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Stable isotope analysis and differences in diet and social status in northern Medieval Christian Spain (9th-13th centuries AD)

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Abstract:	The Iberian Peninsula was at the forefront of the religious, economic, and political changes that swept across Europe during the Medieval Period, including the expansion of Christianity following the disintegration of the Umayyad Caliphate. Between the 9th and the 13th centuries AD, western Europe, and particularly Iberia, witnessed a marked demographic and economic expansion that accompanied the emergence and development of different Christian kingdoms. In Iberia, the growth in religious infrastructure driven by territorial expansion at the expense of Al-Andalus, and the emerging importance of the *Camino de Santiago* (the Way of St. James) from the 11th century AD, represented vital processes in changing urban networks and social stratification. However, shifting diets and social structures brought about by these changes require direct study beyond historical texts or localised osteoarchaeological and biomolecular studies in order to determine their wider impacts on peoples' lived experience. Here, we apply radiocarbon dating (n=6) and stable carbon and nitrogen isotope analysis to bone and dentine collagen from various locations (n=10) across the north and north-eastern areas of modern Spain, where three prominent medieval Christian Kingdoms (Aragon, Castille and Navarre) developed. We sampled 40 human and 32 faunal remains dating to between the 9th and 13th centuries AD, including historical personages such as Sancho Ramirez, Count of Ribagorza, an illegitimate son of King Ramiro I of Aragon; Saint Raymond William or San Ramón de Rodas; Pedro de Librana, first bishop of the city of Zaragoza after its conquest by the Christians in the 12th century AD; an unknown princess from the royal house of Aragon; and individuals from urban and rural nucleus of Pamplona, Logroño, Lobera de Onsella (Zaragoza), and San Roque de las Quintanillas (Burgos). We compared them to existing data from the same region demonstrating clear differences in access to animal protein and marine/freshwater resources between rural, urban, and high social status populations on a regional scale. Our data show significant differences in $\delta^{15}N$ values between the different groups, with the highest values seen among the 'elite', followed by urban populations, who benefited from trade and socio-economic diversity. This dataset acts as an important reference point for future studies focusing

	on changes in the diet and health among different sectors of Medieval society and, in particular, the development of social inequality in the Christian Kingdoms of Iberia as they formed at the centre of novel cultural and religious exchanges across Europe.
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18. May 2021

Re: `Stable isotope analysis and differences in diet and social status in northern Medieval Christian Spain (9th-13th centuries AD)´

Dear Sir/Madame,

Thank you for the opportunity to submit our manuscript as an article to the *Journal of Archaeological Science: Reports.* We believe that the evidence reported in our paper is of international and interdisciplinary significance and should be of interest to the wide readership of your journal, including archaeologists, historians, stable isotope practitioners, osteoarchaeologists, and anthropologists. Our paper presents and interrogates one of the largest stable isotope datasets available for the Medieval Iberian Peninsula in order to probe how the growth of urban networks and solidifying political structures between the 9th and 13th centuries AD impacted human diets and lifestyles in north and northeastern Spain.

We applied stable carbon and nitrogen isotope analysis to bone and dentine collagen from human and faunal remains from sites dating between the 9th and 13th centuries AD in the region characterised by similar climatic conditions today. By sampling 72 individuals (40 humans and 32 fauna), including historical personages such as Sancho Ramirez, Count of Ribagorza, an illegitimate son of King Ramiro I of Aragon; Saint Raymond William or San Ramón de Rodas; Pedro de Librana, first bishop of the city of Zaragoza after its conquest by the Christians in the 12th century AD; an unknown princess from the royal house of Aragon; and individuals from urban and rural nucleus of Pamplona, Logroño, Lobera de Onsella (Zaragoza), and San Roque de las Quintanillas (Burgos). These were compared to data from existing literature from the same region and a similar temporal span, the results obtained demonstrates clear differences in access to animal protein, and marine/freshwater resources, between rural, urban, and high social class populations. Notably, urban and upper social status individuals were evidently able to gain access to resources from a wider cultural and geographical range than rural populations.

Our study fills a major gap in biomolecular studies of social differences in diet in Medieval Spain by developing a large regional dataset, in a part of Iberia where some of the most major shifts in settlement patterns and politica structures occurred in the Medieval period. We believe that this dataset will act as an important reference point for future studies focusing on the changing diet and health of different sectors of Medieval society, and the repeated, dynamic generation of social inequality in Medieval Iberia as it transitioned from a relative backwater to a key node of novel cultural and religious exchanges across Europe.

In terms of potential reviewers who are knowledgeable in the various fields of enquiry covered by our manuscript, we suggest the following, independent assessors:

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We hope that you find our Manuscript of sufficient appeal to the wide readership of the *Journal of Archaeological Science: Reports*. Do not hesitate to contact us should you require any further information or documentation.

Sincerely yours,

Patxi Pérez Ramallo
Max Planck Institute for the Science of Human History, Jena

Stable isotope analysis and differences in diet and social status in northern Medieval Christian Spain (9th-13th centuries AD)

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Abstract

The Iberian Peninsula was at the forefront of the religious, economic, and political changes that swept across Europe during the Medieval Period, including the expansion of Christianity following the disintegration of the Umayyad Caliphate. Between the 9th and the 13th centuries AD, western Europe, and particularly Iberia, witnessed a marked demographic and economic expansion that accompanied the emergence and development of different Christian kingdoms. In Iberia, the growth in religious infrastructure driven by territorial expansion at the expense of Al-Andalus, and the emerging importance of the *Camino de Santiago* (the Way of St. James) from the 11th century AD, represented vital processes in changing urban networks and social stratification. However, shifting diets and social structures brought about by these changes require direct study beyond historical texts or localised osteoarchaeological and biomolecular studies in order to determine their wider impacts on peoples' lived experience. Here, we apply radiocarbon dating (n=6) and stable carbon and nitrogen isotope analysis to bone and dentine collagen from various locations (n=10) across the north and north-eastern areas of modern Spain, where three prominent medieval Christian Kingdoms (Aragon, Castille and Navarre) developed. We sampled 40 human and 32 faunal remains dating to between the 9th and 13th centuries AD, including historical personages such as Sancho Ramirez, Count of Ribagorza, an illegitimate son of King Ramiro I of Aragon; Saint Raymond William or San Ramón de Rodas; Pedro de Librana, first bishop of the city of Zaragoza after its conquest by the Christians in the 12th century AD; an unknown princess from the royal house of Aragon; and individuals from urban and rural nucleus of Pamplona, Logroño, Lobera de Onsella (Zaragoza), and San Roque de las Quintanillas (Burgos). We compared them to existing data from the same region demonstrating clear differences in access to animal protein and marine/freshwater resources between rural, urban, and high social status populations on a regional scale. Our data show significant differences in $\delta^{15}N$ values between the different groups, with the highest values seen

among the 'elite', followed by urban populations, who benefited from trade and socio-economic diversity. This dataset acts as an important reference point for future studies focusing on changes in the diet and health among different sectors of Medieval society and, in particular, the development of social inequality in the Christian Kingdoms of Iberia as they formed at the centre of novel cultural and religious exchanges across Europe.

1. Introduction

Following Late Antiquity, after the collapse of the Western Roman Empire, Europe experienced several major economic and political changes that were to influence its social landscape for centuries to come. From the 8th century AD onwards, bounded states, ruled from Latin Christian urban nuclei, came to characterise the northern and western Mediterranean world and Central and Western Europe. From the end of the 10th century to the final decades of the 13th century, these regions experienced a sustained boom in population growth and increased agricultural and livestock production, (Lopez, 1998), favoured by the warm conditions of the Medieval Climate Anomaly (MCA) 900-1350 AD (Graham *et al*., 2011). Between these centuries, social restructuring took place parallel to the reorganisation of territory and domains, with a new hierarchy and codes of values (Bloch, 1986; Sánchez Pardo, 2008). This was in part catalysed, and also represented, by solidification of a Christian identity and its political association with the increased pursuit of Crusades to the Holy Land (11th-13th centuries AD), the "*Drang Nach Osten*" of Germanic nations to the East (12th-13th centuries AD) (Cardini, 1991; García Fintz, 2019a; Talaván, 2010) and the '*Reconquista*' in the Iberian Peninsula - a contentious term which is understood here as an ideology used to justify the process of territorial expansion of the Iberian Christian kingdoms following Umayyad rule (711 AD) or (756 AD) local Umyadd ruling Al-Andalus (see García Fintz (2019a)). Together, these changes transformed the Christian Kingdoms of the Iberian Peninsula from a relative 'periphery' in Classical and Late Antiquity Europe to one of the major centres of Medieval Christian Europe.

