *et al*., 2016). Palaeoenvironmental data indicate the proliferation of wetland areas, with abundant lagoons and ponds along the coastline. These studies highlight a peak in sea levels during the Iron Age, leading to the expansion of marshes and salt-water areas. In addition, progressive deforestation is observed throughout the Iron Age, evidenced by the reduction in forested areas. In inland regions, palaeoenvironmental data show a landscape dominated by forests, with widespread oak. These studies also reveal more open environments due to deforestation.

Alongside agriculture, livestock farming was a central economic activity. Over recent decades, numerous zooarchaeological studies have focused on Iron Age sites along the cen-

tral coast of present-day Catalonia (e.g. Valenzuela-Lamas, 2008; Albizuri, 2014; Jiménez-Manchón *et al*., 2019), northern present-day Catalonia (Colominas, 2017; Albizuri, 2018; Jiménez-Manchón *et al*., 2023*a*; Colominas *et al*., 2023) and the Languedoc region, in France (e.g., Beylier *et al*., 2018; Gardeisen, 2010; Al Besso *et al*., 2013; Jiménez-Manchón *et al*., 2023*b*). Nieto-Espinet and colleagues (2020*a*, 2020*b*) summarised and discussed zooarchaeological findings, such as taxonomic representation and mortality profiles in the north-eastern Iberian Peninsula and Languedoc. These works reveal a predominance of sheep and goats, followed by cattle and pigs, with evidence of local breeding. This is reflected in taxonomic adaptations to ecological environments, potentially linked to a decrease in livestock size. Strontium analyses strongly support limited mobility in Iron Age sites in Languedoc (Nieto-Espinet *et al*., 2020*b*; Jiménez-Manchón *et al*., 2023*b*) and along the central Catalonian coastline (Valenzuela-Lamas *et al*., 2016, 2018).

Livestock strategies include other factors more difficult to detect with traditional zooarchaeological tools, such as birth seasonality, different morphotypes, animal feeding strategies, animal mobility, and the seasonality of animal birth slaughter. In recent years, new methods have been employed to address these aspects, including geometric morphometrics (Jeanjean *et al*., 2022), stable isotope analyses (e.g., Valenzuela *et al*., 2016; Messana *et al*., 2023, 2025) and strontium isotope ratios (e.g., Valenzuela-Lamas *et al*., 2016, 2018).

The study of animal feeding practices provides valuable insights into farming strategies and land use by herders and farmers. These include understanding the types of grazed pastures, their impact on the environment, and foddering practices. Some researchers have examined how livestock were fed. Colominas and colleagues (2011) propose territorial, and grazing pasture organization based on species. Specifically, they suggest that goats and sheep were fed in wooded areas and scrubland, while cattle grazed in open pastures. Nieto-Espinet and colleagues (2020*b*) observe a higher presence of cattle in sites located near the coast, and more sheep and goats in inland sites.

Given the methodological limitations of traditional approaches, there has been a significant focus in recent years on reconstructing livestock palaeodiets using alternative techniques. These proxies include dental wear and isotope analyses, which provide valuable insights into both animal and territory management. More specifically, these methods open new fields of possibilities by investigating whether animals were managed extensively (i.e., across large areas without supplementary fodder) or intensively (in smaller areas, potentially with foddering and confinement), and whether their diet corresponds to the vegetation available near archaeological sites.

To date, most studies focusing on livestock palaeodiets are case studies, and no overviews of animal feeding strategies on both sides of the Pyrenees in their archaeological and historical contexts have yet been published. In this work, I propose the first summary of published studies addressing animal feeding strategies between the north-eastern Iberian Peninsula and southern France up to 2025. The selected chronological framework covers the transition between the First and Second Iron Ages, specifically from the sixth to fourth centuries BC. This chronological context was selected for several reasons: 1) it marks a

pivotal moment in the socio-political and territorial organization of Iron Age societies on both sides of the Pyrenees; 2) this period witnessed a significant transformation in economic structures (e.g., the establishment of Greek colonies, reduction in imports, and increase in self-sufficiency and territorial control by local elites); and 3) it is the best documented period in terms of animal feeding strategies.

The aim of this work is to provide a preliminary assessment of the studies carried out on animal palaeodiet reconstruction within this chronological and geographical framework. This review seeks to establish a baseline for current knowledge, identifying the main lines of research, the methodological approaches applied, and the limitations of existing data. It also aims to highlight future research directions, define yet understudied geographical areas and recommend complementary techniques that could contribute to a more comprehensive understanding of animal management practices in Iron Age societies in the north-western Mediterranean.

