# Diet in Medieval Portugal: exploring Inter-faith and Social Dynamics through Stable Isotope Analysis

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# ABSTRACT

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## Diet in Medieval Portugal: exploring inter-faith and social dynamics through stable isotope analysis

Medieval Portugal, tucked between a Christian north and an Islamic south, and at a crossroads between Africa and Europe, saw the birth and development of a multi-faith and multi-cultural society. Muslims and Christians co-existed in this region, shaping a unique pluralistic society, first under Islamic political control and later under Christian rule following the Christian conquest of the 12th century. This thesis applies carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis to characterises early and late medieval diet under Islamic (8th-12th) and Christian rule (12th-15th), exploring the impact of a shifting political system, status and faith onto economy, food availability and consumption.

Analysis of stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) was performed on bone collagen from 176 animals and 251 humans including Muslims and Christians sampled from sites covering a north-south trajectory (Laranjal, Coimbra, Lisbon, Setubal, Beja, Silves and Loulé) with a date range between the 8th and 15th centuries. Results indicate that a faith-related difference in diet exists but is also related to chronology and geographical location. Early medieval Muslim diet is based on animal protein and $C_3$ plants with possible inputs of low trophic level fish in Setubal and Loulé; while bigger proportions of marine fish appear in the diet of late medieval Muslims in Lisbon. Early medieval Christian diet is based on terrestrial resources with a reliance on $C_4$ plants in Coimbra; while late medieval Christian sites in southern Portugal show a reliance on marine resources. Results show a difference in diet between early and late medieval sites with a clear change in economy possibly brought about by the Christian conquest. Multi-faith sites (Lisbon, Beja and Silves) show an increment of at least 11% in the quantity of marine protein included in the human diet of Muslims and Christians from the early to the late medieval period.

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# DEDICATION

This thesis is dedicated to my family who supported me throughout my research career with tireless dedication, and to Denise, who taught me to live life fully.

Questa tesi é dedicata alla mia famiglia per essere stati un appoggio costante durante il mio percorso accademico; e a Denise, che mi ha insegnato a vivere la vita pienamente.

*Del vote*
*le parole ch'i dovruma*
*sun tant früste*
*che l'üniche cose ch'a l'han un sens*
*sun cule*
*ch'i dima nen*

*Marita Bellino, Parole*

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# AUTHOR DECLARATION

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as references.

Part of this work have been published in the following papers as outlined below. Copies of the publications have been provided in Appendix C. I am the sole author of the portions of this thesis included in these papers.

Toso et al. (2018): Section 3.6 Diet and gender; section 5.4.1 São Jorge Castle; 5.section 4.4 Praça da Figueira; section 6.4.1 Early medieval sites;

Filipe et al. (2017): Section 5.4.2 Alfama; section 6.4.1 Early medieval sites

# 1. INTRODUCTION

## 1.1 Overview

The Iberian Peninsula, at a crossroad between Africa and Europe, located between the Atlantic and the Mediterranean, saw the birth of one of the first multi-faith and multi-cultural societies in medieval Europe. During the medieval period much of the Iberian Peninsula was known as 'al-Andalus' and lay under Islamic rule. Following the conquest in 711 of the previous Christian Visigoth kingdom, Muslims ruled over much of the peninsula for the next five centuries. However, the Christian Kingdoms of the north gradually pushed south and conquered Islamic territory during what is termed the 'reconquest[1]', which gained momentum particularly during the 12th century (Collins 1994; Kennedy 1996; Reilly 1993). By mid-13th century, the Kingdom of Portugal lay under Christian rule. Islamic political power in Iberia ended with the fall of Granada to the 'Catholic Monarchs' of Spain in the late 15th century (Marques 1977; Domingues 2010). During eight centuries then, Muslims, Jews and Christians lived side by side, initially under Islamic rule, and later under Christian rule following the Christian conquest. Thanks to the co-existence of different faiths and cultures, medieval Iberia provides a remarkable framework to investigate the evolution of pluralistic societies. These complex interactions can be explored through the study of Islamic food identity in Medieval Iberia assessing its genesis, evolution and persistence. In this thesis, human and animal samples have been isotopically analysed from selected sites in Portugal, located on a trajectory from the north to the south of the country. The overall aim of this thesis is to isotopically explore dietary practices between individuals of different faith under shifting political and religious systems over time.

## 1.2 Geographical and Political Context

The study of the history and archaeology of Portugal requires a deeper understanding of the geo-political layout of these territories during each historical period. With the new rulers, a new set of political strategies, values and administrative systems would be generated, in some cases borrowing from the previous ones. In order to study the archaeology of Islamic Portugal it is imperative to consider the impact of three main elements on the history of the country: geography, administrative system and cultural exchange.

Firstly, the modern territory of Portugal did not exist until the treaty of Alcañices in 1397. During Roman and Visigothic times, as well as during Islamic rule, the Portuguese territory was divided into different provinces that only partially resemble the present ones. The biggest division in the

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[1] This term is contentious (Boone and Benco 1999) and the general term Christian conquest will be used throughout this thesis. See section 1.4 for an explanation.

country that is still obvious today is not political but is instead due to "ageless geographical realities" (Disney 2009:54) (Figure 1-1). The mountainous north is beaten by wet, rainy winters and less efficient communication due to the terrain, while central and southern Portugal offers a drier, flatter and warmer climate that might have appealed more to the Muslim colonists, while also being closer to the heart of Al-Andalus in Cordoba.

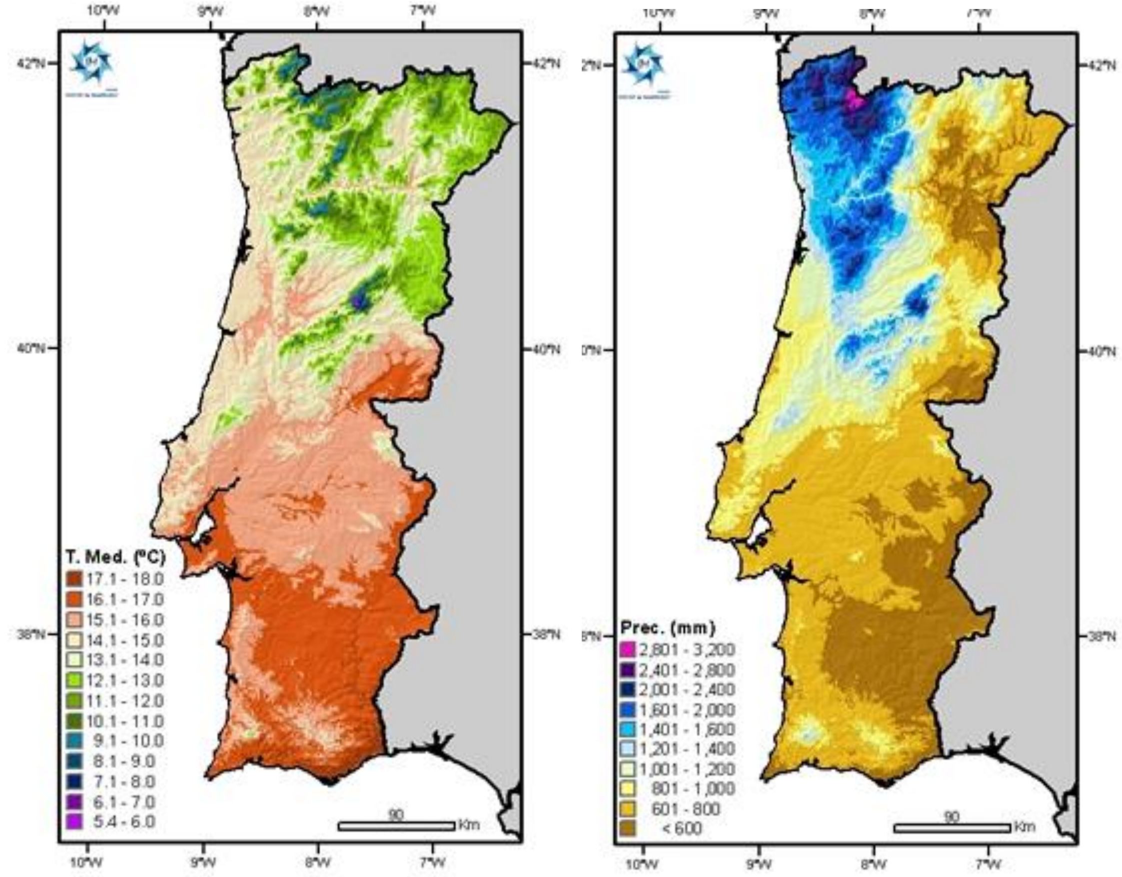

*Figure 1-1 Maps of average temperature and precipitations in modern day Portugal (Minister of Environment INAG-DSRH 2018).*

Secondly, the Portuguese territory under Islamic rule was never a stand-alone administrative entity but has to be studied and understood in relation to the centre of Al-Andalus. Furthermore, the name of this territory, 'Gharb al- Andalus' or 'Al-Gharb', literally meaning western al-Andalus, suggests an idea of unity of the Islamic domain however there is no map of the division between the two areas. The territory of the Gharb al-Andalus had a liminal character to it throughout the entire Islamic period, which was linked to its intrinsic peripheral nature. Tucked between a Christian north and an Islamic south, overlooking the Atlantic while being included in a Mediterranean network of power, trades and values, Islamic Portugal was a borderland. Its dichotomous nature must have had a bigger impact on the multi-faith community living there compared to the political centres of al-Andalus (e.g. Cordoba, Seville), where the system of values would have been more coherent and potentially homogeneous.

Finally, Islamic rule brought about a completely new society and lifestyle compared to the previous Visigoth reign. Although the co-existence of different faiths is one of the most obvious consequences of the Islamic conquest, Portugal already had experience of different ethnic and faith groups living together. After the decline of the Roman Empire Germanic groups settled, the Visigoths in the majority of central Portugal, while the north remained under Suevi rule (Kennedy 1996:10). The Algarve, however, experienced 70 years of Byzantine cultural influence, being part of the Eastern Roman Empire within southern Andalucia between 550 and 620 (Disney 2009:41). Despite all this, Hispano-Roman population made up a large proportion of the populace. Up until the 6th century, Visigoths and Hispano-Romans were considered as distinct groups and benefitted from separate laws and law-courts as well as separate churches: Arian and Catholic. Intermarriage was prohibited and ethnic differences faded only after the conversion of King Reccared to Catholicism in 589 (Crouch 1994). Jews were present at least since the Roman Empire and had a hard time under Visigoth rule, with the approval of anti-Semitic laws that culminated in the decree of King Chintila (636-9) ordering the expulsion of all Jews from his realm. However, the decree does not seem to have been taken too seriously since there are traces of further anti-Semitic laws approved afterwards, witnessing the continuation of Jewish communities[2]. This is the setting that Islamic conquerors found after crossing the Strait of Gibraltar, contributing to an already complicated religious and cultural mosaic that lead the Iberian peninsula to became an open-air laboratory of inter-faith coexistence in Europe.

## 1.3 Historical overview

The Atlantic and the Mediterranean coast of the Iberian Peninsula share a similar history during the Islamic period, and especially during the first centuries of Islamic rule; political tensions became more acute from the 10th century onwards, affecting the two areas in different ways. In addition, Islamic rule ended two centuries earlier in what would become Portugal, compared to Spain. For these reasons and because this thesis is concerned with the modern-day Portuguese territory only, the historical overview will focus on the Al-Gharb. While the summary of the historical context during the first centuries considerably follow the Spanish one, the end of the Islamic rule and its political scene has a more regional focus.

Historical sources are somewhat nebulous for the early 8th century and do not inform on the expansion of Al-Andalus right after the Islamic conquest of 711, leaving a series of open questions on the population and on the political structure in Iberia under the power of the

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[2] Jewish human remains were not accessible and therefore were not given much attention in this thesis.

Umayyad Caliphate of Damascus (8th-9th centuries). The population grew while new and old links were (re)established with the rest of the Mediterranean and with the Near East (Kennedy 1996:67-68). As mentioned above, a number of Hispano-Roman families persisted in the area and while some of them might have converted, this phenomenon seems to have been rare until the 10th century (Glick 2005:23). Therefore, the previous population composed of Hispano-Romans, Jewish and Visigoths is then combined with other ethnic groups including Arab elites and Berbers, Yemeni and Egyptian troupes and settlers, for an estimated 500,000 people living in the al-Gharb during this period (Macias 1997:375; Torres 1997:338)

The 10th century is often described as the golden age of Islamic rule in medieval Iberia, and started with the claim of independence of Abd-al-Rahman III (912-961 CE) from the central power of Damascus. In 929, he proclaimed the Umayyad Caliphate of Cordoba as an independent political entity, under which two of the most important features of the Islamic culture in Iberia began: the process of islamisation of the Peninsula, and the Agricultural revolution, with the introduction of new crops (e.g. hard wheat, citrus fruits, sugare cane) and new irrigation techniques (Kennedy 1996;Watson 1974). During this period, characterised by the centralised tendency of the caliphate of Cordoba little is known about the local political scene in the al-Gharb. However, the end of the Umayyad Caliphate in 1013 due to the murder of the last Umayyad descendent, Hisham II (1012-1013) brought a period of political turmoil that affected the entire peninsula (Torres 1997:378).

The 11th century saw the formation of petty states, called Taifa kingdoms. Although this period confirmed the independent nature of the local powers in the al-Gharb, marked by a fierce competition among several clans and families in taking political control, the resulting political instability was the perfect opportunity for the northern Christian Kingdoms to conquer some of the lost territories (Figure 1-2). Several cities were captured such as Lamego (1957), Viseu (1058), and Coimbra (1064) in the west and Toledo (1085), Huesca (1096), Zaragoza (1118), Tortosa (1148), Lérida (1149) in the east (Kennedy 1996:149-153; Torres 1997:379).

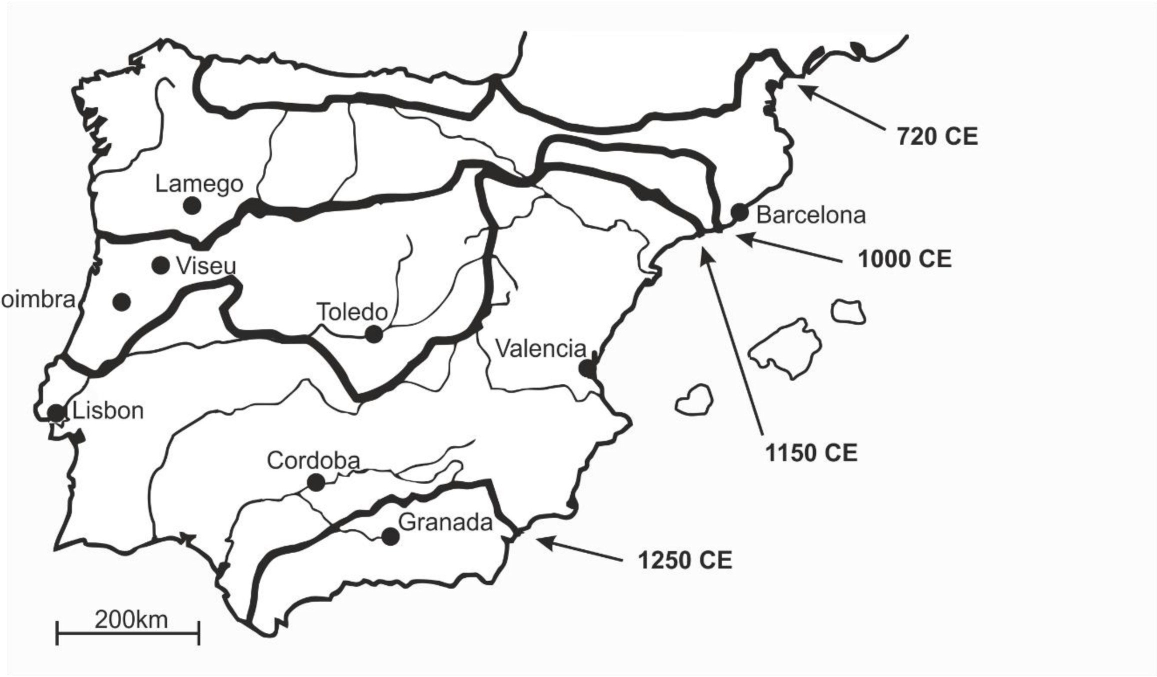

***Figure 1-2*** *Map showing the progress of the Christian conquest and the recessing lines of the frontier of al-Andalus between the 8th and 13th centuries (redrawn and adapted from Carvajal 2014: Figure 1).*

The end of the 11th century marked another important stepping stone in the evolution of the political scene in Al-Andalus: the arrival of the Almoravids, a Berber Muslim dynasty that conquered the remaining petty states, considerably slowing down the Christian conquest in much of the Peninsula, while governing al-Andalus as a province of Marrakesh (Torres 1997:380). The shift of the court from Iberia to North Africa and the enthusiasm created around the crusades in the Holy Land, reinvigorated the effort of the Christian kingdoms to conquer the southern territories along the 12th century. In 1147 the cities of Lisbon and Santarém were taken and with them a series of important defensive structures such as Palmela and Almada castles. In 1158 Alcácer do Sal is conquered and 1159 Tomár followed (Coelho 1989:305). The border was then set at the River Tagus for about 40 years until the battle of Las Navas de Tolosa in 1212. A combined Christian force defeated Islamic squadrons, marking the beginning of the final stage of the Christian conquest in the rest of the Portuguese territories (Torres 1997:381). In the al-Gharb, Moura and Serpa are conquered in 1232, Beja and Mértola followed in 1234 and 1238, while Silves and Faro, the last stronghold of Islamic power in Portugal, were conquered in 1249 (Fonseca 1987).