In a relatively small geographical space at the north of the Iberian Peninsula (Figure 1), new powerful kingdoms emerged out of a series of territorial disputes and alliances (García Fitz, 2019b). Between the 9th and 10th centuries AD, a series of counties in this part of Iberia (e.g., Aragon, Castile, Barcelona), fluctuated in their dependence on the kingdoms of Leon (the kingdom of Asturias until 910 AD), Pamplona (succeeded by the kingdom of Navarre from 1162 AD), or the Carolingian monarchs (García Fitz, 2019b). This occurred during a time marked by border violence against the territories of Al-Andalus, the name given by the Muslim conquerors to the portions of the Iberian Peninsula under their control (García Sanjuan, 2003), that manifested in the form of the consolidation of political and territorial positions and fortified borders (García Fitz, 2019b). The kingdom of Pamplona reached its territorial apogee during the reign of Sancho Garcés III (992/996-1035 AD) which, after his death, was divided between his sons (Orcástegui and Sarasa, 2001). This produced the birth of the kingdom of Aragon after the union of the counties of Sobrarbe and Ribagorza (Bisson, 1991). Consequently, between the end of the 10th century and 13th centuries AD, this area experimented in the formation of powerful Spanish Christian kingdoms with economic, political, and militarily strength enough to dominate a significant part of Iberian Peninsula and the Balearic Islands (García de Cortázar, 1991; García Fitz, 2019b; Martínez García, 2004). This produced a demographic reorganisation and expansion that fostered the creation of new populations and the growth of existing ones. The flourishing of new urban centres such as Logroño, Jaca, or Burgos, where craft specialisation and mercantile expertise developed, was supported by expanding, thriving trade networks along the *Camino de Santiago* (Martínez García, 2004; Martínez Sopena, 2004).

Nevertheless, relatively little is known of the economic and social experiences of the people living within this part of Iberia during a critical period in the formation of the medieval European landscape. Historical records provide some insights into changing status and dietary access between different sectors of society, but they are often biased towards elite members of the population (Andrade Cernadas, 2005; Martínez García, 2018). Archaeobotanical and archaeozoological research provide detailed insights into the resources used, but not the overall dietary reliance on different foodstuffs by different groups (Makarewicz and Sealy, 2015). Here, in order to delve into the practical impacts of growing urban networks and solidifying political structures on populations between the 9th and 13th centuries, we apply stable isotope analysis to 40 human and 32 fauna samples, as well as radiocarbon dating (n=6), from a variety of archaeological sites (n=10) in north-northeastern Iberia (Figure 1). This methodological approach has proven effective at exploring medieval dietary change, including within Iberia (Alexander *et al*., 2015; López-Costas and Müldner, 2016; Jordana *et al*., 2019), and the use of associated geographical and archaeological contextual information (e.g., historical records or grave goods) enables us to divide the samples into broad categories of rural, urban and elite communities within Christian medieval Iberian society. This dataset facilitates the direct tracking of diets, wealth, and access to different resources during the political, economic, and social upheaval caused by the emergence and solidification of powerful Christian kingdoms between the last first millennium and early second millennium AD (García Fitz, 2019b).

2.0. Background

2.1. Historical insights into medieval Iberian diets

Medieval historical records provide broad expectations in terms of variation in diet types and sources in Iberia as well as their relationship to social status and historical and geographical context. On the basis of existing historical records, the diets of the social and economic elites throughout the Middle Ages were primarily characterized by the significant consumption of meat (Jiménez-Brobeil *et al*., 2016; Pérez Samper, 2019). Good quality meat was expensive, meaning that only the best-off individuals could afford it (Pérez Samper, 2019). Poultry was then the most esteemed meat, followed by young and suckling animals (Alexander *et al*., 2015; Pérez Samper, 2019). In urban contexts, beef and lamb were the most commonly consumed on the basis historical and archaeological records (Grau-Sologestoa, 2017). Fish were also a significant contributor to wealthy diets (Alexander *et al*., 2015). In terms of crops, at the general level, the Middle Ages of Iberia saw the cultivation of a wide range of domesticates including wheats, barley, millets, rye and oat (Peña-Chocarro *et al*. 2019). Based on historical sources, although rye was the most commonly cultivated cereal across Iberia, the social elite favoured wheat as a 'luxury' crop (Andrade Cernadas, 2009; Pérez Samper, 2019).

Beyond the social elites, the Iberian Peninsula, as well as most of the European continent, was primarily populated by peasants who lived in small rural communities (Feller, 2015). Their diets have been historically distinguished by a focus on local cereal crops, with the dominant crops varying by region as well as between rural and urban contexts (Rosener, 1992). Dairy products and meat were available on a more limited basis for the majority of this rural population (Grau-Sologestoa, 2017; Pérez Samper, 2019). Historical and archaeological sources also highlight that the individuals with lower social status often resorted to the C_4 crop millet as a food source or for animal fodder, particularly in years of poor harvests or famine

(Adamson, 2004; Peña-Chocarro *et al*. 2019). Beyond social status-based dietary distinctions, the dominance of Christianity across the Medieval Iberian Peninsula led to cultural dietary restrictions that crossed social group divides. Most notably, meat was forbidden on certain fasting dates (150 days per year) noted in the liturgical calendar. On these days, marine or freshwater fish, legumes, nuts, or vegetables, varying in type, quality, and quantity, based on socio-economic availability, were the major alternative protein sources (Andrade Cernadas, 2009; Adamson, 2004; Grumett and Muers, 2010; Pérez Samper, 2019).

2.2. Stable isotope analysis and dietary reconstruction in Medieval Europe

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of bone collagen has proven to be an efficient, direct way of reconstructing the long-term dietary choices and trends of past human and other animal individuals (Makarewicz and Sealy, 2015; Webb *et al*., 2014). The isotopic composition of human and animal tissues is related to their diet (Ambrose and Norr, 1993; Yoder, 2012). C_3 and C_4 are the two dominant photosynthetic pathways that drive $\delta^{13}C$ variability in terrestrial ecosystems due to differential enzyme action during CO_2 fixation (Smith and Epstein, 1971). In C_3 plants, intense discrimination against ^{13}C, results in lower $\delta^{13}C$ values in nearly all trees, shrubs, and temperate grasses, including wheat, relative to C_4 plants, such as maize and millet (Farquhar et al., 1989). C_3 $\delta^{13}C$ values vary from *c.* -24 to -36‰ (global mean -26.5‰), while C_4 values range from *c*. -9 to -17‰ (global mean -12‰) (Smith and Epstein, 1971). C_3 and C_4 plants thus have distinct and non-overlapping $\delta^{13}C$ values (Tieszen, 1991). These distinctions continue into the tissues of consumers, with minor trophic level effects of 1-2‰ (Ambrose and Norr, 1993).

$\delta^{15}N$ varies with trophic level, and $\delta^{15}N$ trophic shifts of +2-6‰ from plants to herbivores and from herbivores to carnivores are well documented in marine and terrestrial systems (DeNiro and Epstein, 1981; Sealy *et al*., 1987). This trophic effect is most likely linked to the loss of ^{15}N-depleted excretion products (Ambrose, 1991), although diet-tissue distinctions are highly variable between animal taxa and even between individuals (Hedges and Reynard, 2007; Sponheimer et al., 2013). The long length of marine food chains leads to distinctively high $\delta^{15}N$ in marine foods and consumers compared to their terrestrial counterparts. Interpreting the consumption of marine resources is aided by $\delta^{13}C$ values that mimic those of C_4 plants due to a different source of CO_2 for primary producers in marine environments (Schoeninger and DeNiro, 1984). Freshwater foods also tend to have high $\delta^{15}N$, though their $\delta^{13}C$ is wildly variable due to the many different possible sources of CO_2 (Dufour *et al*., 1999). Stable isotope analysis is a remarkably successful tool in the context of discerning social distinctions in diet where additional insights from grave goods, burial context, or historical records enable the comparison of individuals from different status within society (Althoff, 1996; Jiménez-Brobeil, 2016; MacKinnon *et al*., 2019; Yoder, 2012).