2. Material and method

Animal palaeodietary data from 11 archaeological sites have been reviewed, drawing on eight works published between 2016 and 2023 (figure 1 and table 1). Three of these sites are located in the present-day region of Catalonia (north-eastern Spain) and eight in the historical region of Languedoc (southern France). In methodological terms, dental wear analyses are the most common, applied to 11 sites, followed by isotope analyses, conducted at four sites. Dental wear and isotope analyses were combined in four sites: Font de la Canya, Cayla de Mailhac, la Ramasse and Lattara. An overview of the collected data is presented in table 2 and figure 2.

The methods employed provide different but complementary information about animal palaeodiets, which can pose limitations for the comparison and interpretation of results. On the one hand, dental microwear reconstructs livestock diet in the last weeks before death by analysing the microtexture and microfeatures produced by food on tooth enamel. Two aspects must be considered in this type of analysis. First, because the data reflect the last feeding of animals, they are highly sensitive to seasonal variation, an important factor to consider. Second, most studies rely on low-magnification dental microwear, which is based on the visual identification of microwear features and may therefore introduce inter-observer error. The data obtained in this work has been produced by two authors – eight studies by one and three by the other – so a certain degree of inter-observer variability cannot be excluded. On the other hand, stable carbon isotope analyses ($\delta^{13}C$) measure the carbon isotopic composition of the plants consumed by animals. The values obtained vary according to the pathway of plants: C3 and C4 plants. Unlike dental wear analyses, stable carbon isotopes do not provide direct information about animal palaeodiets, but rather about the chemical composition of the ingested food.

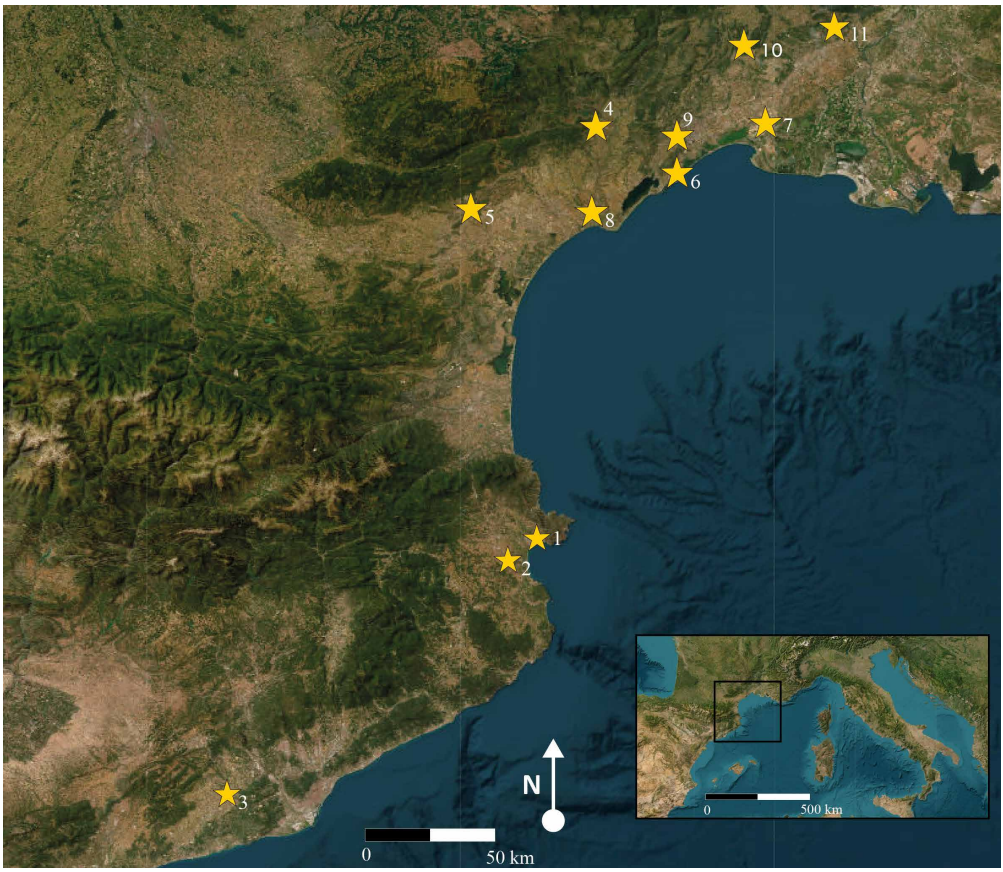

Figure 1. Location of the sites included in this study in the north-eastern Iberian Peninsula and southern France. Site names are listed in Table 1.