A resettlement of Christian population in the newly conquered territories was encouraged by the northern kingdoms, and many of the existing Muslim families migrated to north Africa, Granada or moved to rural areas (Barton 2009:70). A new class of Christian nobles was formed thanks to new arrivals from the northern kingdoms, lured by advantageous fiscal conditions offered to new settlers (Marques 1977:81). However, some of the Muslim population remained under Christian rule (called *mudéjar*) and the creation of Muslim quarters is known for many cities in Portugal including Coimbra, Santarém, Lisbon and Évora among others (Barros 2015).

Meanwhile in Spain, Granada remained under Islamic rule until 1492 when the last Nasrid ruler was defeated. During this year, Jewish populations of Castile were forced to convert or leave the kingdom and while some of them relocated elsewhere, or converted, a significant number turned to Portugal, where persecutions had not occurred since Visigoth rule (Marques 1977:294). However in 1497, following an agreement with Castile, all Jews were expelled from Portugal during a few months of bloodshed and violence. All the remaining Jewish and Muslim populations were consequently forced to convert and baptise. This measure created a class of new-Christians (*moriscos*), who were still object of discrimination in the 16th century (Marques 1977:297). Eventually, all the remaining *moriscos* were expelled from the Iberian Peninsula at the beginning of the 17th century.

The last stronghold of Muslim power fell into Christian hands in 1492; the Portuguese started the first overseas explorations. Vasco da Gama came back from India in 1498 with boats filled with species and exotic products, opening the way to the Portuguese expansion along the entire Atlantic coast (Marques 1977:298).

### 1.4 Terminology: ‘Portugal’

As it can be seen in the previous discussion, Portugal did not exist as a political entity with the same geographical border during the medieval period until the end of the Islamic rule in 1249. Whenever possible, more appropriate terms have been used to define the geographical areas under discussion, however the term ‘Portugal’ has been used to refer to the area under study within its modern political borders. The term medieval, is in Portuguese historiography, used for the Christian period only, however it is used in this thesis as the period from the Islamic conquest (8th century) to the discovery of the New World (15th century).

### 1.5 The historiographical discourse and Islamic studies in the Iberian Peninsula

The study of Islamic archaeology in Portugal had a delayed start compared to Spain, which affected the attention that the scholarship devoted to this part of the national history. Because of its particular development, the following section discuss how politics along the centuries prevented the Portuguese national identity to be linked to the Islamic medieval period, causing a lack of interest and research in such discipline until recent times.

Islamic studies of the Iberian Peninsula have been affected by historiographical discourses of the 19th and 20th centuries. One of the main debates in Iberian scholarship during these centuries regarded the Christian conquest of the Iberian Peninsula, also referred to as 'Reconquista' (reconquest). This is a term that continues to generate debate because of its underlying assumption that the conquest of territories under Muslim rule was an essential right of the Christian Kingdoms of northern Spain. The historiography of the 19th century interpreted the Muslim occupation as a temporary condition, hence legitimising the Christian Kingdoms to re-conquer the lands once taken away from them. Modern Catholic Spanish society focussed on its Roman-Visigoth history, leading to denial of Arab heritage and legacy in post-medieval Spain (Romero González and Furió 2015). This misconception was present in Spanish historiography until the 20th century and two main reasons can be identified to explain its persistence in time. Firstly, Christian historical sources such as the Asturian chronicles described the conquest of the Iberian Peninsula by Muslims (or rather the loss of Spain by Christians) as a punishment sent by God to the Christian population because of their sins (Garrido i Valls 2003). As Romero González and Furió (2015:80) observe, until the first half of the 13th century Christian texts referred to Al-Andalus as España (*Hispania* - Spain), refusing to recognise the Islamic power as a legitimate one, and complaining about the destruction and occupation of the Christian Visigothic Kingdom. Secondly, since the early modern period, Christian identity was equated with the national identity, with remarkable consequences as shown by the expulsion of the Jews and Muslims from the Peninsula in the 15th and 16th century up until the manipulation of the Iberian history perpetuated by the nationalisms of the 20th century (Kamen 2008, Thomaz and Alves 1991). In the 20th century, two main voices led the historiographical debate over the origin of Spanish identity: Américo Castro and Sánchez Albornoz. While the latter believed that the Spanish character bore Roman-Visigoth roots and was unchanged by Islamic rule, Castro (1972) maintained that the origin of Spanish modern identity was to be sought in the cohabitation of Jews, Christians and Muslims in the peninsula from the 8th to the 15th century (O'Callaghan 2013:18-20). Although Castro's theory has been widely criticized by Albornoz for lack of supporting elements, he challenged for the first time the idea of "eternal Spain", giving more emphasis to a period of the Iberian history that had long been neglected. Another important contribution to modern Iberian historiography is the work of Menéndez y Pelayo who placed the origin of modern Spanish culture in the classical Hellenic and Roman Catholic tradition. His work was adopted by the fascist dictatorship in the mid-20th century to ideologically legitimise its control over Spain, where Franco was portrayed as the perpetuator of the Spanish long-lasting civilization that from Roman times resisted the immorality of foreign influences.

The historiographical discourse had a direct impact on the subject's academic popularity, where little or no attention was given to the period of Muslim occupation of the peninsula until recent times. Although this trend can be seen in both Spanish and Portuguese historiography, there is a significant difference between the attention that Spanish and Portuguese scholarship has given to the Arabic world. The poignant critique of Marín (2014) on the birth and evolution of Arabic studies in Spain is a useful tool to understand this phenomenon and how the political milieu of Spain strongly affected the development of the discipline. However, as Lopes de Barros (2014) pointed out, while in Spain it is possible to identify a tradition of Arabic studies, Portugal never developed an independent philological framework or a "school" that explored the language, history and culture of Islamic history. It is only after the end of the dictatorship in 1974 that a revival of social and human science brought about new interest for this part of the Portuguese past. An interesting analysis of the Portuguese scholarship is given by Cardeira da Silva (2005) exploring the contribution of history, anthropology and archaeology in the revival of Muslim culture in Portugal after the fall of the Salazar regime. Archaeology is here identified as the discipline that has been the most affected by this change of political setting and academic interest. One of the results of this phenomenon is the creation of the archaeological park of Mértola in south-eastern Portugal. This project had a great impact on the study of Islamic archaeology, renamed by Cardeira da Silva as 'the Mertola effect'. The excavation at this site recovered remains of the Roman, Palaeochristian and Muslim periods and was used to convey an idea of a multicultural and harmonious coexistence of different populations. It had a big effect on the media in the 1990s and was used as an example of local development that could have been applied to other parts of the country (Cardeira da Silva 2005). Archaeology seems to have been the most receptive discipline during the revival of Islamic studies, providing data on the life of the Muslim and Christian communities cohabitating the peninsula. Studies focussing on a range of aspects on Islamic archaeology are increasing, including urbanization and landscape archaeology, zooarchaoelogy and bioarchaeology. However, there are still significant gaps in our understanding of Islamic Iberian society and this research aims to provide a substantial contribution to this developing field.

### 1.6 Research aims and objectives

The overall aim of this research is to explore dietary practices and resources exploitation in the multi-faith society of medieval Portugal (8th-15th centuries) through the application of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic analysis. The isotopic data are combined with the evidence provided by historical and archaeological sources. Within this global framework, several research questions are explored:

- Does geographical location affect diet and resource exploitation?
- Do people of different faith, sex, or status have an isotopically different diet?
- Does diet vary within populations at the same location over time?

Because of the particular context of medieval Portugal, specific aims are formulated that refer to the historical and social context of the populations under analysis:

- To assess the impact of faith on diet in terms of food restrictions and dietary preferences;
- To explore the transformation of an Islamic society along the centuries, before and after the Christian conquest and the influence of shifting political power, and in particular to contribute towards reconstructing the neglected microhistory of the Muslim populations living in Portugal during the medieval time, addressing a long-standing gap in the scholarship of the country;
- To explore the evolution of a Christian society, from taking control of a heavily Islamised agricultural society to the first overseas expansions and the impact of seafaring activities on diet;
- To place this research into a wider European context of medieval diet and economic changes between the early and the late Middle Ages.

In order to achieve the aims stated above, this research has the following objectives:

- To analyse populations of Muslims under both Islamic and Christian rule and populations of Christians under Christian rule;
- To perform isotopic analysis on human and animal samples from a wide range of sites, settlement types, locations and environments to assess their correlation to dietary practices and intra-population variability within these;
- To compare these isotopic results to other European and Iberian studies of medieval chronology.

## 1.7 Thesis format

The reminder of this thesis in composed of eight chapters. The next chapter (Chapter 2) provides the technical background to carbon and nitrogen isotopes, their presence in the biosphere, their inclusion in the bone collagen tissues and their functioning as ecological and dietary markers. Archaeological bone degradation and diagenesis are also tackled in this chapter, which concludes with a review of previous applications of this methodology to explore diet in medieval European populations.

Chapter 3 provides an overview of the historical and archaeological evidence for diet in Iberia, focussing whenever possible on specifically Portuguese sources. The aim of this chapter is to provide the context for the interpretation of the isotopic results.

Chapter 4 introduces the methodology followed in this thesis including the sampling protocol, sample preparation method and analytical procedures employed. Chapter 5 presents the archaeological and historical background of each site from which humans and animals have been sampled and provides a justification for their inclusion in this study.

Chapter 6 and 7 include the presentation and a brief discussion of the results by geographical location. Chapter 6 assesses the data from individual sites from Northern and Central Portugal, while Chapter 7 focusses on Southern Portugal.

Chapter 8 offers an in-depth discussion of the data, building on the previous chapters, to provide an overview of the animal and human dataset across all sites. In addition, explores the variability of diet in relation to sex, faith and chronology in order to address the research themes outlined above. The final chapter (Chapter 9) draws the conclusion of the research and suggests area of further development for future work. Appendix A includes a detailed methodology of the atmospheric and marine calibration curve applied to radiocarbon dates; as well as the equation used to model the contribution of marine protein to the human diet. Appendix B presents all the raw isotopic data for human and animal samples. Appendix C includes the two papers published on the isotopic data from three sites included in this thesis: São Jorge Castle, Calçadinha do Tijolo and Praça da Figueira in Lisbon.

# 2. STABLE ISOTOPES AND THEIR USE IN ARCHAEOLOGY

Stable isotope analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) is an established method of reconstructing human and animal diet through direct analysis of the skeletal remains of the humans and animals themselves. The principle behind this biomolecular technique is that the isotopic composition of the bone reflects the isotopic values of the food and drink ingested in life (Ambrose 1993). The isotopic signature of the diet is incorporated into body tissues, such as bone, as a result of metabolism and this signature is retained after death. The ratios of carbon and nitrogen isotopes vary predictably between broad categories of food such as terrestrial and marine food webs. In addition, in the case of carbon, isotopic ratios vary between plants with different photosynthetic pathways, allowing us to distinguish the consumption of wheat from millet for example. Nitrogen isotopes reflect positions in the food chain, where nitrogen isotopic signatures are higher in the upper orders of the food chain. Therefore, by analysing the characteristic variation in carbon and nitrogen isotopes ratios between food categories, it is possible to identify the origin of dietary resources and reconstruct the diet of specific populations in the past (Katzenberg 2008).

The principles of stable isotope analysis are outlined in this chapter, focusing on the specific terminology as well as exploring the ecological and biological factors that affect the analysis of biological tissues. The chapter concludes with a review of previous applications of stable isotope analysis to medieval European population, including the growing number of studies on Iberian assemblages.

## 2.1 Basic principles, notation and terminology

Isotopes are atoms of the same element with different masses due to differing numbers of neutrons in the nucleus. The extra neutrons in the nucleus do not affect the electrons reactive sphere of an element, which retains the same chemical behaviour (Fry 2008). However, if the relative mass difference between isotopes is large enough, fractionation can occur. Fractionation is defined as a systematic change in the abundance ratio of two isotopes and can be observed during physical, chemical and biological reactions. It is widely used in light isotopes as a marker in biogeochemical cycles and, has been extensively applied in archaeology as a marker for dietary reconstruction (Pollard and Heron, 2008). Because of the small scale at which fractionation occurs, variation in stable isotope ratios are reported in parts *per mille* (per thousand ‰) deviations (δ) from an international standard, as follows (McKinney et al. 1950):

$$\delta\ (‰)= [R_{sample}/R_{standard})-1]*1000$$

Where R is the ratio of the heavier to the lighter isotopes in the sample or standard. After fractionation, if δ becomes more positive, the sample contains more of the heavier isotope and vice versa. The internationally agreed standard for carbon isotope measurements is marine limestone, and the one currently in use is the Vienna Pee Dee Belemnite Formation (VPDB) (IAEA 1995:65). The international standard for nitrogen is atmospheric nitrogen (AIR) (Mariotti 1983). The factors that regulates stable isotopes ratios are mentioned below, however, plants and animals tent to have a negative $\delta^{13}C$ value since marine carbonate is more abundant in $\delta^{13}C$, while $\delta^{15}N$ values are usually higher compared to AIR hence showing positive values (Hoefs 2009).

Stable isotopes do not break down overtime like unstable radioactive isotopes and therefore their ratios reflect the environment in which they were formed. The abundances of the principal stable isotopes examined in this research are provided in table 2-1.

| Element | Stable isotopes | Abundance (%) |
|---|---|---|
| Carbon | $^{12}C$ | 98.89 |
| | $^{13}C$ | 1.11 |
| Nitrogen | $^{14}N$ | 99.63 |
| | $^{15}N$ | 0.37 |

***Table 2-1*** *Average terrestrial abundances of the stable isotopes studied in this thesis (Ambrose 1993:66)*

The use of stable isotopes to reconstruct diet is based on the principle that the isotopic ratios of carbon and nitrogen in the body, in this case in bone collagen, reflect those of the food consumed during life. As certain types of food vary in their isotopic composition, individuals consuming these different diets can be distinguished on the basis of their bone chemistry. However, a number of physiological as well as environmental factors regulates the isotopic values of primary producers and consumers and have to be understood in order to trace dietary practices. These variations are outlined below to support the interpretation of human and animal isotopic data.

Out of the unstable radioactive isotopes, radiocarbon is widely used in archaeology for dating purposes. Radiocarbon ($^{14}C$) is produced in the upper atmosphere and has a relatively short half-life estimated as 5730 a (Bronk Ramsey 2008). Because of its short life, there is virtually no primordial radiocarbon left on earth, however it is found in different quantities in different reservoir. Radiocarbon produced in the atmosphere is in dynamic equilibrium with the one in the hydrosphere. Due to a slower mixing rate between chemical elements in the water body and the atmosphere, aquatic environments (both deep ocean and surface seawater) are depleted in $^{14}C$ compared to the terrestrial biosphere. Consequently, marine and freshwater organisms have a reservoir age (R) consisting in an apparent older age (Soares et al. 2016). R (t) can vary with time because of $^{14}C$ variation in the atmosphere, but also oceanographic conditions in different geographical regions affect its value (water mass mixtures, wind and upwelling of deep water). Stuiver and colleagues (1986) have derived a calibration curve for radiocarbon dating of marine samples to account for the variation between the world ocean and atmospheric $^{14}C$ values. In addition, a parameter denoted as $\Delta R$ (regional marine $^{14}C$ reservoir effect) is required and determined for particular geographical regions. It is calculated as the difference between the reservoir age of the regional ocean and the reservoir age of the average world ocean at a certain time (t) (Stuiver et al. 1986). For the western Portuguese coast, a $\Delta R$ mean value of 95±15 $^{14}C$ years has been calculated and applied to the radiocarbon dated samples[1] in this thesis (Soares and Dias 2006).