The $\delta^{13}C$ signal from bone collagen is comprised 74% from proteins and 26% from lipids and carbohydrates (Ambrose and Norr, 1993; Howland *et al*., 2003; Jim *et al*., 2004; Tieszen and Fagre, 1993). Consequently, the $\delta^{13}C$ and $\delta^{15}N$ of human bone collagen will be heavily weighted towards high protein resources in the diet, such as meat or aquatic foods, where present. In contrast, low protein crops will potentially be less immediately visible. It is also important to note that, as well as dietary contributions, the $\delta^{13}C$ and $\delta^{15}N$ of bone collagen can be influenced by external environmental conditions (e.g., temperature, aridity, and rainfall), making the attainment of a baseline from associated animal or plant remains essential for reliable interpretations of human diet (Casey and Post, 2011; Goude and Fontugne, 2016). This is particularly the case in agricultural societies where the application of manure can lead to

$\delta^{15}N$ increases in plant foods and make them appear isotopically equivalent to animals feeding on un-manured crops (Bogaard *et al*., 2007).

3. Materials and Methods

3.1. The sites, samples, and their historical context

In order to explore the range of isotopic variation between different individuals within varying economic and social contexts in northern-northeastern Iberian medieval populations, we selected bone and teeth samples from 40 human individuals from 10 different sites (Figure 1). In addition, we sampled 32 fauna from the same sites in order to provide an isotopic baseline for interpretation of the human data. The samples were chosen based on their deriving from similar geographic and climatic contexts with a chronology spanning from the 9th to 13th centuries AD. Rural sites are defined here as small nuclear populations with a religious centre composed of distinct physical space between residence and production areas (agricultural fields, meadows and forest), with an important social interaction between the villagers and the lord. 'Rural' individuals (n=20) were sampled from Lobera de Onsella, Zaragoza, Aragon (10th-11th centuries AD) (n=14) and San Roque de las Quintanillas, Burgos, Castille and Leon (9th-12th centuries AD) (n=6). Urban settings are here defined as an agglomeration enclosed by walls, populated by settlers organised in nuclear families, dedicated to agricultural, mercantile, artisanal activities, with houses built around a church, and very often, also a fortress. Urban settlements constitute an individualised community with its own legal conditions and that coordinated the activities of an extensive region. Samples from urban environments (n=14) include individuals from Portales 67, Logroño, Rioja (13th century AD) (n=7) and Plaza de San José, Pamplona (12th-13th century AD) (n=7).

Based on historical and archaeological contextual information (e.g., burial place or grave goods), we also sampled individuals clearly belonging to 'social elites'. In this paper, we use the term 'social elite' to refer to all members of the monarchy, nobility and religious hierarchy, who enjoyed some kind of distinctive social, economic, cultural or religious privileges. These included some renowned historically-documented individuals who were studied and sampled following emergency excavations in the face of renovation and building works at different locations including: Sancho Ramirez, Count of Ribagorza, an illegitimate son of King Ramiro I of Aragon, buried at the Cathedral of San Pedro de Jaca, Aragon (1040 – 1105 AD); Saint Raymond William or San Ramón de Rodas, bishop of Barbastro, located at Cathedral of San Vicente Martir, Roda, Aragon (1067-1126 AD); Pedro de Librana, buried at the Seo Cathedral of Zaragoza, first bishop of the city after its conquest by the Christians in the 12th century, Aragon (1119-1128 AD); and the unknown princess from the royal pantheon of San Pedro el Viejo, Jaca, Aragon (11th-12th century AD). Finally, we integrated into this category a monk who could be an abbot because of his burial place, and one unnamed knight excavated from the rural monastery of San Pedro de Siresa, Huesca Aragon (Sup. Inf. Text S1.9). All the contextual and historical information about the archaeological sites and individuals are reported in the Supplementary Information Text S1.

Overall, the human samples were selected for isotopic analysis on the basis of their availability and state of preservation, although there was a preference for bones reflecting the latest period of life where possible (Hedges *et al*., 2007). Consequently, we primarily sampled ribs (n=25), followed by second molars (n= 14) and long bone fragments (n=1). Stable isotopic values of rib bone collagen record dietary information from the last 10-15 years of life, while the femur has a slow turnover providing resident $\delta^{13}C$ and $\delta^{15}N$ signals that potentially span as much as 30-40 years (Fahy *et al*. 2017; Hedges *et al*. 2007; Hill, 1998). Meanwhile, dentine isotopic values reflect the diet during the years of tooth formation which, in the case of the second molar, ranges between 2.5-14.0 years of age (Beaumont *et al*., 2013; AlQahtani, 2010). Since many of the individuals sampled in this study came from cemetery areas dedicated for 'commoner' populations or even specific crypt burials in the case of the 'social elite', it was relatively challenging to obtain associated faunal remains. Nevertheless, we were able to obtain animals bones from the sites of Portales 67, Logroño (n=5); Plaza de San José, Pamplona (n=4), and Plaza Biscós in Jaca (n=13). We added additional faunal samples from the same regions studied from San Nicolás de Bari, Burgos (n=10) to this dataset. The species analysed are mostly composed of domestic animals (*ovicaprines* or sheep and/or goat (n=17), *Bos taurus* or cattle (n=9), *Sus scrofa* or pig (n=5), and *Gallus gallus* or chicken (n=1)) (Table 2).

3.2. Radiocarbon dating

Establishing a precise chronology for most of the individuals and places analysed here, excluding those historical personages with a well-defined historical and archaeological context, represented a challenge. Consequently, to confirm and/or provide an absolute chronology, we radiocarbon-dated 3 human bones and 3 dentine samples from the sites included in this study that previously only had a somewhat rough relative chronology (Lobera de Onsella; San Roque de las Quintanillas; Portales 67, Logroño; Plaza de San José, Pamplona; and San Pedro de Siresa). These samples were selected following their availability and preservation, and sent to the Oxford Radiocarbon Accelerator Unit (ORAU), Oxford, U.K., and Beta Analytic Inc. Radiocarbon Laboratory, Florida, USA. The full protocol and standards used in each laboratory are reported in the supplementary information (see S2.1 and S2.2). Radiocarbon determinations were calibrated using OxCal v4.4 (Ramsey, 2021) and the IntCal13 calibration curve (Reimer *et al*., 2020).

3.3. $\delta^{13}C$ and $\delta^{15}N$ analysis of bone and dentine collagen

Isotope analyses were conducted following collagen extraction using standard procedures presented in Richards and Hedges (1999) at the Max Plank Institute for the Science of Human History in Jena, Germany. We report the entire protocol in Supplementary Information S3.

3.4. Statistical Analysis

Statistical tests were used to determine if there were significant differences in $\delta^{13}C$ and $\delta^{15}N$ between human individuals based on their social status, origin (urban or rural populations), and biological sex. We conducted Mann-Whitney U test for equal medians ($p_{same-mediane}$) with a Monte Carlo permutation to compare skeletons sexed as male and female. In the case of social groups distinctions between rural, urban and 'social elite' categories, we used the Kruskal-Wallis test for equal means and Mann-Whitney pairwise test for equal medians with Bonferroni correction. We established a significance level (α) at 0.05 (Supplementary Information Table S1). The free software ‘PAST’ was used for all statistical analyses (Hammer *et al.*, 2001).

4. Results

Figure 2 and Table S2 display the radiocarbon results of samples dated in this study. Tables 1 and 2 and Figures 3 and 4 show the $\delta^{13}C$ and $\delta^{15}N$ results of the human and fauna samples. The complete $\delta^{13}C$ and $\delta^{15}N$ data, alongside the measured collagen quality (C:N ratios and % collagen yield) for each individual analysed, are presented in Tables S5 and S6 in the Supplementary Information.