Sheep and goats were analysed in all studies (n= 11), while cattle were examined in fewer cases, namely in seven studies. As a result, feeding strategies for sheep and goats are better documented than those of cattle.

3. Results

3.1. North-eastern Iberian Peninsula

In the north-eastern Iberian Peninsula, only three sites have yielded animal palaeodietary data to date: Empúries (Girona, Spain), Ullastret (Girona, Spain) and Font de la Canya

Table 1. Archaeological sites studied in this work. For each case, the chronological period, the location, the methodological approach, the species analysed, and the bibliographic reference have been specified

Number in figure 1	Archaeological site	Chronological period	Location	Approach	Species analysed	Bibliographic reference
1	Ullastret	6th-4th c. BC	Girona, Spain	Dental microwear and mesowear	Sheep and goats	Ibáñez *et al.*, 2020; Jiménez-Manchón *et al.*, 2020, 2023*a*
2	Empúries	6th-4th c. BC	Girona, Spain	Dental microwear and mesowear	Sheep and goats	Ibáñez *et al.*, 2020; Jiménez-Manchón *et al.*, 2020, 2023***a***
3	Font de la Canya	6th-4th c. BC	Barcelona, Spain	Oxygen and carbon isotope analyzes; dental microwear analysis	Sheep and goats	Valenzuela-Lamas *et al.*, 2016, 2018; Jiménez-Manchón *et al.*, 2020
4	La Ramasse	4th c. BC	Hérault, France	Dental microwear and mesowear	Sheep, goats, and cattle	Jiménez-Manchón *et al.*, 2023*b*
5	Cayla de Mailhac	5th-4th c. BC	Aude, France	Oxygen and carbon isotope analyzes; dental microwear analysis	Sheep, goats, and cattle	Jiménez-Manchón *et al.*, 2023*b*
6	*Lattara*	6th-4th c. BC	Hérault, France	Oxygen and carbon sotope analyzes; dental microwear analysis	Sheep, goats, and cattle	Alagich *et al.*, 2018; Jiménez-Manchón *et al.*, 2023*b*
7	Le Cailar	6th-4th c. BC	Gard, France	Oxygen and carbon isotope analyzes; dental microwear analysis	Sheep, goats, and cattle	Jiménez-Manchón *et al.*, 2023*b*
8	La Monédière	6th-4th c. BC	Hérault, France	Dental microwear and mesowear	Sheep, goats, and cattle	Jiménez-Manchón *et al.*, 2023*b*
9	Sextantio-La Faigoule	6th-4th c. BC	Hérault, France	Dental microwear	Sheep, goats, and cattle	Lespes, 2020
10	Le Plan de la Tour	6th-4th c. BC	Gard, France	Dental microwear	Sheep, goats, and cattle	Lespes, 2020
11	Marduel	6th-5th c. BC	Gard, France	Dental microwear	Sheep and goats	Lespes, 2020

(Barcelona, Spain). Data from Ullastret and Empúries, two settlements located in the Empordà region and just 15 km from each other, reveal that sheep and goats fed in an environment dominated by eudicotyledonous plants, shrubs and bushes, with limited grasses. Although the sheep diet shows a higher intake of grasses than that of goats, the diets of both species are quite similar at both sites, suggesting that both species were fed together or in similar areas. A similar pattern was observed at the Font de la Canya site (Barcelona, Spain), located about 30 km inland from the present-day central Catalonian coast. In this site, sheep and goats exhibit similar palaeodietary patterns, consistent with a plant intake in an environment rich in eudicotyledonous plants, which could indicate foraging in wooded areas with abundant shrubs and bushes. However, dental microwear analysis at Font de la Canya shows a high number of dental enamel pits, suggesting soil

intake, which could be linked to overgrazing in nearby areas. This hypothesis is supported by the absence of evidence for animal mobility at this site (Valenzuela-Lamas *et al.*, 2016, 2018). Stable carbon isotope analysis (δ^{13}) conducted at this site indicates that sheep and goats predominantly consumed C3 plants (Valenzuela-Lamas *et al.*, 2016), consistent with an environment dominated by eudicotyledonous plants such as shrubs and bushes.

At Empúries and Ullastret, dental microwear and cementum analyses were combined (Jiménez-Manchón *et al.*, 2023*b*). This high-resolution multidisciplinary approach allowed for the reconstruction of the seasonal animal palaeodiet. Data indicate a higher consumption of woody plants in the summer and autumn months. According to the authors, two hypotheses can be put forward; on the one hand, this could be related to the lower availability of grasses during this period; on the other hand, it could indicate possible seasonal mobility towards more closed wooded areas in summer and autumn.