The reservoir effect can play an important role in radiocarbon dating of marine samples but also in individuals whose diet proves to be based on marine resources. For this reason, the relative contribution of marine resources is generally calculated and the relative correction is applied to the radiocarbon age of specific individuals. This is a standard practice in dietary studies and can be seen in several geographical areas and time periods (Yoneda et al. 2002; Graig et al. 2013; Olsen 2013). A detailed explanation of the methodology applied in this thesis can be found in Appendix A.

## 2.2 Overview of Carbon distribution in nature

### 2.2.1 The Carbon cycle

The carbon cycle involves an active exchange of $CO_2$ between the atmosphere and the terrestrial and marine ecosystems. This exchange is responsible for the wide variation of

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[1] Radiocarbon dating was undertaken on five individuals from the cemetery of Beja.

carbon isotopes in the biosphere occurring through fractionation. Carbon in both terrestrial and marine ecosystems derives from photosynthesis, a process executed by plants, algae and cyanobacteria (Fry 2008).

Plants are the base of the terrestrial ecosystem. Their $\delta^{13}C$ value is lower compared to the atmosphere because of fractionation occurring during photosynthesis (~4‰). Studying the process of fractionation provides information about water use and efficiency strategy in different kinds of plants according to their metabolic pathways (O'Leary 1981). Two main photosynthetic pathways are identified. The Calvin cycle, followed by the majority of land plants, use the $C_3$ metabolic pathway and results in measured $\delta^{13}C$ ranges of -22‰ to -34‰ (Smith and Epstein 1971; O'Leary 1981). During photosynthesis the carboxylation of a five-carbon sugar molecule (ribulose 1,5-biphosphate) take place and results in a stable three-carbon molecule, giving the name ($C_3$) to this pathway. The second photosynthetic pathway, termed $C_4$ (or Hatch-Slack cycle), uses a different enzyme called phosphoenol pyruvic acid (PEP) which gives a four-carbon compound. The $C_4$ cycle is usually found in tropical grasses and plants as an adaptation to limited water availability and higher temperatures (Pollard and Heron 2008). The $C_4$ metabolic pathway results in $\delta^{13}C$ values that ranges between -9‰ and -16‰ (Smith and Epstein 1971; O'Leary 1981). A third metabolic pathway (Crassulacean Acid Metabolism, CAM) switches between the previous $C_3$ and $C_4$ cycles to maximise the use of water and $CO_2$, however it is significant only for the archaeology of very arid environments that host CAM plants like desert cacti, euphorbias, agaves and bromeliads (e.g. pineapple). The values span across the entire range of $C_3$ and $C_4$ depending on the environment, however are typically close to those of $C_4$ plants (-12‰ to -16‰) (Ambrose and Norr 1993).

In terms of dietary reconstruction in Europe, the majority of the consumed crops, vegetables, shrubs, trees and pulses fall within the $C_3$ category, suited to temperate climates (Ambrose 1993). However, some $C_4$ plants are included in both human and animal diet, such as sugar cane, maize, sorghum and millet, which are of particular relevance for the Iberian Peninsula. Although photosynthetic pathways are the primary factor of isotopic variation in plants, other environmental factors can come into play. These are discussed in the following section.

### 2.2.2 Effects of climate and environment on $\delta^{13}C$ values

The $\delta^{13}C$ values of atmospheric $CO_2$ has decreased by ~1‰  from -7‰ to -8‰ over the past 100 years because of $^{13}C$ depleted $CO_2$ inputs derived from fossil fuel burning (Fry 2008:45). This shift has to be taken into account for the relevant periods, however it does not affect the historical period analysed in this thesis.

Climate is a significant factor in isotope ratios variation in plants, especially in terms of temperature and humidity. Spatial patterning has been identified across Europe, originally identified through measurements of $\delta^{13}C$ values of Holocene charcoal samples. The increment in $\delta^{13}C$ values from north-western Europe (cold and wet) to the South (warmer and drier) is on the order of 2‰ to 4‰ and it is closely related to climatic pattern across Europe (Van Klinken et al. 1994, 2002). This pattern is mirrored by collagen values, suggesting the carbon values are entering the food chain and affecting the consumers' diet. A second trend can also be seen from Atlantic to Continental areas which has particular relevance in the light of this thesis. As Portugal is located along the Atlantic coast, comparison between Portuguese and Spanish sites has to take this factor into account, as a difference of 0.9‰ has been reported between charcoal samples from these two countries (Van Klinken et al. 2002). Further effects of the environment on the $^{13}C$ variability include soil nutrient levels, altitude and drainage. Soil composition and nutrient levels, the presence of chemical forms of nitrogen and soil salinity have an effect on the activity of the carboxylating enzyme and stomatal closure, which may increase $\delta^{13}C$ values (~2.5‰) (Farquhar et al. 1989; Heaton 1999). A positive correlation has been reported between altitude and $\delta^{13}C$ values, with an increment of +0.5‰ to +1.5 ‰ per 1000m (Sparks and Ehleringer 1997; Heaton 1999).

Areas of dense vegetation and particularly forest can generate depleted $^{13}C$ values. The most depleted values are near the ground, where light is scarce, while $\delta^{13}C$ values generally increase with height, sometimes within the same tree. This anomaly in $\delta^{13}C$ values is called the 'canopy effect' (O'Leary 1981; van der Merwe and Medina 1991; Bonafini et al. 2013). This phenomenon directly affects the diet of animals living in a similar ecosystem.  Although this effect was first identified in densely forested areas in tropical climates (van der Merwe and Medina 1991; Ambrose and De Niro 1986), recent studies have proven that a shift of ~5‰ between the $\delta^{13}C$ values of grass grown in open and closed locations can also be found in temperate climate forests (Rodière et al. 1996; Drucker et al. 2008; Bonafini et al. 2013; Goude and Fontugne 2016; Doppler et al. 2017). The possibility of the canopy effect has therefore to be taken into account when assessing the $\delta^{13}C$ values of herbivores from densely forested areas of Portugal, which were located in the north of the country, in Serra da Estrela area and in Alentejo and Algarve. Mentions of highly forested areas exploited for meek pine, oak and cork oak wood are reported for the Roman and Islamic period (Aguiar and Pinto 2007; Reboredo and Pais 2014).

Differences in plant parts such as seeds and stems are also found (1-2‰) and can potentially shift the consumer $\delta^{13}C$ values. In addition, humans and animals frequently consume different parts of the same plant, which can have different isotopic values. For examples, recent studies on millet showed that a statistical significant difference was found between leaves and panicles, and leaves and grains of the same plant (Lightfoot et al. 2016). At a microstructural level, biochemical components of plants have different isotopic composition. Lipids have lower $\delta^{13}C$ (~5‰), proteins are generally higher however a great variation is portrayed in the data (-1‰ to +3‰); while carbohydrate show similar values to the isotopic values of the whole plant (O'Leary 1981; Tieszen 1991; Ambrose and Norr 1993). The use of uncertainties is therefore necessary, especially when using mixing models, to reconstruct dietary pattern of a specific population (Heaton 1999; Ben-David and Schell 2001).

### 2.2.3 Consumers and variation in their $\delta^{13}C$ values

Since the beginning of the application of stable isotope analysis to dietary studies, it clearly appeared that the $\delta^{13}C$ values of the diet were related to the carbon stable isotope composition of animal tissues. In addition, it was observed, that a consistent difference between the diet and the consumer tissue existed ($\Delta_{\text{diet-tissue}}$) (DeNiro and Epstein 1978; Peterson and Fry 198; Ambrose and Norr 1993). The following step was then to identify and quantify not only the isotopic signal of the foodstuff but also the fractionation factor for a particular biological tissue (Ambrose 1993). Hedges and Van Klinken (2002:214) summarised the relationship between consumers and their diet as 'the cliché "you are what you eat +5‰" but only when "you" and "what you eat" are properly defined'.

Feeding studies have attempted to define the two end-members of this relationship observing the values of animals kept at controlled diet. Originally, a small shift in $\delta^{13}C$ values of about +1-2‰ between the whole body of the consumer and its diet was found (DeNiro and Epstein 1978; Caut et al. 2008) as well as between the diet and different tissues (DeNiro and Epstein 1978,1981; Tieszen et al. 1983; McCutchan et al.2003). This discriminating factor has been routinely applied in several following dietary studies for $\delta^{13}C$, however a recent review (Caut et al. 2009) highlighted how discrimination factors are significantly affected by the consumer taxonomic group and the consumer tissue, suggesting the use of diet-dependent discriminating factors to tackle the issue (Caut et al. 2008).

A range of values have been reported in the literature for $\Delta_{\text{diet-collagen}}$ from 1‰ to ca. 6‰ (DeNiro and Epstein 1978; Ambrose and Norr 1993; Tieszen and Fagre 1993; Howland et al. 2003), however standard practice suggests the application of a 5‰ offset for $\Delta_{\text{diet-collagen}}$ in herbivores (van der Merwe and Vogel 1978; Ambrose and Norr 1993; Jim et al. 2004). As highlighted by Caut et al. study (2009), the great variability of these values are attributable to physiological and dietary differences of taxonomic groups but also the inclusion of free ranging animals whose diet cannot be controlled. In addition, the fractionation between tissues of the same animal is the results of metabolic differences during assimilation of the diet biochemical components (Jim et al. 2004). The mechanism that regulates the incorporation of macronutrients and their contribution to collagen (especially proteins and amino acids) is still to be thoroughly understood and quantified; however a brief discussion of the current understanding of proteins routing is provided below (Fogel and Tuross 2003; Hedges et al. 2006; O'Connell and Hedges 2017).

Although trophic level effect is more pronounced in nitrogen, a small shift of up to ~2‰ between herbivores and carnivores in $\delta^{13}C$ values has been observed (van Klinken et al. 2000; Bocherens and Drucker 2003). Herbivore isotopic values are affected by plants, which can present a wide range of $\delta^{13}C$ values, as previously seen, because of several environmental and biological factors. For example, depletion of $^{13}C$ due to canopy effect was reported for herbivores populating forests in Europe and North America (Drucker et al. 2008; Goude and Fontugne 2016; Doppler et al. 2017).

Nutritional stress does not seem to affect the $\delta^{13}C$ values of birds, animals and humans (Hobson et al. 1993; Ambrose 2002) although it does for nitrogen isotope values (Section 2.3.4). Age does not seem to have an effect on $\delta^{13}C$ values (Schwarcz and Schoeninger 1991) although slightly elevated values (+1‰) are reported for breastfeeding non-adults, due to trophic level effect (Fuller et al. 2006; Tsutaya and Yoneda 2013, 2015). Physiological sex differences do not show to be associated with variations in $\delta^{13}C$ values (Schwarcz and Schoeninger 1991). For these reasons, any correlation between $\delta^{13}C$ values and sex and age categories is interpreted in this thesis as a differential dietary pattern.

### 2.2.4 Marine and freshwater environments

Marine plants and phytoplankton are at the base of the marine food chain. In aquatic environments plant δ$^{13}$C values are determined by three main factors: the isotopic composition of dissolved inorganic carbon (DIC) - whose main component is bicarbonate $HCO_3$ -, the isotopic discrimination factor of the enzyme responsible for carboxylation and the intracellular concentration of $CO_2$ or $HCO_3$ (Farquhar et al. 1982). Bicarbonate ($HCO_3$) has a δ$^{13}$C value of ca. 0 ‰, while modern atmospheric carbon has δ$^{13}$C values of ca. 8‰. This difference between the two main carbon sources for marine and terrestrial ecosystems, create a discriminating factor between these two environments that is maintained and transmitted through the food chain (Chisholm et al. 1982). This reflects on marine plants having more positive δ$^{13}$C values than terrestrial $C_3$ plants, however since variation occurs in aquatic plants as much as in terrestrial ones, some overlap has been observed (Fry and Sherr 1989; Goericke and Fry 1994; McMahon et al. 2013). Algae show both $C_3$ and $C_4$ photosynthetic pathways, which can alter the expected δ$^{13}$C values. In addition, environmental factors such as temperature and water depth play a role in the marine isoscape: pelagic and offshore environments show more negative δ$^{13}$C values compared to bottom-dwelling or coastal water (France and Peters 1997; Hobson 1999). Marine fauna from temperate climates possess δ$^{13}$C values ranging from -12 to -16 ± 1 ‰. Following previous studies, -12‰ (measured on collagen) has been used as the δ$^{13}$C value endpoint in this thesis indicating a diet based on marine/aquatic resources (Chisholm et al. 1982; Schoeninger et al. 1983; Richards and Hedges 1999; Schulting and Richards 2001, 2002; Sealy 2001). In terms of trophic level, only a minor discrimination factor has been reported for δ$^{13}$C values in the order of >1‰ with each step in the food chain similar to the terrestrial food web (Post 2002).

Freshwater ecosystems tend to have more negative δ$^{13}$C values than marine environments. Freshwater ecosystems have highly variable δ$^{13}$C values mainly due to a varied ecology in which different carbon sources are used by phytoplankton, algae and aquatic plants. The main sources of available carbon are DIC (originated by reaction with bedrock limestone), dissolved $CO_2$, organic carbon from the decomposition of organic matter, respiration and run-off from terrestrial systems (Peterson and Fry 1987). The relative contribution of each of these sources depends on environmental factors such as size of the water basin, water flow, depth, salinity and pH (Post 2002; Grupe et al. 2009). Freshwater plants show δ$^{13}$C values ranging between -37‰ and -27‰, although several case studies show even wider ranges of δ$^{13}$C values (Peterson and Fry 1987). Variations are caused by spatial (benthic-pelagic environments) and differences in feeding habits (variation of food web base) as well as changes in the values of primary producers or anthropogenic pollution (Gu et al. 2011; Häberle et al. 2016; Whitney et al. 2017). Grupe et al. (2009) report a range of $\delta^{13}C$ values for freshwater fish between -13‰ and -27.7 ‰. Similar wide ranges were found by Häberle et al. (2016) in different Swiss lakes ranging from -15.4‰ to -26.7‰ for archaeological samples and between -22.9 ‰ to -30.2‰ for modern specimens. Dufour et al. (1999) reported similar values for European and Russian lakes in which the wide range of values emphasised the isotopic variability within and between lakes.

Because of the high variability portrayed in freshwater fish data, local and contemporary samples are to be preferred during isotopic analysis; unfortunately, however, none of the fish remains included in this thesis pertained to freshwater species. Although the contribution of freshwater fish to the medieval diet in this region is yet to be explored, this lack of data may have an impact on almost all sites included in this thesis since the majority of the settlements are located near main rivers systems such as Laranjal, Coimbra, Lisbon, Setubal, Silves and Beja.

## 2.3 Overview of Nitrogen distribution in nature

### 2.3.1 The Nitrogen cycle

Almost 100% of the known nitrogen is present on Earth as atmospheric $N_2$ or dissolved $N_2$ in the ocean. Its global isotopic ratio is constant; however, several processes are responsible for its fractionation in the food webs (unlike $CO_2$ whose main fractionation process is photosynthesis) (Mariotti 1993; Hoefs 2009). All stages of the nitrogen cycle in the biosphere are mediated by aquatic or soil micro-organisms and include four main processes: fixation, ammonification, nitrification and denitrification (Hoef 2009). Fixation entails the conversion of gas form $N_2$ into any nitrogen compound such as ammonia ($NH_3$) and ammonium ($NH_4$), while ammonification is the decomposition of organic matter resulting in the production of ammonia and ammonium. Nitrification is the oxidation of ammonia and ammonium producing nitrogen compound such as nitrite ($NO_2$) and nitrate ($NO_3$) while de-nitrification in the conversion of nitrogen (in nitrate form) into gas ($N_2$) (Jaffe 1992). A faster loss of $^{14}N$ over $^{15}N$ occurs during particulate N decomposition resulting in a direct correlation between increasing $^{15}N$ (5-10‰) and depth (both in soils and oceans). Nitrification and denitrification in the sea cause a substantial fractionation (Δ=10 to 40‰) (Fry 2008).