4.1. Radiocarbon Dating

Our radiocarbon dating results confirm that all populations analysed here fall between the 9th-13th centuries AD (Figure 2, Table S2). Alongside the fact that these sites are all from similar geographic and climatic contexts, this provides us with a solid basis for comparing our isotopic data between sites and across social groups. In San Roque de las Quintanillas, two previous ^{14}C dates indicated that the necropolis was used from between the 11th and 13th centuries AD (Martín Carbajo *et al*., 2002). Nevertheless, our results push the use of the cemetery back until at least the 9th or 10th century AD. In Lobera de Onsella and San Pedro de Siresa, our radiocarbon dating results brought us to a time between the 10th and 12th centuries AD when Aragon became an independent Kingdom (Bisson, 1991). In the case of the urban nuclei, Pamplona and Logroño, ^{14}C also corrected the previous relative chronologies. Our results from Calle Portales 67 in Logroño moved the human remains to the 13th century AD, rather than the 11th-12th centuries proposed by archaeologists (González Martín *et al*., 2011), a time when the city was consolidated and had been in existence for more than a century. In Plaza de San José, Pamplona, our results indicated that the sampled human remains were from between the 12th and 13th centuries AD, just before the Navarreria War in 1276 AD (Josué Simonena *et al*., 2010). This suggests that those individuals discovered with scallop (see Supplementary Information S1.1) shells could belong to individuals who had undertaken the *Camino de Santiago* and/or members of Pamplona's St James brotherhood (Josué Simonena *et al*, 2010). The consumption of marine or freshwater proteins by humans can lead to imprecision in the radiocarbon ages (Fernandes *et al*. 2016; Makarewicz and Sealy, 2015). However, except for individual P67(RIJ)10 ($\delta^{15}N$ 12.2 and $\delta^{13}C$ -18.6), there is limited evidence for marine resource consumption in individuals selected for radiocarbon dating, suggesting that major discrepancies are unlikely, although relative marine and/or freshwater inputs cannot necessarily be ruled out (Tables 1, 3, and S2).

4.2. Fauna $\delta^{13}C$ and $\delta^{15}N$

The $\delta^{13}C$ and $\delta^{15}N$ values from the analysed fauna (n=32) demonstrate significant variations between species (Table 2, Figures 2 and 3). Among the herbivores across all sites: *Bos taurus* (n=8) $\delta^{15}N$ values ranged between 2.3 to 5.6‰ (Mean ± SD= 4.5±1.0‰) with a $\delta^{13}C$ range between -21.9 to -18.5‰ (Mean ± SD= -20.7±1.1‰). *Ovis orientalis aries/Capra aegagrus hircus* (n=18) $\delta^{15}N$ values ranged between 3.1 to 6.9‰ (Mean ± SD= 5.1± 1.2‰) and $\delta^{13}C$ values ranged between -21.8 to -19.4‰ (Mean ± SD= -20.2± 0.7‰). These herbivorous taxa had lower $\delta^{13}C$ and $\delta^{15}N$ values compared to omnivorous species such as *Sus scrofa* (n=5) that had $\delta^{15}N$ values ranging between 8.4 to 9.1‰ (Mean ± SD= 8.6±0.3‰) and $\delta^{13}C$ values ranging between -20.9 to -18.7‰ to (Mean ± SD= -20.3±0.9‰) and a single *Gallus gallus* whose $\delta^{15}N$ value is 9.4‰ and $\delta^{13}C$ -18.9‰. To this dataset, we added additional published marine fish samples from Albarracín (Alexander *et al*. 2015) as a reference (Tables 1 and 2, Figures 3 and 4).

4.3 Human $\delta^{13}C$ and $\delta^{15}N$

The human data (n=40) (Table 2, Figure 3 and 4) ranges between 8.3 to 13.7‰ for $\delta^{15}N$ and from -21.0 to -15.3‰ for $\delta^{13}C$, with means and standard deviations of 10.2±1.3‰ and -18.6±0.8‰, respectively. Female individuals (n=8) have $\delta^{15}N$ values ranging from 9.3 to 13.3‰ (mean and SD: 10.5±1.5‰), and $\delta^{13}C$ between -21.0 to -17.8‰ (mean and SD: -18.9±0.9‰). Male individuals (n=25) possessed $\delta^{15}N$ values ranging from 8.8 to 13.7‰ (mean and SD: 10.4±1.2‰), and $\delta^{13}C$ values between –19.2 to –15.3‰ (mean and SD: -18.4±0.9‰) (Table 2). Mann-Whitney U tests indicated no statistically significant differences between the biological sexes for either $\delta^{15}N$ or $\delta^{13}C$ ($p>0.05$) (Table S1).

Individuals classified as ‘rural’ (n=20) have $\delta^{15}N$ values ranging from 8.3 to 11.2‰ (mean and SD: 9.5±0.7‰) and $\delta^{13}C$ values ranging from -19.2 to -16.3‰ (mean and SD: -18.5±0.6‰) (Table 2). Individuals from urban contexts have $\delta^{15}N$ values ranging from 8.3 to 12.2‰ (mean and SD: 10.5±1.0‰) and $\delta^{13}C$ values ranging from -21.0 to -15.3‰ (mean and SD: -

18.7±1.2‰). Individuals classified as 'social elite' (n=6) have $\delta^{15}N$ values ranging from 9.4 to 13.7 (mean and SD: 11.8±1.8‰) and $\delta^{13}C$ values ranging from -19.1 to -17.8‰ (mean and SD= -18.6±0.4‰). The Kruskal-Wallis test and the Mann-Whitney pairwise tests with Bonferroni correction demonstrate significant $\delta^{15}N$ variation between social groups ($p<0.05$), with both the 'social elite' and urban individuals having higher $\delta^{15}N$ than rural communities. However, a Kruskal-Wallis test shows that there are no significant differences in $\delta^{13}C$ between these social groups ($p>0.05$) (Table S1).

Within the 'social elite' group the historical personages (n=4) have $\delta^{15}N$ values ranging from 11.9 to 13.7 (mean and SD: 12.8±0.8‰), and $\delta^{13}C$ values ranging from -18.6 to -17.8‰ (mean and SD= -18.4±0.4‰). By contrast, the individuals from San Pedro el Viejo, Jaca (n=2), have $\delta^{15}N$ values ranging from 9.4 to 9.9 (mean and SD: 9.7±0.4‰), and $\delta^{13}C$ values ranging from -19.1 to -18.8‰ (mean and SD= -19.0±0.2‰). Although some differences in isotopic fractionation may be expected when comparing ribs and teeth due to variations during life (Fahy *et al.*, 2017), there is no clear patterning in either $\delta^{13}C$ or $\delta^{15}N$ between elements (Figure S1).

5. Discussion

5.1. Diet and Social Status

Our dataset shows clear dietary trends between communities of the Middle Ages in northern and north-eastern Christian Iberia between the 9th and 13th centuries AD. While the $\delta^{13}C$ across the sites and portions of the population (rural, urban, social elite) is relatively consistent in indicating a diet dominated by C_3 resources, differences in $\delta^{15}N$ indicate varying contributions of animal products, or perhaps freshwater or/and marine fish, to the diets of people living in rural versus urban settings and among those individuals of higher social status. Higher mean $\delta^{15}N$ values characterise urban residents (Mean and SD= 10.5±1.0‰) relative to rural dwellers, suggesting an increased access to animal and/or freshwater protein. These differences are apparently driven by a subset of the urban population (P67(RIJ)09, P67(RIJ)10, P67(RIJ)12, and PSJP08) whose values overlap with those of historical personages ascribed to a 'social elite'. This is likely representative of growing dietary distinctions between a new urban 'bourgeois' elite, that distinguished themselves from other sectors of society based on access to new resources (Franco Aliaga, 1979; García de Valdeavellano, 2009), and portions of urban settlers that were more similar to rural populations but with some increased access to imported animal products as dairy, meat, fish or shellfish, thanks to developing urban networks. Interestingly, despite finding considerable differences in $\delta^{15}N$ values when classifying our data by social status and origin (rural or urban), we did not observe differences in $\delta^{13}C$ values. This may be due to the geographic context of all the places studied, far from the sea, resulting in minimal consumption of marine resources and/or C_4 proteins relative to other medieval populations closer to the coast (e.g., López-Costas and Müldner, 2016; López-Costas and Müldner, 2020), and/or far from area with an expected significant presence of C_4 plants (e.g., northwest of the Iberian Peninsula) (Peña- Peña-Chocarro *et al*. 2019).