For cattle, data are only available from the sites of the Empordà region. Findings suggest that in the sixth and fifth centuries BC, the cattle diet was rich in grasses, consistent with grazing in open pastures or the intake of agricultural sub-products. In a later chronological period (fifth to fourth centuries BC), cattle intake of eudicotyledonous plants was higher, although grasses remained predominant in their diets.

These results suggest that between the sixth and fourth centuries BC, sheep and goats were primarily herded in environments rich in eudicotyledonous plants. Although data from inland regions are very limited, the evidence from Font de la Canya suggests possible overgrazing in this geographical context. In contrast, cattle appear to have been managed in areas rich in grasses at sites located close to the coast. A change in cattle herding strategies over time cannot be ruled out, potentially indicating shifts to herding in more wooded areas.

3.2. Southern France

In southern France, four sites located along the coast, and four inland sites, have yielded animal palaeodietary data. In all sites located close to the coast (La Monédière, *Lattara*, Le Cailar and *Sextantio*-La Farigoule), the caprine diet (sheep and goats) is predominantly a mixed feeder diet with browsing tendencies. At sites where the sheep and goat palaeodiet could be analysed, sheep diets present a higher intake of grasses than goats. This variability may be due to different species-related dietary behaviour. However, different feeding strategies for these two species cannot be ruled out. In this sense, goats also exhibit dental microwear patterns compatible with a higher ingestion of soil particles, which could suggest browsing in more overgrazed environments compared to sheep.

The cattle diet is predominantly a mixed feeder diet with grazer tendencies. This is consistent with pastures in open grassland areas and the intake of agricultural subproducts. In addition, dental microwear patterns are compatible with low soil ingestion or few hard particles, which does not support the hypothesis of grazing in overgrazed areas.

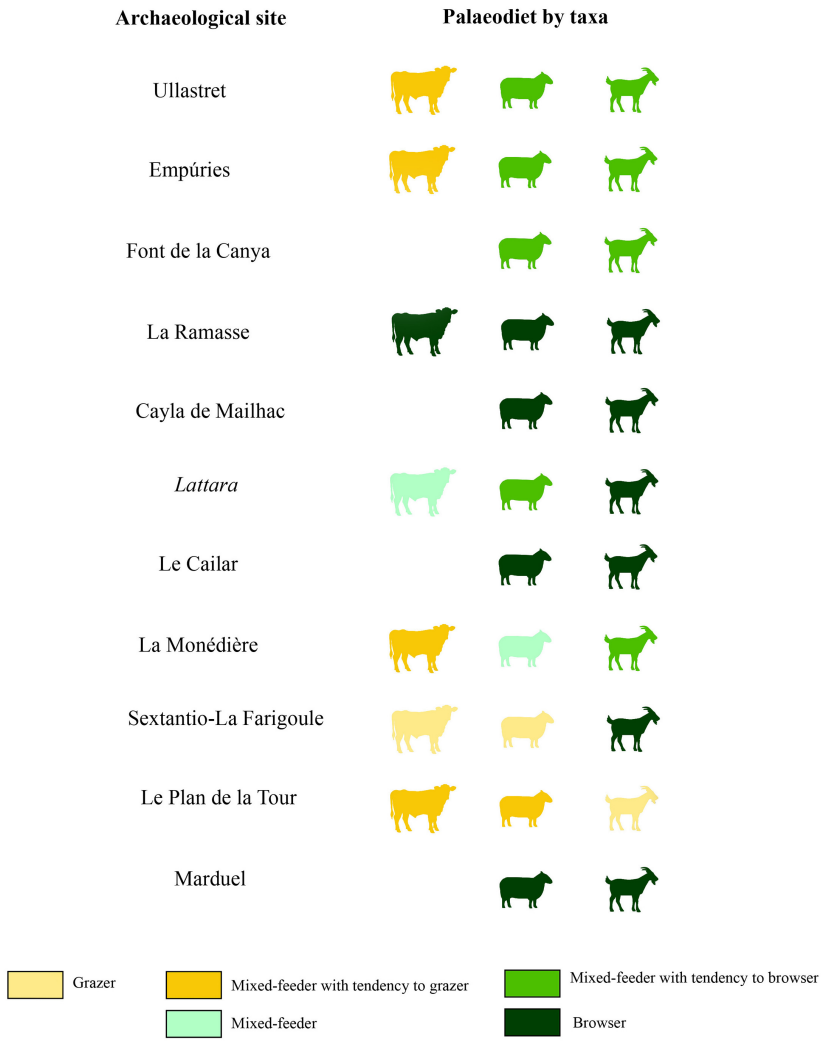

Figure 2. Type of animal feeding by taxon and archaeological site.