### 2.3.2 Producers and consumers

Nitrogen fixation is the only way in which nitrogen can be incorporated into natural biosystems. Biological nitrogen fixation is the source of nitrogen in all living organism and it can be undertaken by a variety of bacteria and algae, independent or symbiotic (Jaffe 1992). Plants acquire their nitrogen from the soil in the terrestrial environment or from water in the case of marine plants. The nitrogen is assimilated in the form of nitrate, a product of decomposition of organic matter undertaken by independent bacteria in the soil (Ambrose 1991; Dawson et al. 2002). Leguminous plants however, use symbiotic bacteria, found on their roots to perform nitrogen fixation (Jaffe 1992).

The main factor leading to $\delta^{15}N$ variation in plants is the different origin of nitrogen sources in the soil. Fractionations occur during nitrogen assimilation; however, the mechanism is poorly understood and previous studies suggested the discrimination factor between soil and plants is generally negligible (Yoneyama et al. 1991; Evans 2001; Dawson et al. 2002). The different ways of nitrogen fixation performed by plants impact their $\delta^{15}N$ values. Leguminous plants, fix nitrogen through a symbiotic bacteria and therefore show $\delta^{15}N$ values close to atmospheric $N_2$. On the contrary, non-leguminous plants possess higher $\delta^{15}N$ values due to the assimilation of nitrates in the soil (DeNiro and Epstein 1981; Franche et al. 2009; Shamseldin et al 2017). Plants can show $\delta^{15}N$ values ranging between -5 to +20‰ depending on climatic, metabolic and anthropogenic factors. However plants in temperate climates usually possess values between +3 and +6‰ (Ambrose 1991; Coltrain et al. 2004).

### 2.3.3 Variation in producers' $\delta^{15}N$ values

The isotopic ratio of nitrogen in both soil and plants is highly variable and several factors affect its percentage. Climatic and environmental factors such as temperature, precipitation and water availability, pH, salinity and anthropogenic inputs have an effect on soil $^{15}N$ content. These variations have an impact on plant $\delta^{15}N$ values and can consequently be passed on to consumers, causing a significant spatial variation in animal isotopic composition.

In plants, there are three main reasons that cause intra-plant variation: fractionation associated with different $NO_3^-$ assimilation rates in roots and shoots; movement of nitrogenous compounds between sources tissues; reliance on variable N sources during the tissue formation process (Szpak et al. 2013). Is it expected that shoots will have higher $\delta^{15}N$ values than roots in plants that assimilate $NO_3^-$ (Evans et al. 1996). During the growing process, N is accumulates in specific parts of the plants (leaves and steam) to be later mobilised and allocated especially to fruits, grains or flowers. During this process, a fractionation can occur and has been reported in several studies, with sources being more enriched in $^{15}N$ in relation to tissues like grains and flowers (Choi et al. 2002; Szpak et al. 2012).

Plant $\delta^{15}N$ values have shown to be positively correlated with mean annual temperature (MAT) (Schulze et al. 1991, Martinelli et al. 1999; Amudson et al. 2003) however this correlation ceases in areas where MAT ≤ -0.5°C (Craine et al. 2009). Conversely, a negative correlation has been found between plants $\delta^{15}N$ values and local precipitation or water availability (Amundson et al. 2003; Murphy and Bowman 2006; Hartman and Danin 2010; Meier and Leuschner 2014).

Salinity can also affect plant $\delta^{15}N$ values. A general positive correlation has been reported in several studies with an enrichment of up to 10‰ (Heaton 1987; van Groeningen and van Kessel 2002), although contradicting results showed a salinity-induced depletion of foliar $\delta^{15}N$ in barley under controlled conditions (Handley and Scrimgeour 1997; Robinson et al. 2000). Coastal proximity can also cause variation in plants $\delta^{15}N$ values because of ocean-derived nitrate input in into the soil (Virginia and Delwiche 1987), however a high rate of rainfall can minimise this effect, diluting soil salinity (Heaton 1987).

Another potentially significant source of $\delta^{15}N$ variation are anthropogenic inputs, which have an impact on the uptake of fertilizer-derived N by plants. Modern fertilizer are usually manufactured from atmospheric $N_2$ (values ranging -4 and +4‰) producing lower $\delta^{15}N$ values, however that's not the case for animal waste (Kendall 1998). The use of animal manure to restore soil nutrients is well documented. It shows higher $\delta^{15}N$ values that can affect soil $\delta^{15}N$ values and therefore plants and consumers (Heaton 1986; Ben-David et al. 1998; Kendall 1998; Bogaard et al. 2007). Increased stocking rate can be an indirect cause of increased animal waste in the soil, but studies have found conflicting results: increasing (Coetsee et al. 2011), decreasing (Golluscio et al. 2009), or having no effect on plants $\delta^{15}N$ values (Wittmer et al. 2011).

Finally, another important variable to consider when assessing plants $\delta^{15}N$ values is the taxonomic variation. In fact, a significant difference is portrayed in plants $\delta^{15}N$ values in relation to mycorrhizal (fungal) associations and allow, in some cases, to distinguish between plant functional types such as grasses, shrubs and trees (Michelsen et al. 1998).

Although there are several factors affecting the $\delta^{15}N$ values of plants, this variability will be averaged when assimilated by the consumers' metabolism. Ideally, $\delta^{15}N$ values of archaeological plant remains from the same location and chronology of the analysed fauna and human individuals would significantly help in interpreting the local plant baseline (van Klinken et al. 2002). However, there is no published record of stable isotopes analysis undertaken on plant remains from Portuguese archaeological sites and It was not possible to access any plant remains to analyse as part of this thesis. For this reason, the faunal baseline plays a key role in determining the value that constitute the base of the food web. In the absence of direct plant measurements caution has to be adopted when considering the effect of feeding and physiology on the $\delta^{15}N$ values of the animals.

### 2.3.4 Variation in consumers' $\delta^{15}N$ values

Intra-individual variation is documented for both plant and animal samples. When analysing the nitrogen cycle in the animal kingdom, numerous studies performed under controlled conditions have shown a quantitative relationship between the nitrogen isotopic composition of animal tissues and its diet (DeNiro and Epstein 1978; Ambrose and Norr 1993; Tieszen and Fafre 1993; Jenkins et al. 2001; Bocherens and Drucker 2003). Recent studies further confirmed the existence of a clear link exists between animal tissue $\delta^{15}N$ values and plant $\delta^{15}N$ values (Murphy and Bowman 2006; Hartman 2011). As the food chain is ascended, an increment between diet and body is observed. In the archaeological literature the $\Delta_{\text{diet-body}}$ value is assumed to be of +3-6‰ (DeNiro and Epstein 1981; Ambrose 2002; Bocherens and Drucker 2003; O'Connell et al. 2012). However, contradicting results have been produced along the years in both ecological and archaeological studies, proving rather difficult the quantification of a universal $\Delta_{\text{diet-body}}$ value. Species-based variation has been observed and it has been associated with different forms of nitrogen excretion. Animals that excrete nitrogen mostly as urea or uric acid, including mammals, birds and insects, have $^{15}N$ enriched tissues compared to those excreting nitrogen in the form of ammonia (aquatic organisms) (Vanderklift and Ponsard 2003). These results however, have been challenged by more recent studies who found no difference between species with different mode of nitrogen excretion (Caut et al. 2009). The anatomy of the digestive system may also affect the $\delta^{15}N$ values (van Klinken et al. 2002). Controlled feeding studies on different species of herbivores showed great variation in $\delta^{15}N$ values due to physiological difference up to 3.6‰ (Sponheimer et al. 2003). A general consensus is reached on the fact that high $\delta^{15}N$ values in animal tissues could have been the result of physiological reaction to drought stress (Sealy et al. 1987; Gröcke et al. 1997) however; controlled feeding studies did not provide any supporting evidence (Ambrose 2002). The existing data do not provide a satisfactory characterization of fractionation effects in mammals and species-specific controlled feeding studies have been long called for (Ambrose 2002).

Despite the high level of variation discussed above, a discrimination value of 3-5‰ is applicable to a number of prey-predator relationships in terrestrial ecosystems and is used in this range is used in this thesis as the expected range of trophic level enrichment. However, the situation is more complicated when dealing with humans. Controlled feeding studies can be and have been performed on a number of human tissues (blood protein, hair keratin) from individuals who self-reported their diet (Kraft et al. 2008; O'Connell et al. 2012; Kuhnle et al. 2013). However, tissues like bone collagen, hair keratin and blood protein are subjected to a turnover effect, incorporating the nutrients at different rates, as well as to isotopic equilibration (O'Connell and Hedges 1999; Petzke and Lemke 2009). Because of these two main constraining factors, medium and long-term feeding studies have been performed on animals kept at a monotonous diet, which would be ethically and practically impossible to sustain in human individuals. The degree of applicability of the animal testing results to human individuals is unknown, although it is generally assumed that similar mechanisms may take place, especially given the biochemical similarities of nitrogen conservation and excretion among different organisms (Singer 2003). The measurements of nitrogen stable isotopes ratio in amino acids is increasingly becoming a routine analysis, providing more in-depth dietary information compared to bulk protein analysis. Amino acids $\delta^{15}N$ values are affected during trophic transfer in a very specific way: in early biomarker studies glutamic acid/glutamine was identified as the most reliable trophic amino acid while phenylalanine the most reliable source amino acid. The trophic level of an organism could subsequently be extrapolated from the values of these two specific compounds (Chikaraishi et al. 2009). Although this new technique has promising application in nutrition, ecology, palaeontology and archaeology, a high degree of variation seem to emerge from recent studies suggesting that because of the complexity of nitrogen cycling, it is unlikely to determine a universal trophic discrimination factor (Fuller and Petzke 2017; O'Connell 2017). In addition, human nitrogen isotopic values vary under a number of conditions such as nutritional stress, growth, illness and pathology.

Nutritional stress has been explored in both captive and wild birds, showing a positive correlation between reduced nutrient intake and $\delta^{15}N$ values (Hobson and Clark 1992, Hobson et al. 1993). Similar research has been done on pregnant women suffering from morning sickness. The results showed higher $\delta^{15}N$ values compared to pre-pregnancy values for women undergoing varying degree of nutritional stress (usually weight loss or restricted weight gain)

(Fuller et al. 2005). The same principle has inspired the use of nitrogen isotopes ratios to detect period of starvation, malnutrition and anorexia in historical populations (D'Ortenzio et al. 2015; Beaumont and Montgomery 2016; Dent 2017); in modern clinical cases (Mekota et al. 2006, 2009; Neuberger et al. 2013; Baković et al. 2016) and in modern heavy exercise and restricted diet regimes (Huelsemann et al. 2015).

If nutritional stress and a lack of protein can produce higher $\delta^{15}$N values, so it does an increasing proportion of animal protein in diet measured in hair keratin (O'Connell and Hedges 1999; Petzke et al. 2005). Contrasting results have been reported for different species, which suggests that the nitrogen excretion and consequent nitrogen isotopes ratios can vary according to species and analysed tissue (Ambrose 2002, Vanderklift and Ponsard 2003). However, in human individuals, $\delta^{13}$C values have been used as an additional parameter. In cases of starvation and lack of protein, while the $\delta^{15}$N values increase, the $\delta^{13}$C values seem to decrease. On the contrary, if the higher $\delta^{15}$N values are due to a higher protein intake, the $\delta^{13}$C values are unchanged or show an increment of ~1‰ (Neuberger et al. 2013). A previous knowledge of the context as well as the parallel analysis of carbon and nitrogen isotopic ratios might help in reducing the uncertainty of interpreting enriched nitrogen isotope values. However, this type of analysis are possible only for serial measurements of hair and/or dentine, but not bone.

The influence of illness and pathology over the human metabolism and the ratios of carbon and nitrogen isotopes is unknown. One study on stable isotopes of pathological bones reported higher ratios of nitrogen, which was linked to the processing of protein catabolism similar to those acting during nutritional stress (Katzenberg and Lovell 1999; Olsen et al. 2014). In order to avoid any confounding variables pathological bones have been excluded from this thesis. Reitsema (2013) has recently compiled a review of physiological conditions reflected by stable isotopes signature and independent of diet. Although there is potential for stable isotopes to be used as reliable indicators of health in past population, further research needs to be undertaken as well as a new sampling methodology.

The last factors to consider in relation to variability in $^{15}$N are sex and age-related differences. Previous studies have not found a significant correlation between physiological sex and $\delta^{15}$N values in archaeological populations (Schwarcz and Schoeninger 1991; Tsutaya 2017). The same can be said for $\delta^{15}$N values and the individuals' age (Minagawa and Wada 1984; Ambrose 2002; Tsutaya and Yoneda 2015). However, a clear trend in non-adult $\delta^{15}$N values has been reported in many published studies on modern and archaeological populations. From a dietary point of view, childhood could be divided into three phases: the first one lasting until the first 6 months of a child life during which breastfeeding is the only source of nutrition; a second one starts with the introduction of solid food and ends when the child is not breastfed anymore and solid food is the only source of nutrients; a third phase, when the child has adapted to solid food sharing the same diet of the adult population. Several studies have looked into breastfeeding and weaning practices in past population and although variation can occur, a breastfeeding effect is reported. The suckling individual usually displays a trophic $\delta^{15}$N increment of around 2-3‰ compared to the adult values, until weaning is completed. This trend has been found in a number of archaeological populations across historical periods and geographical locations (Fogel et al. 1989; Richards et al. 2002; Beaumont et al. 2015; Burt 2015; Tsutaya 2017). While the breastfeeding signal is generally easy to recognise in archaeological population and has been widely documented, the same level of attention has not been given to weaning and the post-weaning period. During the weaning period a decrease in the $\delta^{15}$N values is seen as more solid food is introduced in the diet of an infant. When weaning is completed, the consumers were thought to share the same diet of the adult population. However, a recent review by Tsutaya (2017) collated data from more than fifty published isotopic studies and identified a significant difference between adult diet and the one of weaned non-adult individuals. The non-adults, consumed less protein compared to the adult individuals and more $C_3$ plants, although a couple of studies reported a specific childhood diet based on marine and terrestrial animal products (Tsutaya et al. 2015; Tessone et al. 2015). The juveniles' diet was found to be generally closer to the female individuals in non-hunter-gatherer populations while no difference was found between female, males or juvenile diet in hunter-gatherers. This pattern has been linked to gender asymmetry: childcare is usually covered by female individuals in most historical populations and may prompt communal food sharing between females and juveniles. Some concern has been expressed about the variability of $\delta^{15}$N values in juvenile individuals and how this has been often times interpreted as a dietary change (Beaumont et al. 2015). The bone collagen at fetal and neonatal stage has a very fast turnover (Valentin 2002) and its $\delta^{15}$N values is related to the mother's one, which may vary during pregnancy (Fuller et al. 2005,2006). The bone remodelling slows down after birth and therefore unexpectedly high or low $\delta^{15}$N values in perinatal bone collagen could still refer to the period in utero. Additionally, $\delta^{15}$N values of juveniles at any age, may be affected by factors other than diet (Reitsema 2013). Incremental dentine analysis provided further insight on breastfeeding and weaning patterns. Recent data (Beaumont et al. 2015) suggest that $\delta^{13}$C values of dentine collagen are a robust dietary indicator, however $\delta^{15}$N values are more likely to reflect physiological stress, especially when elevated δ$^{15}$N values do not show corresponding rise in δ$^{13}$C. The exploration of breastfeeding, weaning practices and childhood diet are briefly considered in this thesis. Juvenile individuals were sampled and analysed only when sample size was relatively low, with the intention of increasing samples number and provide a more accurate representation of the population.

## 2.4 Bone collagen

Human and animal bones are regularly recovered during archaeological excavation and are a valuable resource to paleodietary studies. Both the organic and inorganic fraction of the bone can be analysed, however in this thesis, research on bone collagen only has been conducted. The following section provides an overview on bone and collagen structure, synthesis and deterioration.

### 2.4.1 Bone and collagen structure and synthesis

Bone is a living, dynamic and highly specialized tissue that continuously adapts to different stages of life: development, growth, maintenance and repair. Although it is perceived as a static, hard and unchanging structure, this open living system changes constantly throughout life (Seeman 2007:123). Bone is composed of an organic matrix (25% by weight), whose 95% is collagen protein, and calcium hydroxyapatite minerals (75% by weight) that enables the bone to retain its structure (Schwarcz and Schoeninger 1991).