This is not to suggest that no status-linked dietary differences existed within rural populations, and such distinctions have been identified elsewhere in the north of the Iberian Peninsula, such as at Zaballa or Treviño (Lubritto *et al*., 2018). Indeed, some variability is evident in our dataset with the rural individual SRQ(BUR)21 ($\delta^{15}N$ 11.2‰ and $\delta^{13}C$ -16.3‰), and urban individual PSJP(NAV)06 ($\delta^{15}N$ 11.5‰ and $\delta^{13}C$ -15.3‰), showing evidence for significant inputs of marine and/or C_4 proteins into diets in places located at some distance from the sea (Figures 1 to 3, Table 2). In the case of the urban individual PSJP(NAV)06 of Pamplona, it is possible that this individual was a 'non-local' buried at a centre that was becoming an important point along the *Camino de Santiago* (Josué Simonena *et al*, 2010). This is supported by the fact that the city was divided into three different burgs (neighbourhoods formed around a market that had previously been established next to a church (Vicens Vives, 1975)) based on the origin of their inhabitants, with two being heavily populated by people who grew up elsewhere (Irurita Lusarreta, 1988). A similar situation may exist for the individual from San Roque de las Quintanillas which was a key step along the *Camino de Santiago*, or it may be indicative of differential access to trading networks. It is possible that SRQ(BUR)21 could also be related to the period of demographic reorganisation realised after the territorial expansion undertaken in this zone between the 9th and 10th centuries AD by the Kingdom of Asturias (García Fitz, 2019b). Further investigation of the factors behind this dietary variability would require additional analyses (e.g., $^{87}Sr/^{86}Sr$, $\delta^{18}O_{ap}$, or aDNA).

The $\delta^{13}C$ and $\delta^{15}N$ values of individuals designated as 'social elite' suggest increased animal product, or freshwater fish, consumption relative to rural and urban communities. The $\delta^{15}N$ values measured for most of the historical figures analysed here reflect a high contribution of protein of animal origin (Figures 3 and 4, Table 2). On the basis of existing historical records, a reliance on fish is expected to be particularly evident among the religious elite (Andrade Cernadas, 2009; Montanari, 1993). However, the bishops San Ramón de Roda and Pedro de Librana show no clear evidence for this. While this could result from the consumption of low trophic level marine foods or freshwater resources, our data suggest that some of the bishops analysed maintained the diets of the lay aristocracy – from which most of them originated (Sanz Sancho, 2013). However, interestingly, the abbot and knight from San Pedro de Siresa seem to have diets closer to the values observed in the rural populations of Lobera de Onsella or San Roque de las Quintanillas (Figures 3 and 4, Table 2). This suggests that individuals from San Pedro de Siresa could have more strictly respected the diet imposed by religious standards, focusing on bread, wine, vegetables, and fruit, with limited meat and marine proteins (Andrade

Cernadas, 2009). Nevertheless, we cannot ignore the historical and geographical context related to the monastery and these individuals (Sup. Inf. Text S.1.9). They may have had a more limited diet in terms of access to animal protein, and freshwater or marine protein, due to a lack of economic means and limited external connections to the seat of power of the Kingdom of Aragon. This further highlights the potential for dietary differences present within the identified 'communities', despite the overall observation of economic distinctions.

5.2. Comparison with published data

We also undertook a broad comparison of our data with others available in the literature that are geographically (north-northeastern of Iberia) and chronologically close (9^{th}-13^{th} centuries AD) (Figures 1 and 5, Table S5). Most of the rural populations such as Dulantzi (Mean and SD= $\delta^{15}N$ 9.1±1.2‰, and $\delta^{13}C$ -18.8±1.4‰) (Quirós Castillo *et al.*, 2013), Aistra (Mean and SD= $\delta^{15}N$ 8.0±1.1‰, and $\delta^{13}C$ -18.9±1.0‰) (Lubritto *et al.*, 2017), Treviño (Mean and SD= $\delta^{15}N$ 9.6±1.1‰, and $\delta^{13}C$ -19.5±0.7‰) (Lubritto *et al.*, 2017), Las Gobas (Mean and SD= $\delta^{15}N$ 8.9±0.9‰, and $\delta^{13}C$ -19.0±0.6‰) (Guede *et al.*, 2018), and Palacios de la Sierra (Mean and SD= $\delta^{15}N$ 9.4±1.5‰, and $\delta^{13}C$ -18.9±0.8‰) (Jiménez-Brobeil *et al.*, 2016) have similar values to those obtained in San Roque de las Quintanillas (Mean and SD= $\delta^{15}N$ 9.7±1.0‰, and $\delta^{13}C$ -18.1±0.9‰) and Lobera de Onsella (Mean and SD= $\delta^{15}N$ 9.5±0.5‰, and $\delta^{13}C$ -18.7±0.3‰). However, San Baudelio de Berlanga (Mean and SD= $\delta^{15}N$ 10.3±0.5‰, and $\delta^{13}C$ -18.2±0.4‰) (Jiménez-Brobeil *et al.*, 2020) shows stable carbon and nitrogen isotope values closer to the urban individuals analysed here (Mean and SD= $\delta^{15}N$ 10.3±0.5‰, and $\delta^{13}C$ -18.2±0.4‰). As the authors suggest, this could be a consequence of geological and environmental factors or livestock farming which provided a larger input of protein of animal origin at San Baudelio de Berlanga (Jiménez-Brobeil *et al.*, 2020).

Dietary studies of other medieval individuals considered as being of high social status from the northern Iberian Peninsula, such as king Pedro I of Castille and other members of the royal family buried at the Cathedral of Seville (Mean and SD= δ^{15}N 13.3±1.5‰, and δ^{13}C -18.6±0.5‰) (Jiménez-Brobeil *et al*., 2016); priests from Capela do Pilar, Cathedral of Santa María, Lugo (Mean and SD= δ^{15}N 13.7±0.9‰, and δ^{13}C -18.5±0.6‰) (Kaal *et al*., 2016); and San Salvador Cathedral, Oviedo (Mean and SD= δ^{15}N 12.0±1.2‰, and δ^{13}C -18.6±0.2‰) (MacKinnon *et al*., 2019) also found δ^{15}N and δ^{13}C values that suggest diets rich in animal protein (see Table 4). Although some geographical differences should be expected, these values are similar to our analysed historical personages: Sancho Ramirez (δ^{15}N 11.9‰, and δ^{13}C -18.4‰); Saint Raymond William or San Ramón de Rodas (δ^{15}N 12.4‰, and δ^{13}C -18.6‰); Pedro de Librana, bishop of Zaragoza (δ^{15}N 13.7‰, and δ^{13}C -18.6‰); and the unknown princess from the royal pantheon of San Pedro el Viejo (δ^{15}N 13.3‰, and δ^{13}C -17.8‰). Nevertheless, as described above, the monk (δ^{15}N 9.9‰, and δ^{13}C -19.1‰) and the knight (δ^{15}N 9.4‰, and δ^{13}C -19.8‰) from the abbey of San Pedro de Siresa, illustrate values with little input of animal proteins and/or marine foods, being closer to those values observed in rural individuals. Interestingly, this dichotomy is also reflected in the analysis of the House of Aragon (Martínez-Jarreta *et al*., 2017), where the Count of Aragon showed lower δ^{15}N values than the individuals from the Royal House of Aragon. As the authors of that study suggest, this is potentially the consequence of the humble origins of the Count (9th-11th centuries AD), whose power only significantly grew following the creation of the Kingdom of Aragon in the 11th century AD and its territorial expansion.