Overall, these findings suggest a scenario in which, at sites located near the coast, cattle were managed in grass-rich areas, while sheep and goats were herded in more wooded environments. Although dietary variability between sheep and goats could be related to species-specific feeding behaviours, the authors suggest that goats may have been fed in more overgrazed environments than sheep.

In the same geographical area, four archaeological sites (La Ramasse, Cayla de Mailhac, Marduel and Plan de la Tour) provide data from inland areas (table 2 and figure 2). At the

Table 2. Summary of dental microwear patterns and isotope analyses of cattle, sheep, and goats (n = number; Mn = Mean; SD = standard deviation; Min = minimum; Max = maximum)

		Methodological approach							
			Dental Microwear						
			Pits		Scratches		Carbon isotope (δ^{13})		
Archaeological site	**Species**	**n**	**Mn**	**SD**	**Mn**	**SD**	**n**	**Min**	**Max**
Ullastret, 6th-5th c. BC	Sheep	4	26.5	11	20.5	3.3	-	-	-
	Goat	7	28.2	5.2	18.6	4.4	-	-	-
	Cattle	1	15.5	-	18	-	-	-	-
Ullastret, 6th-5th c. BC	Sheep	15	28.9	8	18.5	3.5	-	-	-
	Goat	14	24.1	8.9	16.7	5.7	-	-	-
	Cattle	32	19.2	5.8	21.8	4.7	-	-	-
Empúries, 6th-5th c. BC	Sheep	12	25.8	10.4	18.1	5.2	-	-	-
	Goat	7	26.5	10.8	17.1	4	-	-	-
	Cattle	22	16.5	4	19.6	3.4	-	-	-
Empúries, 5th-4th c. BC	Sheep	8	23.6	7.2	18.8	4.9	-	-	-
	Goat	8	24.3	9.5	19.8	4.2	-	-	-
	Cattle	11	22.3	8.4	20.9	5.8	-	-	-
Font de la Canya, 6th c. BC	Sheep	9	34.5	6.7	15.5	2.1	3	-10 ‰	-12.2 ‰
	Goats	10	35	6.7	15.2	3.6			
La Ramasse, 5th-4th c. BC	Caprinae	2	35.5	9.2	16	5.7	4	10.68 ‰	11.74 ‰
Cayla de Mailhac, 5th-4th c. BC	Caprinae	4	35.5	9.2	16	5.7	7	9.72 ‰	14.4 ‰
	Cattle	1	40	-	20	-	-	-	-
Lattara, 6th-5th c. BC	Sheep	4	24.3	5.5	17.6	0.3	-	-	-
	Goats	3	37.6	8.2	16.6	0.3	-	-	-
	Caprinae	14	34.1	11.9	14.4	3.6	-	-	-
Lattara, 5th-4th c. BC	Sheep	6	27.1	9.6	16.3	3.8	-	-	-
	Goats	1	41	-	14	-	-	-	-
	Cattle	4	21.6	13.1	19.1	4	10	18.7 ‰	21.8 ‰
	Caprinae	-	-	-	-	-	22	18.8 ‰	21.7 ‰
Le Cailar, 6th-5th c. BC	Caprinae	4	30.3	8.6	17.5	2	-	-	-
Le Cailar, 5th-4th c. BC	Sheep	15	28	7	17.2	2	-	-	-
	Cattle	37	19.9	6.9	15.9	4.3	-	-	-
La Monédière, 6th-5th c. BC	Sheep	3	24.3	6.8	20.3	6.1	-	-	-
	Goats	5	30.8	12.3	18.9	2.6	-	-	-
	Cattle	19	19.3	4.3	20.8	1.8	-	-	-
La Monédière, 5th-4th c. BC	Cattle	6	15.9	4.4	21.3	4.2	-	-	-
Sextantio-La Farigoule, 6th-4th c. BC	Cattle	5	20.2	7	26	3.8	-	-	-
	Goat	4	30.2	6.9	16.2	1	-	-	-
	Caprinae	5	20.4	4.9	21.9	4.6	-	-	-
Le Plan de la Tour, 6th-4th c. BC	Sheep	8	15.4	4.5	22.4	3.5	-	-	-
	Goat	6	13	3.5	22.9	4.7	-	-	-
	Cattle	10	15.3	4.1	22.2	5.2	-	-	-
Marduel, 6th c. BC	Caprinae	4	20.8	1.9	19.4	2.32	-	-	-
Marduel, 5th c. BC	Caprinae	7	21.9	2.6	18.2	2.1	-	-	-