Collagen is a major component of connective tissue including skin, tendons, ligament, teeth and bone. It is a triple helix structure of three polypeptide chains forming a macromolecule called tropocollagen. Approximately 30 different types of collagen have been recorded to date, showing slightly different amino acid sequences along the polypeptide chains. In humans, 19 different types of collagen are formed and can be divided into four groupings on the base of their structure: tendons, ligaments, bones and dentine are formed by Type I collagen (Whitford 2013:93-94). While the protein fraction of collagen is responsible for its flexibility, its second component, hydroxyapatite, provide a stiff dense inorganic filling, impregnating the collagen matrix (Jee 2001). The different nature of these components can be best observed during deposition of new bone, occurring at different rates: the process of mineralisation starts approximately 15 days after the deposition of the first collagen fibres and non-collagenous proteins by osteoblasts, forming the osteoid seam (Chappard et al. 2011). Hydroxyapatite appears initially in the form of small crystals increasing in size during calcification, filling the gaps between the collagen fibrils with new crystals. The newly formed fibrils are arranged in arrays of parallel fibrils, then organised in lamellae, and subsequently in cylindrical motifs called osteons (Fig. 2-1) (Weiner and Wagner 1998).

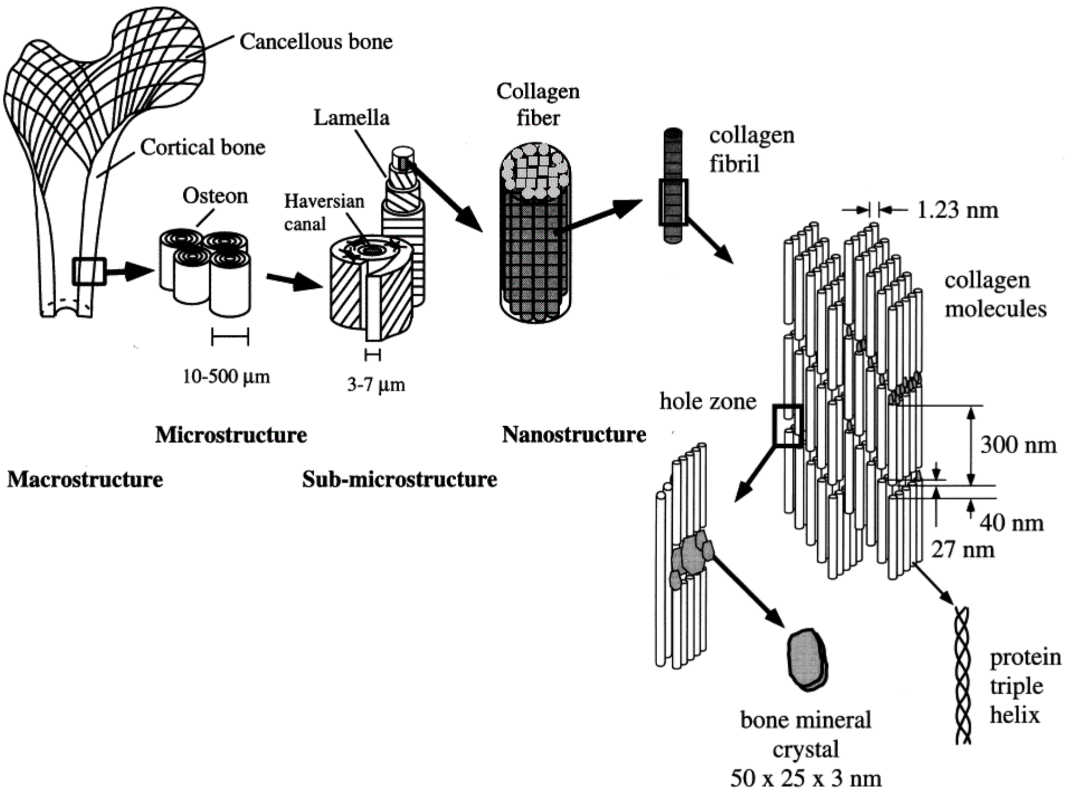

*Figure 2-1 Structure of bone tissue from macroscopical structure to protein (adapted from Rho et al., 1998 Fig.1 and 2).*

All vertebrates and mammals share almost the same collagen structure and composition, allowing the direct comparison of collagen isotope ratios between different species. This is a fundamental factor in archaeological studies comparing dietary habits of animal and human individuals (Ambrose 1993). Interestingly, the amino acid composition of fish bone differs from that of mammals, however experiments on fish bone collagen proved that the extracted collagen is very similar and comparable to mammalian collagen and the same quality control standards can be applied (i.e. C:N ratios; C% and N%) (Szpak 2011).

### 2.4.2 Mechanisms of protein routing

Nitrogen is present almost exclusively as protein in the body and in the diet: 98% is found in amino acids from which protein in synthesised, while the remaining small quantity is present in nucleic acids, urea and ammonia. This direct link implies that $\delta^{15}$N values of collagen reflect the isotopic ratios of the dietary protein (Schoeller 1999).

Carbon, on the other hand, may be derived from all dietary macronutrients. Proteins are synthesised from 20 common amino acids classified as indispensable (essential), dispensable (non-essential), and conditionally indispensable (Young and El-Khoury 1995). The latter group includes amino acids whose precursors are essential and whose synthesis is linked to dietary supply. Indispensable and conditionally indispensable amino acids cannot be synthesised from scratch by the organism and they have to be supplied through the diet. They make up ca. 20% of the carbon atoms in the bone collagen. This value is therefore the minimum amount of direct carbon routing from dietary protein to bone collagen. In theory the remaining non-essential amino acids make up ca. 78% of carbon in collagen, and may be derived from non-protein sources such as lipids and carbohydrates, however, the degree to which this occurs is highly debated. When protein intake is adequate, it is likely that there non-essential amino acids will also derive from dietary protein (Jim et al. 2004). The origin of carbon atoms has been of central importance to paleodietary reconstruction, and there has been much speculation on whether specific macronutrients are routed to specific body tissues or whether the carbon from all dietary fractions is pulled together and ‘scrambled’ before tissue synthesis (DeNiro and Epstein 1978; van der Merwe 1982; Lee-Thorp et al. 1989). At present, the results from feeding experiments indicated that $^{13}$C content of bone apatite reflects the whole diet, while dietary protein is mostly routed to bone collagen. The implication of this model, confirmed by feeding experiments, is that $\delta^{13}$C value of bone collagen can be biased towards that of dietary protein, underestimating the contribution of other macronutrients such as lipids and carbohydrates (Ambrose and Norr 1993; Jim et al. 2004). This has clear implication for paleodietary studies, as vegetable and grain consumption will be underrepresented in $\delta^{13}$C and $\delta^{15}$N values of collagen when sufficient amount of animal protein are consumed (Ambrose and Norr 1993; Craig et al. 2013).

### 2.4.3 Bone taphonomy and diagenesis

Diagenesis is the final step of taphonomy (the processes an organism undergoes from death until recovery) and indicates all the biological, chemical and physical post-depositional processes an organism is subjected to (Nielsen-Marsh et al. 2007; Smith et al. 2007). Diagenesis usually implies a biochemical alteration of the tissues under study and for this reason has to be taken into account in order to interpret the isotopic values of collagen in dietary reconstruction. Since bone is composed of protein and mineral in the form of collagen and bioapatite, the following aspects have to be considered and are discussed below: deterioration of the protein fraction, deterioration of the mineral fraction and microbial attack.

#### 2.4.3.1 Deterioration of mineral fraction

Water is the medium through which the majority of chemical reactions occur in the soil. Skeletal remains that have been subjected to fluctuating ground water content with water flowing around and through the bones, show poorer preservation than remains from constant water saturated environments (Nielsen-Marsh et al. 2000). However, water alone is not enough to cause severe dissolution of the mineral fraction and has to be paired with increased porosity of the bone tissue (Nielsen-Marsh et al. 2007). Dissolution can occur at a local gradient in diffusive environments: water penetrates the small pores and gets saturated in $Ca^{+2}$ and $PO_4^{2-}$, however a considerable resistance to the flow of water out of the bone can follow, leading to very slow and limited dissolution of the mineral matrix. An example of diffusive environments are waterlogged or clays sediments (Turner-Walker 2008). On the contrary, a repeated cycle of wetting and drying soil can cause the successive loss of calcium and phosphorus from the bone matrix, initiating a spiralling process of increased bone porosity, increased water flow through the bone and consequently increased mineral dissolution (Hedges and Millard 1995).

The solubility of apatite depends on the water's pH and the presence of dissolved ionic species. It has been observed that the calcium phosphate increases its solubility as pH decreases. The pH of the water is also responsible for the other ions present in solution, which can potentially exchange with the bone mineral, causing dissolution and leaching into the burial environment (Nielsen-Marsh et al. 2000). The loss of bone mineral has a direct effect on the preservation of protein, leaving the organic fraction exposed to chemical and microbial deterioration (Collins et al. 2002).

The content of carbon within bioapatite has been used to reconstruct diet and is considered an indicator of the whole diet (Ambrose and Norr 1993). Combined analysis of collagen and apatite has been used to infer contribution of animal versus plant based components to the diet of past populations (Ambrose et al. 1997; Kellner and Schoeninger 2007). However, the inorganic fraction of bone is susceptible to contamination from carbonates in the burial environment and recrystallization processes; its preservation is harder to assess and as a results many researchers prefer to analyse bioapatite in dental enamel because it is less susceptible to diagenesis (Koch et al. 1997; Collins et al. 2002). Because of the controversy surrounding the establishment of reliable quality controls for bone apatite, it was not analysed in this thesis.

#### 2.4.3.2 Deterioration of protein fraction

In most environments, the growth of microbes and the dissolution of protein by hydrolysis, both triggered by water, can accelerate the process of protein deterioration. When collagen is mineralised, the bound between protein and mineral has a protective and stabilising effect and microbial attack is deterred by large size of microbial collagenases that do not fit the small pores of the bone. When collagen is demineralized, enzymatic hydrolysis take place, breaking down the collagen fibres into peptides which are assimilated by bacteria and fungi (Turner-Walker 2008; Nielsen-Marsh et al. 2000). Therefore, mineralised collagen has the best chances of survival, and although a certain degree of hydrolysis would still occur, and if the pH is ranging from 3 to 7.5, collagen can preserve for thousands of years (Collins et al. 1995; Nielsen-Marsh et al. 2007).

#### 2.4.3.3 Microbial attack

Decomposition of a corpse and subsequent skeletonisation cause by the loss of soft tissues is mostly due to the action of bacteria and fungi, whose presence is dictated by local groundwater, oxygen availability, temperature and pH (Grupe 2007). The bacteria infiltrates the interior of the bone and can affect one or several part of a skeleton. Unfortunately, the manner and location of its appearance are unpredictable, although trabecular bone such as that of the ribs is more vulnerable to attack than skeletal elements with higher proportions of cortical bone, such as the femur. Microbial attack usually starts with the dissolution of the mineral phase, following therefore a similar pattern to what described above, however the zones of destruction are localised to specific focal points (Collins et al. 2002; Hackett 1981). The influence of soil bacteria on stable isotope values of carbon and nitrogen has been explored and experiments point towards a shift in $\delta^{13}C$ up to -2.9‰ and $\delta^{15}N$ up to +5.8‰. A change in the ratios of remaining amino acids also occurs because of the selective bacterial metabolism resulting in depleted C:N ratios (Balzer et al. 1997). Quality control criteria are used to discriminate against collagen with poor preservation. In addition, microbial attack can be identified by microscopic examination through the analysis of the micro-structural lesions and it has been recently proposed as a valuable method to assess the relation between pattern of bacterial bioerosion and funerary treatments (Booth 2016; Jans et al. 2004).

### 2.4.4 Collagen quality standards (yield, atomic C:N ratio, %C and %N content)

All archaeological bones sampled for this thesis are expected to have suffered at least one of the diagenetic patterns described above. Samples from Central and Southern Portugal display lower collagen yields compared to other medieval population from Northern Europe, because of the soil composition and climate. However, the application of quality controls to the collagen will monitor the accuracy and reliability of the generated data. For the purpose of this thesis and in line with the current dietary isotope studies, analysis of collagen yields, atomic C:N ratios and the percentage carbon and nitrogen content in collagen are used as quality controls, following the work by Ambrose (1990,1993) and van Klinken (1999). Any sample that did not meet the criteria of the outlined quality controls was excluded from the study.

Yield (%) of collagen is an immediate and reliable measure of the quality of the preserved organic fraction in a bone sample (van Klinken 1999). Compared to modern bone that exhibit around 20% collagen yields, archaeological bones, undergoing diagenetic pathways, always produce lower values. Although this scenario is expected, a threshold has to be identified since highly degraded collagen may produce altered results. Collagen yields lower than 5% should be checked against other quality controls while it is recommended to reject values lower than 1% (Ambrose 1990; vanKlinken 1999). However, the ultrafiltration step, which is used to remove contaminants and degraded polypetides as well as lipids molecule, decreases the collagen yield due to the loss of molecules smaller than 30kDa. This decrease has been calculated to be up to 50% (Jørkov et al. 2007). In addition, some concerns have been expressed on the efficiency of ultrafiltration in removing most of the contaminants since it is still unclear what substances it actually removes. However, since the method prove to improve C:N ratios and the quality of the product, it is the most reliable technique at present and was applied to all samples in this study (Brock et al. 2013).

One of the quality controls applied to collagen is the measurement of carbon and nitrogen content by percentage weight. Mammalian bone collagen can vary between 20% to 47% carbon and 11% to 17% nitrogen by weight (Ambrose 1990, 1993). Van Klinken (1999) suggested a smaller range of 34.8 ±8.8 (1σ) carbon and between 11% and 16% nitrogen by weight. It has been suggested that lower percentages of C indicate the presence of inorganic substances while higher values of %C suggest the inclusion of organic carbon. Variations in %N are not known to be linked to a specific reason however humic substances, soil compositions and fertilisers might alter the amount of nitrogen in skeletal remains (Ambrose 1990; van Klinken 1999).

The recommended acceptable range of C:N ratio, based on the elemental composition of the collagen molecule itself, has been identified between 2.9 and 3.5 (DeNiro 1985; van Klinken 1999). Ratios below 2.9 may indicate microbial deterioration of the substrate, while ratios above 3.5 can suggest the presence of carbon-rich contaminants such as humic acids and lipids (DeNiro 1985; vanKlinken 1999). For the purpose of radiocarbon dating analysis, a tighter range between 3.1 and 3.5 is generally used (vanKlinken 1999); however, in paleodietary reconstruction both ranges can be applied depending on the researcher preference.

## 2.5 Application of carbon and nitrogen isotopes in archaeology

One of the very first papers on the use of stable isotopes analysis in medieval archaeology studied carbon isotope ratios ($\delta^{13}C$) of human bone collagen to investigate the timing of the adoption of maize (a $C_4$ crop) in agriculture in the New York state territory (Vogel and van der Merwe 1977). Following this, the technique rapidly expanded within archaeology (e.g. Hedges and Reynard 2007; Murray and Schoeninger 1988; Richards and Hedges 1999; Schoeninger and Moore 1992) and the last fifteen years have seen a steady growth in the application of this methodology to medieval population as well. The majority of the isotopic studies on medieval populations have been carried out in Northern Europe focussing on a number of themes such as substistence economy (Richards et al. 2006; Ryan et al. 2018; Lahtinen and Salmi 2018); status, including religious vs lay diet (Barrett and Richards 2004; Müldner and Richards 2005, 2007; Müldner et al. 2009; Quintelier et al. 2014; Yoder 2012; Colleter et al. 2017) geographical location including coastal, inland, rural and urban populations (Hemer et al. 2017; Olsen et al. 2016).

While subsistence economy can be variable, few trends have been identified in the exploration of social factors such as status and sex. Differences in status have been found to be related to greater consumption of animal and/or marine protein by high-status individuals compared to others (Kjellström et al. 2009; Linderholm et al. 2008; Müldner et al. 2009; Polet and Katzenberg 2003). Differences in sexes also follow a similar pattern with males consuming higher trophic level protein than females (Müldner and Richards 2007; Reitsema et al. 2010; Richards et al. 2006) with the exception of one case from Sweden (Kjellström et al. 2009). To these established studies, a growing body of research has been produced in the last few years from Central and Eastern Europe. Dietary adaptation during period of transitional political power have been considered in rural Poland (Reitsema et al. 2010;2017) and Czech Republic (Halffman et al. 2015), Hungary (Gugora et al. 2018), Croatia (Lightfoot at al. 2012) and Bavaria (Hakenbeck et al. 2010). Although variability exists in these case studies, an interesting trend of $C_4$ plants consumption is identified especially in Poland, Czech Republic and Hungary.