Comparison of our compiled dataset of medieval Christians to the chronologically and geographically close medieval Muslim individuals from Tauste (8th-10th centuries AD) (Guede *et al*., 2017); Zaragoza (Mundee, 2010) (10th-12th centuries AD), and Albarracín (Mundee,

2010) (10^{th}-12^{th} centuries AD), also show some differences (see Table 4). The individuals from Tauste (Mean and SD= $\delta^{15}N$ 15.0±1.7‰, and $\delta^{13}C$ -19.1±0.5‰), on the banks of Ebro River, the second largest river in the Iberian Peninsula, probably had easy access to freshwater resources, and also had access to crops that were growing in rich alluvial soils and that were perhaps also being fertilized with manure (Guede et al., 2017). By contrast, the Muslim populations of Zaragoza (Mean and SD= $\delta^{15}N$ 10.9±1.4‰, and $\delta^{13}C$ -19.0±0.3‰), and Albarracín (Mean and SD= $\delta^{15}N$ 10.8±0.6‰, and $\delta^{13}C$ -19.0±0.2‰), yielded values closer to those observed here in the urban populations of Pamplona (Mean and SD= $\delta^{15}N$ 10.6±0.9‰, and $\delta^{13}C$ -18.7±1.8‰) and Logroño (Mean and SD= $\delta^{15}N$ 10.5±1.2‰, and $\delta^{13}C$ -18.6±0.4‰) (Table 3 and 4, Figure 4). In Al-Andalus, the Muslim rulers inherited and developed an important urban network after conquering the Iberian Peninsula (Carballeira Debasa, 2013). These cities, and the new ones created in Al-Andalus, controlled and delimited meat prices in order to allow consumption by all social strata, varying the quality and quantity among its inhabitants (García Sánchez, 1996), while maintaining and developing long-distance trade and supply chains, and allowing access to products such as fish to populations in the interior of the Iberian Peninsula (e.g., Albarracín. See Alexander *et al*., 2016). Thus, despite dietary variances that could arise because of religious, ethnic and even socio-economical differences between individuals from the same confession (Alexander *et al*., 2015; Guede *et al*., 2017; Grau-Sologestoa, 2017), it seems that urban nuclei under Muslim control, such as Zaragoza and Albarracín, did not differ significantly to those of the Christian urban populations that developed or emerged after the 11^{th} century AD, at least at the resolution of isotopic analysis.

6. Conclusion

Northern and north-eastern Iberia witnessed the origins and development of three of the major medieval Christian kingdoms that played a definitive part in the future of the entire Peninsula during the Middle Ages. Here, we present a new stable isotope dataset which we use to probe how diets varied between rural and urban settings, and between social status groups, during the 9th and 13th centuries AD, a time of major socio-economic transformation in the region. The data demonstrate clear differences in access to animal protein and marine/freshwater resources among individuals from rural, urban, or elite communities. We argue that the influence of changing economic, social, and political contexts, and growing opportunities to make use of new exchange networks, shaped the isotopic distinctions observed between different social contexts that emerged in and around the 11th century AD with the development and consolidation of the Christian Kingdoms of Aragon, Pamplona and Castille. The development of cities at the heart of these Christian Kingdoms drove the appearance of a new social group, whose status came from the negotiation of new economic and political markets rather than their birth or religious status, as well as increased access to varied food resources for social elite. Our work further highlights the role stable isotopic analyses can play in exploring dietary distinctions between individuals and communities even over historical timescales.

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Figure 1. Map of the Iberian Peninsula between the 11th-12th centuries AD showing the distribution of sites mentioned in this study (red) and the literature (black): 1. San Roque de las Quintanillas; 2. San Nicolás de Bari, Burgos; 3. Logroño; 4. Pamplona; 5. Lobera de Onsella; 6. San Pedro de Siresa; 7. Jaca; 8. Zaragoza; 9. San Pedro el Viejo; 10. Roda de Isábena; 11. Lugo; 12. Oviedo; 13. Alegría-Dulantzi; 14. Aistra; 15. Treviño; 16. Las Gobas; 17. Palacios de la Sierra; 18. San Baudelio de Berlanga; 19. Tauste; 20. Albarracín; 21. Seville. *The map was created using QGIS 2.16 and based on the map created by the Instituto Geográfico Nacional in Atlas Nacional de España (source: http://atlasnacional.ign.es/wane/Archivo:Espana_Configuracion-de-los-reinos-cristianos.-Imperio-Almoravide-(1086--1144)_1086-1147_mapa_13996_spa.jpg).

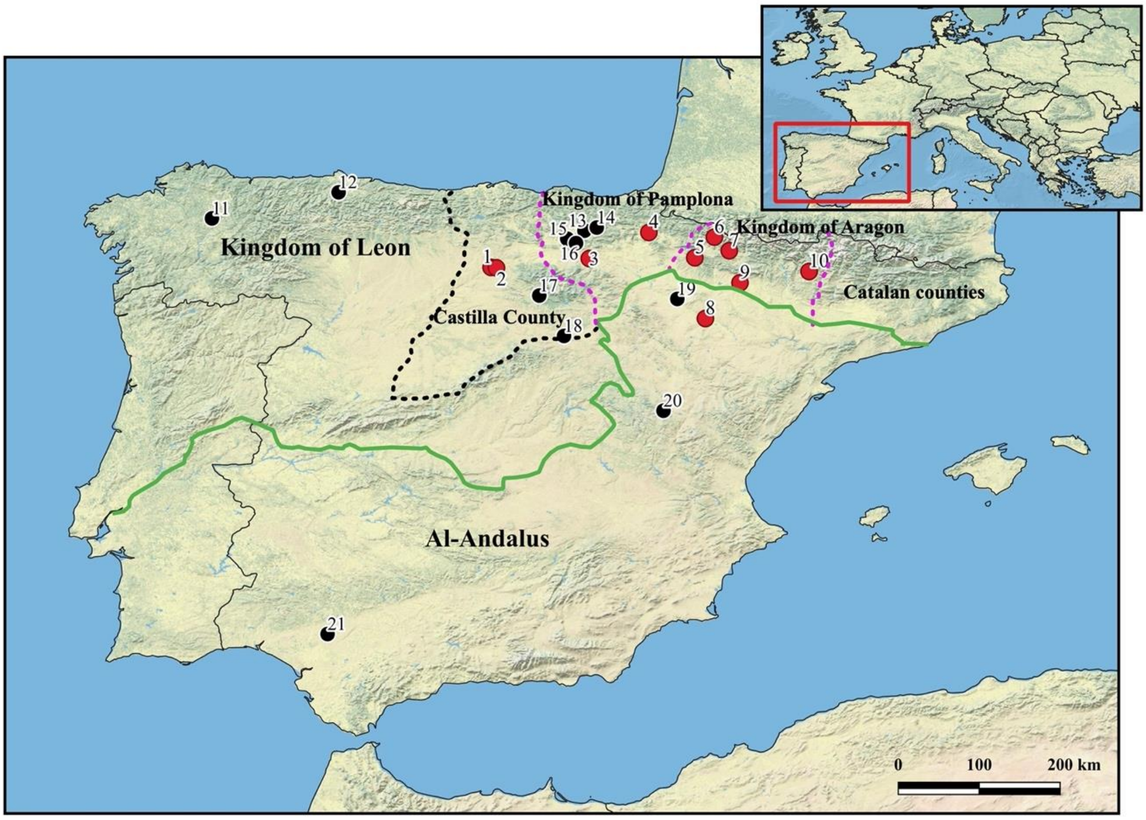

Figure 2. Radiocarbon dating results calibrated using OxCal. v4.4 Bronk Ramsey (2017) and the IntCal13 atmospheric curve (Reimer *et al*., 2020)