sites of La Ramasse and Cayla de Mailhac, the caprine palaeodiet is clearly a browser diet, characterised by the predominant intake of eudicotyledonous plants, shrubs, and bushes. Cattle were only analysed at La Ramasse, based on a single specimen, which also showed a browsing diet. At both sites, dental microwear patterns are consistent with the ingestion of hard particles and/or soil ingestion, suggesting browsing in overgrazed environments (table 2). In addition, strontium isotope analyses conducted at these sites indicate the absence of seasonal mobility (Jiménez-Manchón *et al*., 2023*b*). At the site of Marduel, sheep and goats also exhibit a dental microwear pattern consistent with the intake of eudicotyledonous plants. However, in this case, there is no evidence of browsing in overgrazed environments. In contrast, Plan de la Tour presents a different palaeodietary pattern. Here, sheep are mixed feeders with grazing tendencies, whereas goats are predominantly grazers. This suggests that both species were likely managed in open areas, unlike the other cases. However, the possibility of grass-rich fodder supplies cannot be ruled out.

Overall, these findings reveal diverse feeding strategies at inland sites in the Languedoc region. The available data indicate a caprine diet rich in eudicotyledonous plants at three sites, two of which show evidence consistent with overgrazing. Meanwhile, at a fourth site, caprines were fed in open areas.

4. Discussion

This work presents a preliminary review of research on animal palaeodiets in assemblages from the north-eastern Iberian Peninsula and southern France between the sixth and fourth centuries BC. In recent years, palaeodietary analyses have become increasingly frequent, although generally in a context of isolated case studies. As a result, to date, no study has compiled and examined these data in relation to their broader archaeohistorical context. The primary objectives of this work were: 1) to establish a baseline of current knowledge on livestock feeding practices in this region and period and to better understand their relationship with economic and social dynamics: 2) and to identify existing methodological and geographical limitations, in order to define priorities for future research. The following sections discuss the results obtained from archaeological sites located close to the coast, in inland areas, and finally, the main limitations of the available data and future perspectives.

4.1 Sites located close to the coast

The results obtained on both sides of the Pyrenees show that the sheep and goat diet was mixed with a browsing tendency. This suggests that they were fed in deciduous forest areas near settlements (figure 3). The hypothesis that they were managed close to settlements

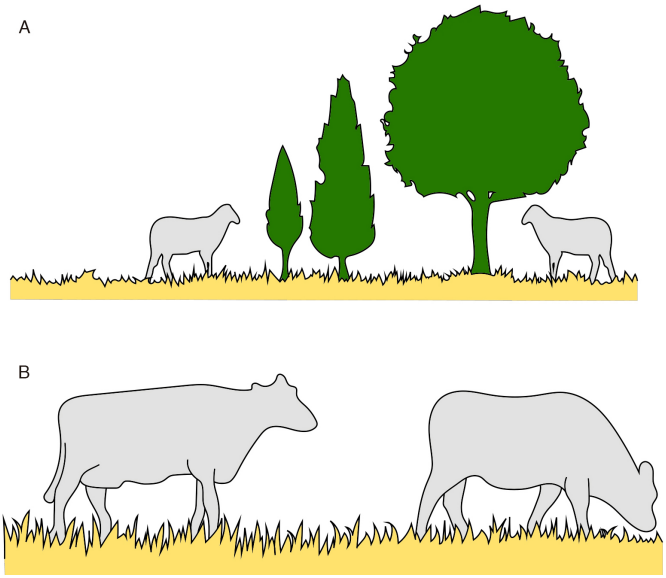

Figure 3. Hypothetical model of feeding strategies of sheep/goat (A) and cattle (B) in sites located near the coast in the sixth and fourth centuries BC.

is supported by the absence of animal mobility at the sites of La Monédière and *Lattara* (Nieto-Espinet *et al*., 2020*b*). Palaeoenvironmental studies have brought to light the presence of forests at coastal sites like Empúries and *Lattara* (Aquilué *et al*., 1999; Piqué, 2002; Chabal, 2007; Ponel and Rocq, 2007). Some plant species include *Tamarix* sp., *Ulmus campestris*, *Salix* sp., and *Populus* sp. This implies that sheep and goats were herded in riparian forests, a forest type still present and preserved along the Catalan and Languedoc coasts today, such as the Bois de Tourtolen (Arles, Bouches-du-Rhône, France) or the riparian forest of the Petit Rhône (Aigues-Mortes, Gard, France).