Southern European populations have also been increasingly studied in the last few years, addressing the big disparity that traditionally existed in isotopic research between northern and southern Europe. A multi-period study from Greece including Greek Orthodox, Frankish and Ottoman Muslim populations also found that $C_4$ resources were increasingly present in the diet of the Muslim individuals, although no difference was found between the other two groups (Garvie-Lok 2001) and sex-related difference was recorded in medieval Thebes with females consuming more $C_4$ resources than males (Dotsika et al. 2018). Data from north-eastern Italy also suggested heavy reliance on $C_4$ plants for early medieval populations (Iacumin et al. 2014), while mixed-diet with inclusion of $C_4$ resources have been documented for north-west (Reitsema and Vercellotti 2012) and central Italy (Buonincontri et al. 2017; Ciaffi et al. 2015).

Generally, medieval populations exhibit variability in their diet, both in terms of $\delta^{13}C$ and $\delta^{15}N$ values, which is in accordance with the dietary complexity of the medieval period associated with a market economy, the freedom of choice to access specific foodstuffs but also with a number of complex social relationships and hierarchical structures that may have a local impact (Herrscher et al. 2001; Reitsema et al. 2017; Salamon et al. 2008). The reminder of this chapter will be concerned with the research carried out so far on Medieval populations in Iberia.

### 2.5.1. Application to Iberian medieval populations

In recent years, a number of isotopic studies have been focusing on the medieval Iberian Peninsula, applying this methodology to dietary and mobility questions (figure 2.2, table 2-2). However small sample sizes and geographical and chronological gaps are frequent limitations in these studies. Sites along the Atlantic coast such as Rennes in Brittany, the Basque countries and Galician sites have been reviewed in this section to provide background on the diet of populations facing the ocean. Mediterranean sites such as the Balearic Islands and the south of Spain have also been studied in relation to Muslim diet along the entire medieval period (8th-15th century). This section concludes with the introduction of three recent studies that explored the diet of historical populations from Portuguese diet.

The increasing number of studies in this historical period of the Iberian Peninsula is a symptom of the rising interest on its multi-cultural and multi-faith society. Although the majority of the studies focused on Christian populations, a few have explored Islamic populations and their diet. The first paper that addressed this topic by Fuller et al. (2010) compared the diet of the communities living in the Balearic Islands over several centuries across the Chalcolithic, Punic, Byzantine and Islamic period.

***Figure 2-2*** *Location of published isotopic studies on medieval populations in the Iberian Peninsula*

| | Location | Isotopes | Authors |
|---|---|---|---|
| 1 | Galicia | $\delta^{13}C$, $\delta^{15}N$ | López Costas 2012 |
| 2 | Basque Country | $\delta^{13}C$, $\delta^{15}N$ | Kennedy 1988; Quirós Castillo et al. 2012; Scott and Poulson 2012; Lubritto et al. 2013; Ortega et al. 2013; Quirós Castillo 2013; Quirós Castillo et al. 2013, Sirignano et al. 2014, Lubritto et al. 2017 |
| 3 | Pamplona | $\delta^{18}O$, $^{87}Sr/^{86}S$, $\delta^{13}C$ | Prevedorou et al. 2010 |
| 4 | Castile and León | $\delta^{13}C$, $\delta^{15}N$ | Huelga-Suarez et al. 2016, Guede et al. 2017 |
| 5 | Madrid | $\delta^{13}C$, $\delta^{15}N$ | Garcia-Collado 2016 |
| 6 | Valencia, Aragón and Navarra | $\delta^{13}C$, $\delta^{15}N$ | Mundee 2010; Alexander et al. 2015, Guede et al. 2015, Martinez-Jarreta et al. 2017 |
| 7 | Alicante | $\delta^{13}C$, $\delta^{15}N$ | Salazar-Garcia et al. 2016 |
| 8 | Andalusia | $\delta^{13}C$, $\delta^{15}N$ | Jimenez-Brobeil et al. 2016 |
| 9 | Balearic Islands | $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}S$ | Dury et al. 2018 ; Fuller et al. 2010; Nehlich et al. 2012 ; Pickard et al. 2017 |
| 10 | Tomar | $\delta^{13}C$, $\delta^{15}N$, $^{87}Sr/^{86}S$ | Curto et al. 2018 |
| 11 | Coimbra | $\delta^{13}C$, $\delta^{15}N$ | Luxton 2015 |
| 12 | Monte da Cegonha | $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$, $^{87}Sr/^{86}S$ | Saragoça et al. 2016 |

***Table 2-2*** *Location of the discussed isotopic studies with bibliographic references.*

Isotopic values indicated a significant shift in diet after the Islamization of the islands in comparison to the earlier periods with a significant inclusion of $C_4$ plants in human and/or animal diet. A following study by the same group analysed the stable isotopes of sulphur in order to explore mobility in the Islamic population, identifying the presence of migrants (Nehlich et al. 2012). In fact, 18 out of the 20 analysed individuals were identified as non-locals, shedding light on the pattern of mobility of the first generations of Muslims in the medieval Iberian Peninsula. Similar results were also found in Pamplona, where an early medieval Islamic necropolis was recovered and two individuals with dental modifications proved to be of early chronology and potentially migrated from the North of Africa during the Islamization of the peninsula (Prevedorou et al. 2010). A recent multi-period study from Tossal de les Basses, Alicante, reported the values of a Muslim population dating to the early medieval period (8th-9th C CE). Interestingly, the human values from the site did not change significantly across periods, however under Islamic rule; a significant use of $C_4$ crops was detected in the animal diet (Salazar-Garía et al. 2016). A rather different trend has been found by Guede and colleagues (2015) analysing the diet of an Islamic population (777-1021 CE) from Tauste, Zaragoza, showing a large consumption of $C_3$ plants and freshwater fish. Similarly, the early medieval individuals from Pamplona have found to be very reliant on $C_3$ resources.

Late medieval populations were also subject of study by Alexander et al. (2015), providing the first published Muslim data for mainland Iberia by examining the diet of two contemporaneous communities of Muslims and Christians in the Christian Kingdom of Valencia in the 13th – 16th century. The results showed a statistically significant difference in the value of carbon and nitrogen stable isotopes. This difference was interpreted as a reflection of the differing economies of contemporaneous faith communities and perhaps an indication of the declining status of the late medieval Islamic population under Christian rule. A similar pattern in $C_4$ consumption for a contemporaneous (13th-15th C CE) Muslim population from Granada is reported by Jiménez-Brobeil et al. (2016). Only five individuals are included as a comparative sample; however, they show a similar trend with low nitrogen isotopes ratios and higher $\delta^{13}C$ values. This brief overview helps to appreciate an emerging trend of $C_4$ resources exploitation brought about by the Islamic population, regardless of chronology, along the Mediterranean coast. In addition, despite the easy access to marine resources, the majority of the populations had a terrestrial diet.

The north of the Peninsula and Brittany do not seem to match this pattern, although northern Christian populations show $C_4$ resources in their diet in earlier periods (López-Costas and Müldner 2016). The high-status Christian population from Brittany show great similarity to other monastic sites in the UK, where high $\delta^{15}N$ values are coupled with terrestrial $\delta^{13}C$ values, suggesting a reliance on animal proteins, freshwater fish and suckling animals (Colleter et al. 2017; Müldner and Richards 2005, 2007). This population, although facing the Atlantic coast, seems to have a rather different diet from other Iberian populations and social and cultural factors might be the reason behind these dietary preferences. The northern Spanish sites located in Galicia and the Basque Country show different diets. Galician populations rely on marine resources and have high $\delta^{13}C$ and $\delta^{15}N$ values (López-Costas 2012; López-Costas and Müldner 2016), while the Basque Country sites have a mainly terrestrial diet based on low trophic level proteins and $C_3$ plants; although some individuals have a mixed diet with inclusion of $C_4$ plants (Lubritto et al. 2017). Interestingly none of these two Northern Iberian populations shows a predominance of $C_4$ resources which has been found in southern populations during the late medieval period, both in Iberia and other medieval populations (see section above).

Only three studies have now provided isotopic data on historical Christian populations from Portugal. Few individuals have been analysed for a master dissertation (Luxton 2015) from three late medieval Christian sites (12th-15th): Coimbra, Santarem and Cacela-a-Velha; while Saragoça et al. (2016) explored the dietary customs and mobility pattern of the Late Antique (7th C CE) population of Monte da Cegonha and Curto et al. (2018) analysed the diet of a late medieval population from Tomar. The Late Antique data show a $C_3$ based diet complemented with terrestrial meat and its by-products. Interestingly, Luxton (2015) data show quite different subsistence strategies at the three sites and while Santarem and Cacela-a-Velha had a mixed economy based on both terrestrial and marine resources, similar to what has been found for Tomar; a significant reliance on $C_4$ crops has been found for the Coimbra population. More research is necessary in this field, especially on Muslim populations since no data has been published on Portuguese population for this period. This thesis is therefore the first application of isotopic techniques on a Muslim medieval population from Portugal, addressing the gap in our current knowledge on the everyday life of the Muslim and Christian communities in this area, while serving as a first major body of isotopic data that may promote further research.

The brief overview presented in this section identified a number of trends in diet among Iberian medieval populations, which would not be necessarily recognised from historical sources alone; offering further insight onto subsistence strategies and dietary practices medieval multi-faith societies. However, the successful application of isotopic methodology relies on fundamental contextual information provided by both historical and archaeological evidence and a holistic approach will prove useful in untangling the complex set of factors interplaying in defining food access in past populations.

# 3. FOOD AND DIET IN MEDIEVAL IBERIA

One of the main benefits of investigating historical populations is the possibility of integrating the results of stable isotope analysis with historical sources and other archaeological data on diet within those societies. This chapter will discuss historical and archaeological evidence for food and diet in Medieval Portugal. While historical sources from Islamic Spain are sometimes used as a reference as they are the only cookbooks and treatises for the Islamic West, Medieval Christian sources (including the only late medieval Portuguese cookbook) and secondary literature have also being considered as a useful approximation of food and produce availability in the present-day Portuguese territories. In some cases, these sources are considered more relevant to the territory in analysis than general Islamic sources and provide a more in-depth knowledge of the local area and foodstuffs consumed.

## 3.1 Archaeological and historical evidence of food and diet

The symbolic value and the importance that food holds within a society is a clear feature of almost every culture. The way in which a food is chosen, prepared and consumed offers an insight into the more diverse aspects of a society: social and family organization, social status, economic strategies as well as resource management and exploitation. Food, far from having a solely nutritional role, also has a strong cultural connection and can be perceived as a cultural object (MacClancy 1992; Montanari 1999). Food is often a marker of individual and group identity and as such, binds people together, not only through space, but also time, and is eventually transformed into heritage (Di Giovine and Brulotte 2016:1). The consumption or restriction of a certain diet is one of the elements that tend to define and shape a religious group, marking a distinction between the people who belong to those who do not.

In multi-faith societies, co-existence and rulers' religious tolerance are inextricably linked, affecting all aspects of socio-religious life including dietary requirements. Because of the chronology of the sites included in this thesis, embracing both pre- and post-conquest periods, different types of contributions to diet have to be taken into account as well as the impact of the conquest on different resources, their availability, access and distribution. Archaeology and historical sources often reveal a gradual and continuous passage from one society to the other between the Muslim and the Christian period and although archaeological evidences for fires, destruction and abandonment levels have been identified; cultural practices carried on in a more fluid way, sometimes facilitated by influential Mozarab elites (Simões 2012:21).

Much of the historical evidence for diet and food consumption originates from historico-geographical texts, agricultural and medical treatises, culinary texts, household and markets accounts (ḥisba) and legal texts (García-Sánchez 1996). Historical-geographical and travel literature usually provide information on the production sites and on the supplying options for the population, describing fields as they come across them. The agricultural calendars offer a view onto the calendar's events taking place in the farmers' life and are all strictly connected to the *Calendario de Cordoba* (961 CE), while agricultural treatises include information on supplying systems for the urban population, focussing on the different types of crops and sometimes identifying their varieties and qualities (García-Sánchez 1996:220). Medical and dietary texts usually include a section on the most appropriate foods for different phases of life (childhood, pregnancy, illness) following the four humours system, a shared medical culture known to both Muslims and Christians, aimed at balancing the characteristics of a person's body fluids with their diet (García-Sánchez 1983, 1986). In terms of cooking manuals, at present only two are known for Andalusian cuisine and date to the 13th century. The *Kitāb Fadālatalkhiwān fī tayyibāt alta'ām walalwā'n* ('Book of the Excellent Table Composed of the Best Foods and the Best Dishes'), or *Fadalat alkhiwan* is specifically Andalusian and originated in Murcia; while the other is by an anonymous Hispano-Maghrebi author and is called *Kitab al tabikh filMaghrib walAndalus fi `asr alMuwahhidin, limu'allif majhul* ('The Book of Cooking in Maghreb and al-Andalus in the era of Almohads, by an unknown author') usually referred to as 'The Anonymous 13th Century Andalucian Cookbook' (García-Sánchez 1996:221). For medieval Portugal, only one 15th c text survives in a later compilation, and includes recipes divided in four sections: meat based dishes (including a recipe for lamprey); egg based dishes, milk preparations and preserves (Manuppella 1987). Although these sources are a useful indication of the availability of specific species and products, they refer to what was included in the diet of higher social groups, lacking information on the lower ones. In addition, the treatises were compiled from different cookbooks and prescriptions from all parts of the Islamic and Christian worlds, meaning that references to plants in these sources are not necessarily a proof of their cultivation or import on a regional level.

Two main Hispanic-Arab botanical treatises have recently being analysed along with archaeobotanical data in order to characterise the flora of medieval Islamic Portugal with specific interest for those plants that were relevant to human consumption (Rei 2017:68). Different vegetal products were found in the markets such as cereals, legumes, vegetables, fruits, herbs and spices. Although the production was mainly local, some urban markets might have stocked products from more remote regions.

Christian historical sources describe the main products consumed in Medieval Christian Portugal, which can be applied with some approximation to the late Islamic period under analysis. In a few cases, the link between the persistence of Islamic customs or products is evident; for example in the existence of enwalled gardens and orchards in the surrounding urban areas that were well irrigated and manured. Vegetables and legumes were grown, following Islamic customs, with fruit trees and flowers (Marques 1987:100). Similar mention of allotments, gardens and plantations of figs, almond, olive trees and wines are found for Loulé suburbs (Martins 2016:28).

Archaeological evidence for diet discussed in this chapter derives from excavated animal bones and preserved plant remains. In addition, the use of plants in the human diet, including imported ones, is widely documented in historical sources. There is, however, a scarcity of paleobotanical data for the Islamic period in Portugal, mostly due to the time sensitive nature of the emergency and commercial archaeology excavations. However, a number of contexts have being analysed from southern Portugal, including both rural and urban sites (Peña-Chocarro et al. 2017; Queiroz and Mateus 2012).

Assemblages of animal bones from medieval excavations are rarely published and some of the zooarchaeological report are of difficult access. Until recently, a lack of sieving on most archaeological sites has resulted in an under-representation of fish, rodents and small species or young animals (Morales-Muñiz 2002). With these limitations in mind a summary table of the zooarchaeological studies discussed in the text is provided at the end of the chapter (Table 3-1). Discussion of animal bone assemblages that have been studied from the sites sampled for this thesis can be found in Chapter 5.

The following section provides a summary of diet in medieval Portugal. Unfortunately, no historical source survived from Islamic Portugal informing on dietary practices, therefore a combination of secondary sources had to be used. Three different types of historical evidence have been consulted: one referring to common practices in the Islamic cuisine across the Islamic medieval world, one focused on Al-Andalus and what is known for Islamic Spain; while the last line of evidence included the dietary information known for Christian late medieval Portugal, in order to gain further understanding of the local resources.

### 3.2 Cereal grains and bread

Cereals, with wine and olive oil, constituted the staple diet in the Middle Ages in Portugal and in southern Europe (Vicente 2013), with some restrictions on wine for the Muslim populations (see below). The importance of cereals to the economy of Al-Andalus is recalled by historical sources that describe abundant local cultivation in specific areas (such as Lisbon and in the River Tagus valley) (Catarino 1998); although the lack of cereals supply seems to have been a significant problem, especially in years of bad harvest. The south of Portugal did not grow much wheat and cereals and a lack of bread in the markets of Loulé is evident from the council minutes (Martins 2016:47). The scarce cereal production of the Algarve was supplemented with imported cereals from different areas of Portugal such as Entre-Douro-e-Minho, Beiras, Ribatejo and Estremadura during the late medieval period (Gonçalves 1984). The difficulty in maintaining a steady supply favoured in addition, contacts with the Maghreb and other areas of North Africa during the Islamic period and these connection were maintained throughout the Middle Ages (Constable 1996:142).