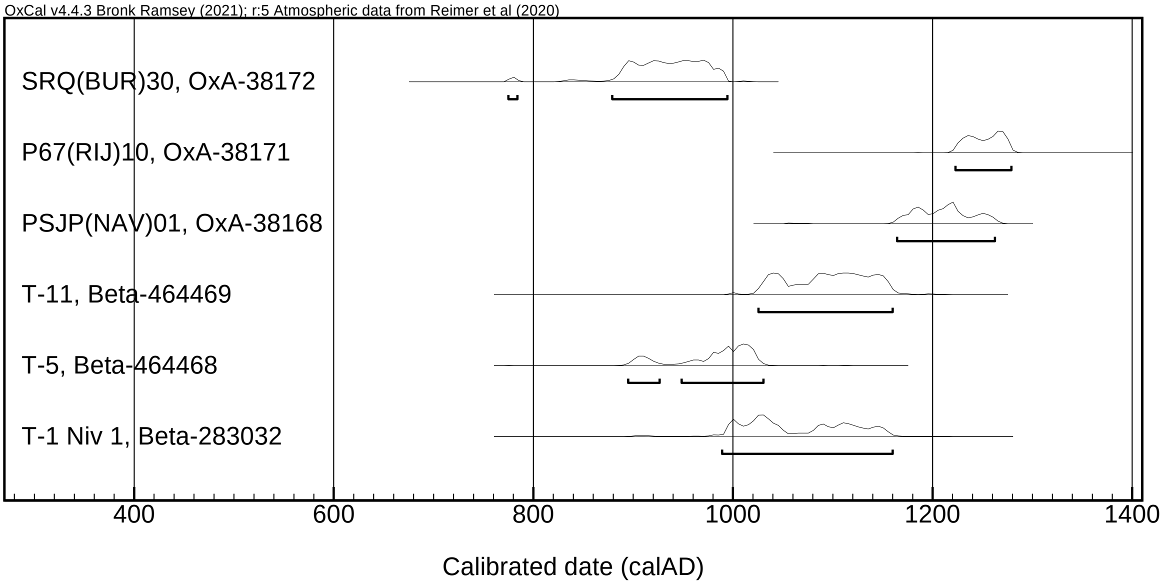

Figure 3. δ[13]C and δ[15]N of human samples from the present study data based on their site of origin and fauna analysed in the present study.

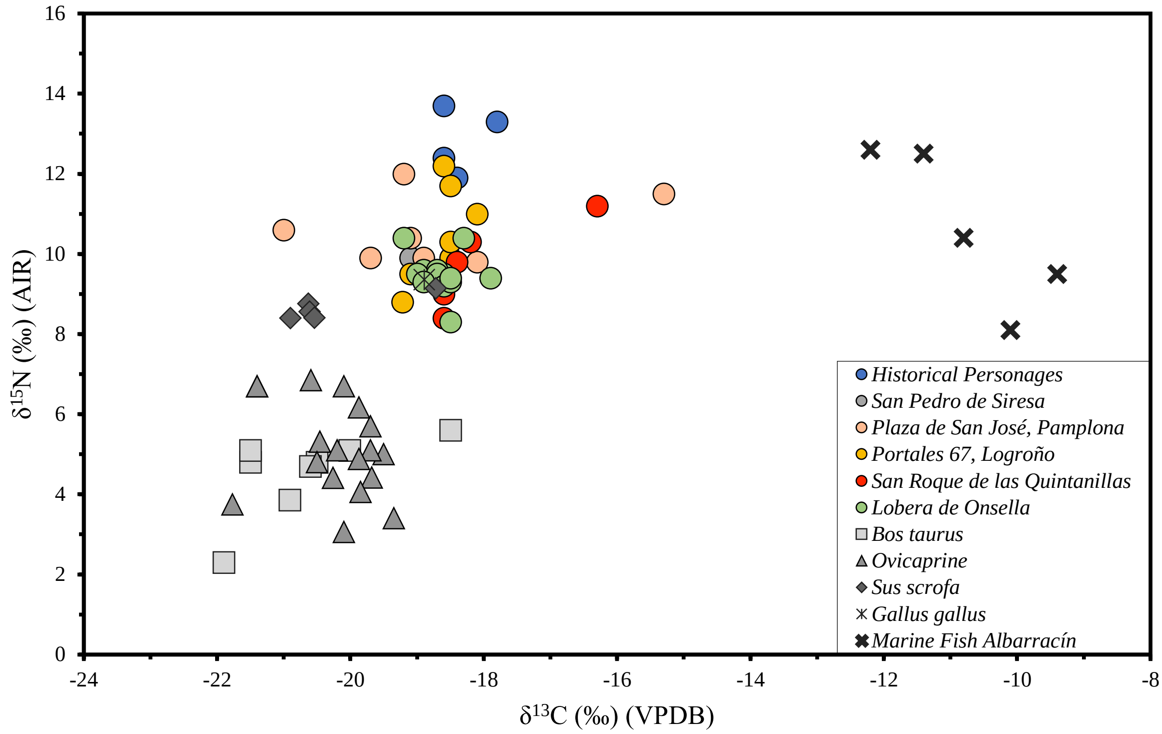

Figure 4. δ[13]C and δ[15]N of human samples from the present study data based on their social group category and fauna analysed in the present study.

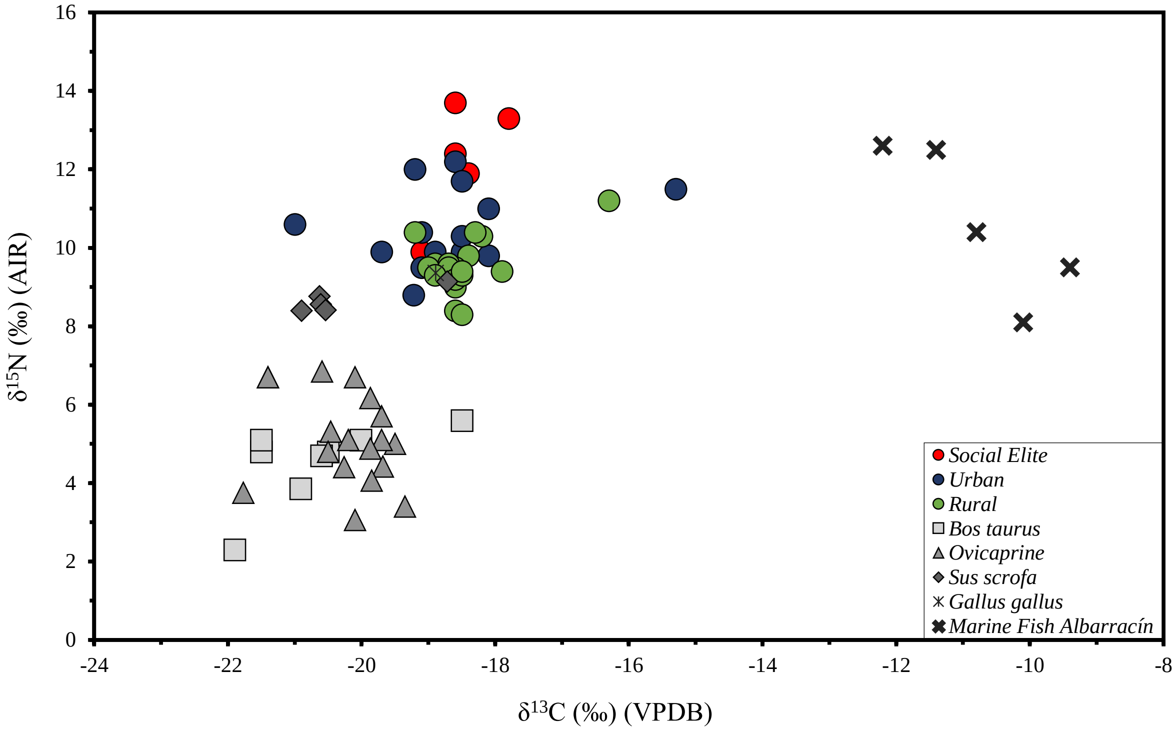

Figure 5. *δ¹³C and δ¹⁵N of fauna and humans from the present study grouped by social group and compiled literature data for the 'Christian' and 'Muslims' (Social Elite= triangle; Urban: square; Rural: circles; Muslims: rhombus).*