In later periods, caprines were fed in C3 environments, specifically at the site of Pontós in the third century (Messana *et al*., 2025). Similarly, during the second century BC and the third century AD, sheep appear to have fed in shrubland pastures (Gallego *et al*., 2017). These data suggest that such livestock strategies may also have been employed in later periods.

It should be noted that most of the available data come from sites located in the Languedoc region. In contrast, there is a significant gap in the north-eastern Iberian Peninsula, where data is currently limited to the Empordà region. A second major hiatus is the area between the Pyrenees and the Hérault River, where no palaeodietary studies have yet been conducted.

Unlike for sheep and goats, the cattle diet is based on a higher intake of grasses, suggesting grazing in grass-rich pastures, such as humid prairies. However, cattle may have also been fed with agricultural sub-products or allowed to graze in cultivated fields. Another possibility

is grazing in marshes and ponds along the coastline. Previous studies have shown that the abundance of water in ungulate diets can affect plant abrasiveness. In a dental microwear study conducted on guinea pigs, Winkler *et al*. (2019) demonstrated that fresh grasses produce a high density of enamel peaks and accentuate surface roughness. In the same way, Uzunidis (2020) analysed a present-day cattle population grazing in the Camargue wetlands, specifically at Tour du Valat (Bouches-du-Rhône, France), and found that dental microwear patterns exhibit abundant pits. Since cattle from the archaeological settlements included in this study do not show such microwear patterns, grazing in wetlands can probably be ruled out, while grazing in dry grasslands appears to be the most plausible scenario (figure 3). The archaeological results from cattle also indicate an increase in the intake of eudicotyledonous plants at the sites of Ullastret and Empúries from the sixth to fourth centuries BC. Two hypotheses can be put forward to explain this: on the one hand, it may reflect a change in the economic exploitation of cattle, as observed in the shift in mortality profiles. In the sixth-fifth centuries BC, cattle were primarily raised for meat, while in the fifth to fourth centuries BC, their use was diversified (Jiménez-Manchón *et al.,* 2023*b*). On the other hand, this shift could be related to a reduction in cattle populations at both sites, potentially due to increased environmental pressure, resulting in cattle being kept in more wooded environments. It is also important to highlight that, in some archaeological sites, cattle are entirely absent, as at le Cailar site, while in other sites, the number of studied specimens is notably low, such as at *Lattara* (table 2).

Considering the limitations related to geographic representativeness, as well as the disparate number of sheep/goat and cattle specimens, the available data suggest that sheep and goats appear to have been herded in shrubland areas unsuitable for agriculture but appropriate for livestock (figure 3). These areas were probably located near settlements, as supported by strontium isotope data showing ratios consistent with the local geology (Nieto-Espinet *et al*., 2020*b*). This strategy is linked to the socio-economic and political framework of a period marked by territoriality, pressure on resources and increased agricultural land use. It may also be connected to the increase in pig husbandry during the fifth and fourth centuries BC, as pigs do not compete with agricultural land. Unlike caprines, cattle were herded in grass-rich areas, such as agricultural fields, or open landscapes. However, according to the results presented here, they probably did not have access to wetlands, which may have been prioritised for agriculture. Previous works have identified dental pathologies and size reduction, and suggest that these changes may have been produced by feeding stress (Nieto-Espinet *et al*., 2020*b*). The fact that wetter areas were prioritised for agriculture may have resulted in cattle grazing in less optimal areas, which could explain size reduction and dental pathologies. However, this hypothesis must be treated with caution, as the available data are limited.

4.2 Sites located in inland regions

In inland regions, the number of analysed sites is lower, notably in the southern Pyrenees, where only one site, Font de la Canya, has been studied. At this latter site, the diet is con-

sistent with feeding in woodland areas with probable soil ingestion. This could indicate that sheep and goats fed close to the ground, pointing to an overgrazed environment. In southern France, four sites have yielded palaeodietary data. At three sites, sheep, and goats were probably fed in wooded environments. At two of these three sites, dental microwear is compatible with feeding in overgrazed environments. In contrast, at a fourth site, Plan de la Tour, caprines were fed in open environments, probably rich in grasses. These findings suggest a scenario in which livestock feeding strategies in inland areas were more heterogeneous than in settlements located close to the coast. This may be due to the presence of more diversified environments in inland areas, where herds were bred locally. This hypothesis is also supported by strontium isotope results (Valenzuela-Lamas *et al.*, 2016, 2018; Jiménez-Manchón *et al.*, 2023*a*).