Among all grains, wheat was by far the most consumed.  Three types of wheat are mentioned in historical sources: common wheat in its winter (*triticum vulgare hibernum*) and summer (*triticum aestivum*) varieties, emmer wheat and durum wheat (*triticum durum*) introduced by the Muslims in the Iberian Peninsula and referred to in the sources as Moorish wheat (Marques 1962:80). Arab sources identify a specific type of wheat that is grown in the Lisbon and Santarém area and, thanks to its short natural cycle of about three months, permitted two harvests (Rei 2017:70). Late medieval sources documenting the contribution that northern Christian farmers had to give to King Afonso III in 1258 included wheat, rye, millet and oats (Gonçalves 1999). Historical sources mention millet, a $C_4$ plant, in both forms (*panicum miliaceum* and *setaria italica*). While the first type was widely used to produce mixed bread in the Christian north, the foxtail millet was mainly employed for animal consumption (Catarino 1998:78). In addition, paleobotanical research in the same area found evidence of spelt, barley, rye, oats and millet (Queiroz and Mateus 2012 [2015]:182).  Although wheat was most appreciated and accessible, secondary crops such as rye, barley, oats, sorghum and millets were available and consumed, and could be used to supplement the lack of wheat by both Muslims and Christians in years of bad harvest (Catarino 1998; García Sánchez 1982). Time of particular scarcity are known in the 14th century (especially 1333 and 1374-6) and the early 15th century (Marques 1987). Cereals were used for bread production but also for others basic preparations like soups, paps, gruel, porridges etc. (García Sánchez 1983:139).

Bread was at the base of medieval diet, especially in southern Europe where the triad bread-olive oil-wine formed the foundation of the Mediterranean diet of Roman reminiscence. In the Roman period, Columella describes how millet flour was eaten by the poor and slaves as a bread or porridge, particularly in times of scarcity (Tafuri et al. 2009). Bread could be made with wheat or mixed-grains including variable proportions of wheat and a secondary crops like millet, rye, barley and even chestnuts or legumes in years of shortage. Because of the difficulty in making soft and leavened bread with millet and sorghum, these two crops were disregarded in the Middle Ages, when white bread was considered the best type and preferred by higher social classes (Montanari 1999:173). Bread had a strong symbolic value for Christians as white bread becomes the "body of Christ" after being blessed during the Eucharist (Montanari 1999:77). However it was not a prerogative of Christian diet and bread was a staple food for populations across the Islamic world (García Sánchez 1983, Waines 1987). In the countryside, Muslim women generally ground the flour, while in cities, mills had on sale different types of milled flour (Lindsay 2005:131). Usually only the wealthiest could afford to have an oven at home and for this reason community ovens were used to bake bread (García Sánchez 1983:150, Waines 2003:579). In late medieval Coimbra, women are also linked to bread making and names of female bakers are preserved in historical records as well as the location of their houses (Campos 2014, Coelho 1990).

Although wheat was preferred for many preparations, other cereals were also available and used for different purposes. Historical sources from Minho province, in north-west Portugal, indicates that in the 13th century wheat did not hold primacy among secondary crops, and millet and rye were consumed as frequently as wheat (Gonçalves 1999). Various documents from others Portuguese regions also recall the use of barley, millet and rye among the grains used to make bread (Catarino 1998:76). Lower status groups, especially in rural areas, were often consuming mixed-grain bread in both the Christian and the Islamic period; however research on the prices of cereals during the Middle Ages in Portugal shown fluctuating values, which would have affected their accessibility across the population. In general, the north seemed to have less of a gap between wheat and secondary cereals compared to southern regions (Viana 2007). In addition to their moderate prices, secondary crops provided greater food security , and rapid growing grains such as millet and sorghum were available in spring, when other supplies were low (Marques 1962:83). After wheat, barley is the most often mentioned cereal in agricultural treatises from Al-Andalus and Christian Portugal (Gárcia-Sánchez 1992:994, Catarino 1998:76). Barley is a strong crop, resistant to climatic variations and grows during winter and spring. It was used with wheat for bread-making but also as animal fodder, and especially for horses, oxen and mules (Marques 1981:46, de Castro-Martínez 1996:284).

Rye is, after wheat, the most nutritious of the crops and it is suitable for bread making. It grows in poor soils and mountainous areas, and its cultivation was widely spread across Europe and specifically the northern regions of Portugal and Estremadura (Montanari 1996, Catarino 1998:77, Gonçalves 1999:228). Its use is not limited to human consumption, since rye plants could be used fresh or dried as animal fodder (Conde 2000:276). Oats, also used as animal fodder, sometimes appears as a secondary crop for human consumption. However, it does not grow in the hot and dry climate typical of the southern Portuguese summer and its use can be attested on the basis of sporadic mentions only for the northern regions (Entre-Douro-e-Minho and Trás-os-Montes) (Gonçalves 1999:231). The southern regions substituted this crop with barley for both human and animal consumption thanks to its adaptability.

Millet is the last of the secondary crops that hold a relevant role to medieval diet. Its use it recorded in a variety of historical documents for both the Christian and Islamic periods in the Iberian Peninsula. Archaeobotanical evidence from the same region indicates that two species of millets, Italian/foxtail (*Setaria italica*) and broomcorn/common millet (*Panicum miliaceum*) were grown from the Bronze Age onwards (Alonso and Buxó 1995, Tereso et al. 2016). However, during the Middle Ages broomcorn millet is more frequent than foxtail in the Iberian Peninsula: while the latter is more common in the northern regions, broomcorn millet was found in significant proportions at an Islamic assemblage in Santarém (Queiroz 2001). Millet grows well in humid and hot weather and therefore was planted during spring, especially in river valleys, and used for both human and animal consumption. A French agronomic study on farming customs of the Middle Ages, and the Ibn al-Awwam 12th century *Treatise on Agriculture* suggest the use of millet as animal fodder, and specifically to fatten chickens and cattle (de Serres 1805:9, Ibn al-Awwam 1802). Ethnographic evidence from north-west Spain demonstrates that millet is still traditionally fed to these species (Moreno-Larrazabal et al. 2015).

The use of millet in the human diet was mainly reserved to bread production, especially in the north of Portugal (Gonçalves 1999); however, it served also for porridges, soups and gruel-like preparations, or was added to other cereals and legumes in stews or soups and couscous (Perry 2001:237). These two species are particularly relevant to this thesis as they use the $C_4$ photosynthetic pathway and therefore their consumption can be discriminated from the above-mentioned $C_3$ crops through carbon isotopes analysis. Altogether millet is associated with hunger and poverty during the medieval period and consumed only when other more desirable crops were lacking (Adamson 2008:5). Although this direct association might not be completely true for the northern regions of Portugal, according to historical sources, this point should be born in mind when assessing the isotopic data from animals and humans in this data set (Chapters 6 and 7).

Sorghum, another $C_4$ crop, was introduced in the Iberian Peninsula in the 11th century and is believed to have had a similar role, with millet, in the diet of the poorer strata of the populations (Glick 1982:82). Its drought-tolerant characteristics were appealing to farmers cultivating in drier areas with little rainfall, such as southern Portugal. However, the 11th century Andalusian geographer al-Bakrī, recorded the cultivation of sorghum and millet in Galicia and northern Spain and other historical documents indicate its presence in the south of France in the 12th century (Watson 1995:63). Although historical evidence testifies that sorghum was available and consumed across the medieval Iberian Peninsula, archaeobotanical remains are yet to be found (Pradat and Ruas 2017). In this case, isotopic techniques can be used to explore the availability of $C_4$ plants such as millet and sorghum and their contribution to the diet of both rural and urban populations (Chapters 6-7-8).

Rice was another ($C_3$) crop present in medieval Spain, but rare elsewhere in Europe. It is believed to have been introduced by the Byzantine Greeks to the Iberian Peninsula in the 6th century; however, its cultivation was expanded by the Arabs in coastal areas such as the Ebro Valley and Valencia, Seville and along the Guadalquivir Valley (Lagardère 1996). Ibn al-Awwam in the 12th century provides instructions for how to successfully grow this plant, and in the 13th century, rice is among the Majorcan exports to Flanders (Barcelo 1984:52). A few rice-based dishes are reported for Muslim populations in Al-Andalus, often including fish, although many Arab authors considered rice cooked with milk and butter a heavenly food (Gárcia-Sánchez 1983:176).

Rice is included in three recipes from the sole late medieval Portuguese cookbook dating to the end of the 15th century (Arnaut and Manuppella 1967). In addition, direct mention of cooked rice is found in a document from 1552, in which women (white and black, free and enslaved) are said to be selling couscous and rice every morning in the street of Lisbon (Fernandes 2002:138-139). Although its contribution is difficult to estimate from written sources, the evidence here provided indicates that rice was available on the market since the early Middle Ages and offered as a street food in 16th century Lisbon, suggesting a certain degree of easy access to this crop.

This is contrasting to northern Europe, where rice was always an imported high-status food, used as a thickener for sauces and in a few special dishes (Adamson 2008:5).

### 3.3 Legumes

Legumes were an important source of protein for Medieval populations. They were grown along with grains and in many cases, their cultivation, with secondary crops, was performed to diversify growing times and ensure a greater protection against bad harvests (Montanari 1999:173). Legumes were used to fertilise fields thanks to their rich nitrogen content. In addition, they were ground and used as substitute flour during periods of grain scarcity. Among the legumes, fava beans (*vicia faba*) and three types of peas: green pea (*pisum sativum*), grass pea (*lathyrus sativus*) and red pea (*lathyrus cicera*) are reported to be grown in the area surrounding Lisbon during the Islamic period (Queiroz and Mateus 2012 [2015]:182). Legumes were a reliable resource in time of scarcity, but also in mountainous and less accessible areas during the late medieval period, where the soil type and the remoteness of the places limited cereal supply. In some northern and interior regions of Portugal (Beira and Trás-os-Montes) in the 14th century, people were commonly using fava beans, chestnuts and acorn to produce or substitute bread. Fava beans were imported to densely populated areas where the local supply would not suffice the demand (Rei 2017:71).

Legumes were commonly included as ingredients in stews and pottages in the Islamic period and were used for bread making as previously discussed (García Sánchez 1983:164). Medieval Islamic agronomic texts recommended growing lentils for soil fertilisations thanks to their nitrogen-fixing properties (García Sánchez 1992:994). Legumes such as bitter vetch were used as animal fodder, especially for cattle and sheep, and were said to produce good and abundant milk in all species (Ibn al-Awwam 1802). Archaeobotanical evidence backs up the historical evidence for both the Islamic and Christian periods in the Iberian Peninsula. The most commonly recovered pulses for in this period included broad bean, lentil, grass and red pea, pea, common vetch, bitter vetch and chickpea, together with a fodder crop, Medicago sativa (lucerne), in the south of the Peninsula (Peña-Chocarro et al. 2017). A reliance on legumes might produce lower $\delta^{15}N$ values in the consumer tissues, as legumes tend to possess lower $\delta^{15}N$ values compared to other plants, because of their nitrogen fixing properties (Chapter 2). This is a factor to consider in the interpretation of both animal and human isotopic results.

### 3.4 Vegetables and fruits

Fruit and vegetable production was a significant activity in the extensive irrigated areas of Al-Andalus, although gardens and allotments would exist in almost every household in both urban and rural settings (Marques 1987:100). Islamic agronomic sources as well as Christian ones mention a remarkable range of varieties being cultivated, especially from the 12th century, as a consequence of the agricultural progress implemented during the Taifa kingdoms (García Sánchez 1996:228). Thus Andalusian people would benefit from fresh fruits and vegetables almost all year round, including gourd, aubergines, watermelon, cucumber, fava beans, turnips, cabbage, carrots, onions, mushrooms, lettuce, asparagus, spinach, artichokes, cabbages and leek (García Sánchez 1996:228). Almost the exact same vegetables are still seen on the markets a few centuries later under Christian rule including cabbage, spinach, turnips, radish, lettuce, carrots, aubergines, onions, garlic, parsley, saffron, and flaxseed (Marques 1987:100-101). Vegetables such as carrots, asparagus and spinach were introduced to the Iberian Peninsula by the Muslims and by the end of the medieval period they had spread to the rest of Europe (Adamson 2008:9-11). Vegetables would have played a significant part in the diet of the medieval populations, especially of the poorer strata of the society with little access to meat. However, in both Islamic and Christian cookery books, the emphasis is never on the vegetables and although they were fundamental ingredients in a number of preparations, they are never the focus of the recipes (García Sánchez 1996; Buescu 2014). Vegetables appear on the wealthiest Christian tables only during the fasting days, when "lean" meals were preferred (Gonçalves 1997:23); however, these assumptions are based on cookery books, which might not mention them because they were not considered as important as other foodstuff.

During the Islamic period fruit was commonly consumed either fresh or dried as well as in juices, compotes and marmalades (García Sánchez 2002:285). Ibn al-Jatīb provided the order in which fruit was to be eaten: before meals figs, grapes, plums, apricots and similar fruit; whereas quince, apples, pomegranates and other astringent and acidic fruit in general should be eaten at the end because they are digested more slowly. The most popular fruits were pomegranates, watermelons, melons and citrus fruits, such as bitter oranges and lemons (Salas-Salvadó et al. 2006). Dried fruits and almond milk were widely used in all types of dishes as illustrated by the Anonymous Andalusian cookbook (Martinelli 2012) and nuts were also consumed in the late medieval period by Christian populations especially in period of fasting (Catarino 1998:107). Late medieval Christian sources including onomastic studies, mention plantations of several fruit trees across the country including apple, fig, pear, plum, peach, cherry, pomegranate, lemon and orange among other trees. In addition, walnut, almond, hazelnut and chestnuts trees are also found (Coelho 1983:194, Marques 1987:99, Rodrigues 1992:205).

Olive oil was the most popular fat in Al-Andalus and used more often than other oils for cooking, although animal fat and butter were also used in both the Muslim and Christian period (García Sánchez 1996:228; Catarino 1998:130). Salt was used as a condiment but also to preserve meat, fish and other foods that needed to be shipped or preserved for longer (Marques 1987a:13).

The archaeobotanical evidence for fruits and vegetables back up the historical sources also in this case. Following a recent review of published plant remains studies in the Iberian Peninsula, the presence of cultivated fruits under Islamic rule is significant (Peña-Chocarro et al. 2017). A new species, the apricot, is recorded for the first time at Mértola during the 11th and 12th century. Grape is the predominant species at Islamic sites followed by fig. Oil seeds are represented by camelina, flax and poppy. As far as herbs and spices are concerned, the Islamic contexts reveal the same species as Christian sites (celery, coriander, fennel, lavender, mint, rosemary, thyme, verbain and carrot). In addition, two assemblages are known for Islamic Lisbon, in NARC (Núcleo Arqueológico dos Correeiros) and Praça D. Pedro IV with a high concentration of fruit seeds including melon, strawberries, plums, grapes and figs. Aromatic plants such as mint, celery, common vervain and cumin were recorded especially in Praça D. Pedro IV (Queiroz 1999, Bugalhão and Queiroz 2006, Queiroz and Mateus 2012). Surprisingly, in both Lisbon contexts, there was no trace of leguminous plants or cereals. This misrepresentation is to be linked to the nature of the sediments, which especially for NARC was linked to a possible fruit processing and transformation industry (Bugalhão and Queiroz 2006).

Unfortunately, the low trophic level of fruit and vegetables and the low values of the majority of these plants (mainly $C_3$) do not produce a specific isotopic signal that could inform on the popular and regular consumption of fruit and vegetables by medieval populations.

### 3.5 Meat and animal products

Meat is considered the most noble of foodstuffs in the Islamic tradition and meat dishes are central in cookbooks from all corners of the Islamic world, including meat from domestic animals, fowl and game (Rosenberger 1999). For Al-Andalus however, some researchers believe that legumes, vegetables and fruits were more common than meat in everyday life, which may be true for those of lower status (Watson 1995:71). However, the wealthiest indulged in rich meat dishes in Al-Andalus like in other Islamic regions (Waines 2003). The most popular meats were lamb and mutton, followed by fowls and beef (García-Sánchez 1986). Goat seems to be consumed prevalently in the Islamic period compared to the late medieval Christian period in

Al-Andalus; and the consumption of beef is virtually absent from Eastern recipes and may be the result of Berber influence in the Iberian Peninsula (Waines 1994).