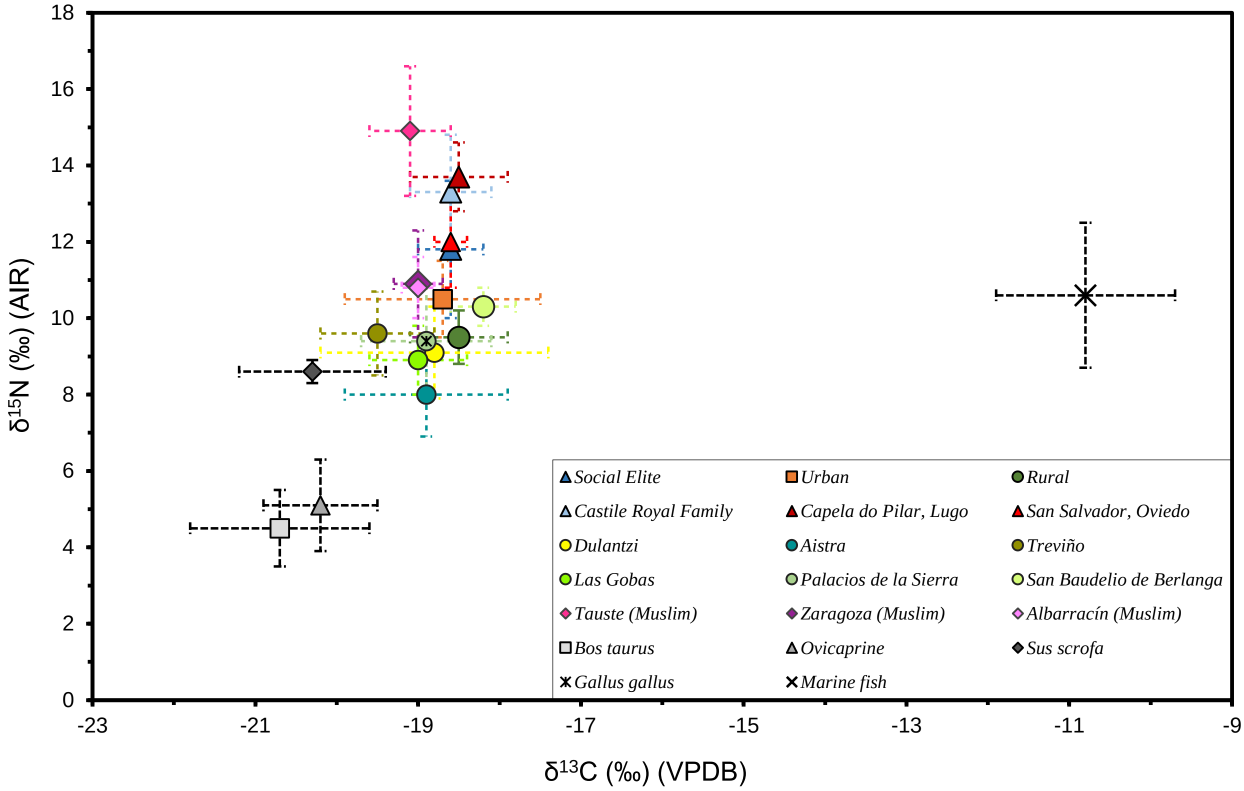

Table 2. Summary data (range, mean, standard deviation, number of samples) for $\delta^{13}C$ and $\delta^{15}N$ measurements of humans analysed in this study displayed by origin, chronology and social group.

Site	# in map (Figure 1)	Context and Chronology	$\delta^{15}N$ (‰) and $\delta^{13}C$ (‰) Mean ± SD, Range and number of samples
San Roque de las Quintanillas	1	Rural nucleus 9th-12th centuries AD	9.7±1 (8.4 to 11.2) -18.1±0.9 (-18.6 to -16.3) n=6
Portales 67, Logroño	3	Urban nucleus 13th century AD	10.5±1.1 (8.8 to 12.2) -18.8±0.4 (-19.4 to -18.1) n=7
Plaza de San José, Pamplona	4	Urban nucleus 12th-13th centuries AD	10.6±0.9 (9.8 to 12.0) -18.8±1.8 (-21.0 to -15.3) n=7
Lobera de Onsella	5	Rural nucleus 10th-11th centuries AD	9.5±0.7 (8.3 to 10.4) -18.8± 0.3 (-19.4 to -18.3) n = 14
Abbey of San Pedro de Siresa	6	Social Elite (rural nucleus) 10th-11th century AD	9.5±0.3 (9.3 to 9.9) -18.9±0.2 (-19.1 to -18.8) n=2
Sancho Ramírez, Count of Ribagorza	7	Social Elite (Urban nucleus 11th-12th century AD	11.9 -18.4 n=1
Pedro de Librana. Bishop of Zaragoza	8	Social Elite 11th-12th centuries AD	13.7 -18.6 n=1
Unknown Princess Aragon	9	Social Elite 10th-12th century AD	13.3 -17.8 n=1
Saint Raymond William or San Ramón de Roda	10	Social Elite 11th-12th centuries AD	12.4 -18.6 n=1
Total Rural	-	Rural 9th-11th centuries AD	9.5±0.7 (8.3 to 11.2) -18.5± 0.6 (-19.2 to -16.3) n = 20
Total Urban	-	Urban 12th-13th centuries AD	10.5±1.0 (8.8 to 12.2) -18.7±1.2 (-21.0 to -15.3) n=14
Total Social Elite	-	Social Elite 10th-12th centuries AD	11.8±1.8 (9.4 to 13.7) -18.6±0.4 (-19.1 to -17.8) n=6

Total Females	-	Rural, Urban and Social Elite 9th-12th centuries	10.5±1.5 (9.3 to 13.3) -18.9±0.9 (-21.0 to -17.8) n=8
Total Males	-	Rural, Urban and Social Elite 9th-12th centuries	10.4±1.2 (8.8 to 13.7) -18.4±0.9 (-19.2 to -15.3) n=25

Table 1. δ^{15}N (‰) and δ^{13}C (‰) Mean ± SD, Range and number of samples of fauna analysed in this study.

Site	*Bos taurus*	Ovicaprine	Sus scrofa	*Gallus gallus*	Marine Fish
San Nicolás de Bari, Burgos	5.6 -18.5 n=1	5.2±1.3 (3.4 to 6.9) -19.8±0.2 (-20.6 to -19.4) n=6	9.0±0.3 (8.8 to 9.1) -19.7±1.3 (-20.6 to -18.7) n=2	9.4 -18.9 n=1	-
Portales 67, Logroño	-3.1±1.1 (2.3. to 3.9) -21.4±0.7 (-21.9 to -20.9) n=2	4.9±0.4 (4.4 to 5.3) -19.9±0.5 (-20.5 to -19.5) n=3	-	-	-
Plaza de San José, Pamplona	5.4±0.9 (4.7 to 6.5) -21.1±0.5 (-21.5 to -20.6) n=2	6.7 -20.1 n=1	8.4 -20.9 n=1	-	-
Plaza Biscós, Jaca	4.9±0.2 (4.8 to 5.1) -20.7±0.8 (-21.5 to -20.0) n=3	4.9±1.2 (3.1 to 6.7) -20.7±0.7 (-21.8 to -19.9) n=8	8.5±0.1 (8.4 to 8.6) -20.6±0.1 (-20.6 to -20.5) n=2	-	-
Albarracín, Teruel (Alexander *et al.*, 2015)	-	-	-	-	10.6±1.9 (8.1 to 12.6) -10.8±1.1 (-12.2 to -9.4) n=5
Total	4.5±1.0 (2.3 to 5.6) -20.7±1.1 (-21.9 to -18.5) n=8	5.1±1.2 (3.1 to 6.9) -20.2±0.7 (-21.8 to -19.4) n=18	8.6±0.3 (8.4 to 9.1) -20.3±0.9 (-20.9 to -18.7) n=5	9.4 -18.9 n=1	10.6±1.9 (8.1 to 12.6) -10.8±1.1 (-12.2 to -9.4) n=5