The herding of sheep and goats in overgrazed environments could be related to the higher proportion of goats compared to sheep, as identified at sites such as Cayla de Mailhac, Marduel and La Ramasse (Lespes, 2020; Jiménez-Manchón *et al.*, 2023*a*). Goatsare well adapted to grazing in overgrazed environments (Orengo and Knappett, 2018). All these data suggest a more obvious reduction of animal grazing areas in inland sites. The issue of providing supplementary food to animals has been poorly addressed, probably due to methodological limitations. Even so, stable isotope analyses suggest that caprines fed on fodder at Cayla de Mailhac (Jiménez-Manchón *et al.*, 2023*a*). This strategy has also been observed in later periods, specifically at the Pontós site during the third century BC (Messana *et al.*, 2025). Overall, as in sites located close to the coast, livestock feeding strategies certainly had to adapt to the socio-economic and political context, where sheep and goats were probably herded in areas close to settlements and less suitable for agriculture. It is important to note the absence of available data for cattle.

In inland regions, the number of settlements is significantly lower than in areas close to the coast. In the north-eastern Iberian Peninsula, data come from a single site, compared to four in the Languedoc region. Moreover, environmental and topographical conditions in these inland areas are considerably more heterogeneous than in coastal regions. As a result, the limited number of settlements must be taken into account when interpreting data, and conclusions should be considered with caution. In addition, the representation of cattle in inland sites is notably scarce. No palaeodietary data on cattle are currently available from inland sites such as Marduel, Font de la Canya and Cayla de Mailhac, further restricting our understanding of livestock management practices in these environments.

4.3 Limitations and lines of research

Firstly, it should be noted that no data are available from archaeological sites located along the central and southern coast of Catalonia, as well as in the area between the Pyrenees and the Hérault River. In inland regions, the number of studied settlements is very low, notably in Catalonia, where data only derive from one site, although some data exist for

later periods in this region (e.g., Gallego *et al.*, 2017). Future research should thus focus on enhancing our understanding of animal feeding practices in the coastal areas of central and southern Catalonia. As for inland sites in the north-eastern Iberian Peninsula, research has mostly concentrated on later periods, so future studies should also address earlier chronologies. Secondly, in terms of species, cattle are underrepresented compared to sheep and goats, with cattle data from only seven sites, so future research should include more data on cattle to enhance our knowledge of their diet. It would also be advisable to expand the analysis to other animal species, such as pigs, for which practically no data exist.

From a methodological perspective, most of the data presented in this paper were obtained by dental microwear analysis. This proxy provides high-resolution information about animal feeding before death (Teaford and Walker, 1984; Grine, 1986). Consequently, one of its limitations is that it reflects the seasonality of death, and this factor must be considered. In future studies, other techniques such as dental cementum analysis could be included. It is important to emphasise that, although stable isotope analysis and dental cementum microwear analysis provide complementary information, they operate on different temporal scales, which must be taken into consideration when combining results. In short, while research into animal feeding practices has progressed in recent years, future research should expand into other geographic regions and include other animal species, such as cattle and pigs.

5. Conclusion

In this paper, I reviewed published studies of animal palaeodiets based on assemblages from the north-eastern Iberian Peninsula and southern France between the sixth and fourth centuries BC, to propose a comprehensive overview of animal feeding strategies and to glean information on the socio-political and economic contexts in which these strategies developed. This study has shown that, in general, sheep and goats were fed in environments dominated by shrubs, bushes and eudicotyledonous plants, both at sites located close to the coast and in inland areas. In contrast, cattle fed primarily on grassland areas, although probably not in wetlands. These strategies are consistent with other archaeological and zooarchaeological data, which indicate local breeding, a period of territorialization (evidence of weapons and fortified *oppida*), and the rise of aristocratic elites. Due to pressure on resources and competition with agriculture, sheep, and goats were probably herded into areas less suitable for agriculture. In parallel, although cattle fed on grassland pastures, coastal wetlands were probably reserved for agricultural use. All this also suggests a degree of organization and planning in livestock management practices, consistent with the crucial role that animal husbandry played in the economy in this chronological and geographical context. However, it should be noted that the current dataset is limited, and these interpretations must be considered with caution. In future works, palaeodietary

analysis should be expanded to other geographical regions and animal species, including cattle and pigs. Furthermore, although analyses are relatively common for later periods, particularly for sheep and goats, studies focusing on earlier periods are still lacking. It would therefore be relevant to consider these chronologies in future research.

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