Meat, and especially meat from the most regarded animals such as lamb and mutton, would be an expensive item for those of lower status, during both the Islamic and Christian period, and was consumed at specific marked occasions such as religious and family celebrations. Other types of meat such as fowls, small wild animals or offal cuts would be more accessible during the rest of the year (García-Sánchez 1986:250-251). High status individuals preferred meat of young animals and historical sources and medical treatise consider the meat of yearling lamb, suckling kid, veal and castrated kid as the most pleasant and nutritious (Díaz- García 1985:180, Salas-Salvadó et al. 2006:S103).

All strata of society enjoyed some common dishes, although quality and amount of meat would vary accordingly and low status people would often use all parts of the animals as opposed to the best cuts. During the Islamic period meat was consumed in stews and pottage, roasted or fried. Stews of meat with vegetables are among the most common dishes in Al-Andalus and included boiled meat with spices to which some vegetables would be added such as spinach, gourd, turnip, cabbage and cauliflower (García-Sánchez 1986:255). Roast meat was generally a luxury and more expensive; good quality, cuts of meat has to used for this preparation. Roasting was commonly done outside; however to avoid meat dryness and smoke, some people preferred to use the *tannur*, a bake oven (Rosenberger 1999:215). Fried meats included fried sausages, fritters and meatballs and were commonly found in markets as street food (García-Sánchez 1986:257).

Christian sources from medieval Portugal indicate that the diet of the medieval people relied on proteins from herbivores like cattle, sheep, pork and goat and mostly probably on birds like chickens and partridge (Catarino 1998:126; Gonçalves 1989:294). Dairy and eggs would also be widely consumed, and were a substantial part of the protein intake of the lower classes as mainly high-status people consumed capons (fattened castrated males) (Catarino 1998:130-131). The price of the meat was highly variable and could differ from city to city. In 12th century Coimbra, pork and sheep were the most expensive items, while beef and goat meat was more affordable. In 13th century Évora, however, beef was the most expensive meat, followed by pork, and lamb and goat are considerably less expensive (Marques 1987). The price fluctuation between regions would have affected both quantity and quality of the meat consumed by the population, and especially among the lower strata. Historical sources suggest overall that sheep and pork were the most consumed meat for the late medieval Christian period in Portugal (Ferreira 2008).

It is known that animals consumed in urban areas were not always reared near the settlements but could have been sourced from further away (Catarino 1998:39). In addition, the lay-out of the medieval Islamic city, especially in Al-Andalus, included a 'green belt' surrounding the urban centre, whose existence has been hypothesised for Portuguese sites as well (Gomes Barbosa 1994:18). Forage grass areas but also pastures are indicated by toponyms in the surroundings of Lisbon, with particular mention of the areas up the river Tagus for the Muslim and Christian period (Gomes Barbosa 1994:20; Catarino 1998:34); however, livestock could be imported from further away if supply was scarce. Thus, it must be borne in mind that meat and dairy products in urban centres might originate from a wide catchment area, and this could be reflected in their isotopic values.

Evidence from animal bone assemblages (Table 3-1) shows a strong prevalence of sheep/goat being consumed, followed by cattle and rabbit. Out of 34 reviewed faunal assemblages, ovicaprids are the most represented species in 23 of them. The second most represented species is rabbit, which is in addition, the main resource at nine sites. Only two sites show different species as being the most common: pig in Torre Vedras (Gabriel 2003) and cow in Conimbriga (Detry et al. 2014). The presence of pig is quite surprising, although somehow common at Islamic sites (Detry et al. 2014:101). This is usually due to pig breeding for Christian consumption or wild boar hunting, a practice that was permitted in case of need, and still exists in modern Maghreb tribes (Simoons 1961) (see section below). Cattle is very common and is usually the second or third most represented species across all sites. The slaughter age of these individuals highlighted a preference for younger meat for sheep/goat, while cattle seem to be used for traction and milk and was generally consumed at an older age, in accordance with Arabic culinary treatises and the humoral theory (Nasrallah 2007).

### 3.5.1 Poultry and eggs

Chickens and other fowls were widely consumed in Al-Andalus, and especially chicken was regarded as a very nutritious and pleasant meat (García-Sánchez 2002:282). Chickens and other birds were also reared and consumed during the Christian period, including pigeon, partridge, pheasant, duck and goose (Coelho 1990). Medical treatises and cookery books indicate that chickens had to be fattened, especially capons, before being consumed. Females would have not been eaten unless poor layers or too old to lay eggs (García-Sánchez 1990:61). A French agronomic study on farming customs of the Middle Ages, and the Ibn al-Awwam 12th century *Treatise on Agriculture* both suggest the use of millet especially for this purpose, indicating that it may have been a common practice in Medieval Europe (de Serres 1805:9, Ibn al-Awwam 1802). Ethnographic evidence from north-west Spain demonstrates that millet is still traditionally used as animal fodder, particularly for cattle and chickens (Moreno-Larrazabal et al. 2015). However chickens are very adaptable and do not require much attention and could be reared in the backyard or free-ranged. In northern Christian Portugal chickens were known to be left to roam in the same fields with sheep and goat and provided a shelter for the night with some food, usually domestic waste or millet (Gonçalves 2013:166).

Chickens, partridge, duck and pigeon eggs are found in the markets of Al-Andalus and were a significant addition to the diet of the lower classes (Lewis 1997, Salas-Salvadó 2006). However, eggs are frequently used in numerous substantial preparations in the two Andalusi cookbooks that survive, suggesting that they were widely consumed by higher classes and somehow a signature ingredient of Andalusi cuisine (Waines 1994:733). One common method was to cover the cooked dish with a layer of lightly beaten eggs and, in one source, market cooks were forbidden from doing this since it concealed the food underneath (Lévi-Provençal 1955). Another common method was to stir the beaten eggs into a cooking dish and one of these popular preparations included a soup made of bread and meat which still exists today in Portugal with the name of açorda (Rei 2016).

Zooarchaeological remains of chickens are common at most sites (Table 3-1), although an underrepresentation of this species is caused by the lack of sieving methodologies applied on site, especially in commercial archaeology. Studies of chicken remains from Santarém confirmed what is known from historical sources and showed that males were killed at a much younger age, while females were kept to lay eggs (Davis 2006:68) and a similar culling profile is found at Silves (Davis et al. 2008: 207).

### 3.5.2 Dairy products

Milk was widely appreciated in Arab cuisine for its medical and nutritious values (Ibn Habib 1992) and as a staple food in the countryside and among nomadic Berber tribes. The most regarded milk was that of camel, goat and sheep in the East; while the milks of goat, sheep and cow were the most commonly sold in the market of Al-Andalus (García-Sánchez 1986:270, Waines 1994:733). Zooarchaeological remains from Mértola highlighted that female goats were slaughtered at an older age, suggesting that they were kept for milk (Morales-Muñiz 1993). Milk was used to produce cheese, using rennet from the stomach of a lamb or goat, usually in spring, and would be left drying outside until May to cure. Advice was given in historical sources on how to avoid the milk souring too quickly, and on how to keep good hygienic standards during the procedure, suggesting that cheese production was a rather common practice (Waines 1994:728, García-Sánchez 1986:276-277). In both Islamic and Christian medieval cuisine, milk was added to a number of preparations including meat, vegetables and cereal (Adamson 2008, Martinelli 2012). Almond milk was also used in addition to a number of dishes from both culinary traditions and in Christian Europe, during Lent, was turned into a cheese and milk substitute (Adamson 2008:46,72).

In the Christian period, similarly to the rest of Europe, milk and dairy products were consumed on a daily basis in Portugal. Cow milk was preferred to sheep or goat milk and its high-fat content was considered beneficial to children and the infirm (Patrone 1981:344-345). Also in this case, milk and cheese complemented the diet of the lower classes, especially in the countryside, while being part of higher status diet to enrich and diversify the table of the wealthiest (Catarino 1998:129).

### 3.6 Fish

Fish has always being a major resource across the history of Portugal, due to its littoral location on the Atlantic Ocean. At the same time, its proximity to the Mediterranean basin included Portugal in a wider Mediterranean trade system, providing fishing opportunities on both shores. Arab authors had different opinions on the benefit of fish; however, a common belief considered fish less nutritious than meat and generally not as good for human consumption (García-Sánchez 1986:259). It is allowed by the Koran and although some sections of Islam considered it unlawful, specifically Shia Islam, al- Andalus was of Sunni tradition and would have had a religious ban on fish (Pellat et al. 2012). Fish recipes are also very scarce in medieval Andalusian cookbooks, usually accounting for 4-10% of the presented recipes (García-Sánchez 1986:264-265). However, fish was certainly consumed: inshore and coastal fishes are an easy catch and can help integrate the diet of the lower classes living along the coast or along rivers in rural settlements. The most consumed freshwater fish in Al-Andalus were mullet, shad and sturgeon; while marine species included sardines, tuna, bonito, grey and red mullet, hake and shark (García-Sánchez 1986, de Castro-Martínez 1996). In Christian medieval Portugal, similar species were consumed, although off shore fishing was practised on a bigger scale. Expensive species included marine fish such as croaker, red porgy, red bream, and hake and freshwater catches such as salmon, lamprey and eel. Less expensive fish like sardines, sole and allis shad were also present and would be easily accessible by the lower strata of the population (Catarino 1998, Martins 2016). During the Christian period fish consumption gained a symbolic value because of its importance during Lent and other fasting days. During a total of around 182 days each year, including

Wednesdays, Fridays and Lent, meat, dairy and eggs were proscribed by the medieval Church (Woolgar 2003). Fish was allowed during fasts and would have been the only available source of animal protein during much of the year.

Availability of fish would have been reliant on the local supply and although Portugal has an extended coastline, riverine fishing is often mentioned in historical Christian sources (Catarino 1998:142). Fish could be consumed fresh, salted, dried, smoked or pickled (Adamson 2008:39-40, Marques 1987:10). Its provision was not always easy: a general deterioration of distribution systems is documented in 12th century sources indicating that the court was given dried fish in Guimarães, because fresh ones were not available (Gonçalves 1997:22). Later sources recall that in the 15th century, the court visiting Évora was served sardines, a traditionally low-status fish, because of the difficulty in supplying other type of marine fish (Buescu 2014:26). Seasonality, climate change affecting fish migration, warfare and plague may all have affected supply of both fish and salt, necessary to preserve fish for the market. The limited steady supply of fish would have likely affected the price of this product and this is reflected in the number of complaints of its availability and fluctuating prices in the northern Portuguese markets (Catarino 1998:144, Gonçalves 1995:46).

Although fish would be of relatively easy access for those of lower status, it was included in the menu of high-status people too as well, partly because Christian fasting rules applied theoretically to all strata of society (Santos 2002). Tuna, whale and dolphin were sought after by the court and in the 15th century, 60% of the tuna fished in the Algarve was given to the king (Coelho and Santos 2012:236). Afonso V of Portugal (1438-1481), during a visit to Santarém, asked for four marine species to be served at his table including bastard sole, flounder, sole and mullet.

At the beginning of the 13th century Portugal was at the brink of a big expansion and the focus of marine activities and fishing shifted from south to the northern Atlantic coast (Delgado 1991). In the 13th century merchants from Portugal together with northern Castilian merchants from Cantabrian, Asturian, Galician coasts, began to take advantage of economic opportunities in the Bay of Biscay and northern Europe. Gradually, these traders as well as Italian merchants from Genoa, came to control much of the traffic from the Iberian Peninsula to England and Flanders (Constable 1996:243). English rulers were amongst the first to grant safe-conducts to the Portuguese in the 13th century. In 1226, Henry III (1216–72) allowed 106 merchants from Portugal to engage freely in trade in England for one year (Miranda 2013). In 1353, King Edward III (1327-1377) signed a commercial treaty with Portuguese ambassadors to allow Portuguese fishermen to carry on their industry off the coasts of England and Brittany (Prestage 1934:72). These contacts with the northern shores of the Ocean brought Atlantic cod onto the table, which was salted (with salt from Aveiro and Viana do Castelo) or dried, to be preserved during the long journey back to Portugal (Azevedo 1982, Cole 1990:2).

The only seasonal fishing settlement for the Portuguese Islamic period has been identified in Ponta do Castelo, Aljezur, dating to the 12th-13th century. Archaeological artefacts linked to fishing practices were also found including weights and fish hooks as well as a whale bone potentially used as a seat (Gomes 2010). A lack of zooarchaeological data hinders the assessment of the consumption of marine resources in Medieval Portugal, mostly due to the time constraint imposed on rescue and commercial archaeology excavations where sieving is not a common practice. However, fish have been recorded from Islamic Santarém including barbel, mullet, sea bream and sturgeon (Davis 2006:20) and from Silves including remains of pink dentex, gilt-head sea bream, porgies, moray and golden grouper (Davis et al. 2008:277). In addition, fish and molluscs were recovered at several sites in the Algarve, including Alcaria d'Arge, Alcariais de Odeleite, Portela 3, Ribat da Arrifana, Salir and Silves in variable quantities (1 to 12%) (Pereira 2014). Shell middens were also found on site for the population from Loulé in this thesis; however, the faunal remains from the site are still being studied. Freshwater fish were found including barbs in Mértola (Antunes 1996) and grey mullet in Alcácer do Sal (Moreno-García and Davis 2001). The archaeologically documented species include the ones mentioned by the historical sources but expand the selection of consumed fish, suggesting that a wider range of species were exploited to sustain the market demand.

### 3.7 Food taboos in Islamic and Cristian laws

Dietary laws with specific requirements for both Muslims and Christian were in place during the Middle Ages and are often seen as one of the main characteristics of the two faith group dietary practices. The *Shari'ah* was a detailed Islamic law proscribing Muslims from consuming pork, carrion, spilt blood and alcohol (Insoll 1999:95; Adamson 2008:ix). Pork meat is therefore a notoriously prohibited food (*haram*) under Islamic law and it is challenging to find historical sources on pig farming in Al-Andalus. However, two mentions are found in Arabic sources: one from Ibn al-Wafid of Toledo (11th C), who included a chapter about killing pork in his *Tratado de agricultura* (Millás 1943: 300), and a Syrian doctor, Ibn Bajtisu (11th C), who wrote a text about domestic pigs (*Sus scrofa domesticus*), focussing on medicinal and nutritional advantages of the consumption of different parts of this animal (Ibn al-Durayhim 1981: 23–27; Álvarez de Morales 1990: 85–86). Pig remains, although low in number, are still found in the zooarchaeological record in Islamic Iberia (Estaca-Gómez et al. 2018, Morales-Muñiz et al. 2011, Moreno-García 2013, Pereira 2014). As a recent review of zooarchaeological assemblages in central Spain highlighted, the sites that present this unusual pattern of consumptions are never urban centres, but rather tend to be either rural or defensive sites (Estaca-Gómez et al. 2018). This trend seems to be confirmed in Portugal as well, with a virtually absolute absence of pig remains in major urban sites like Silves (Davis et al. 2008) while pig/wild boar remains have been found in the castle of Palmela for the Islamic period (Fernandes et al. 2012). Some of the reasons that are generally used to explain the presence of pig on Islamic sites are the co-existence of Christian communities or the presence of wild boar, which is difficult to discriminate from domestic pig remains. Mozarab communities existed throughout the Islamic period in Al-Andalus, and active dioceses with Christian bishops are known for Coimbra, Lisbon, Beja, Évora and Faro (de Matos 1999; Real 1998). Unfortunately, little is known about the life of this minority group under Islamic rule and, often, decorative arts and religious artefacts constitute the only physical record of this community (Real 1998, Fernandes 2003). However, a recent study from Cercadilla, a multi-phase medieval site near Cordoba, showed the presence of pig remains linked to the existence of a Christian community at the Islamic site (6th-11th C) and an almost complete lack of remains for the Caliphal period (10th-11th). The following decline in pig remains frequency is used to infer the completion of the process of islamisation, whose norms would be shared by both Muslims and Christians during the Caliphal period (García-García 2017). Modern examples of Christian communities that are allowed to keep pigs for their own consumption are found in the Coptic community in Cairo and similar privilege may have been granted to Mozarabs in the Al-Gharb (Fahmi and Sutton 2010). While this could be one possible scenario for the presence of pig remains, wild boar has also been pointed to as a likely resource to be exploited. The differentiation between domestic pig and wild boar is possible with the aid of biometric analysis; however, in some cases, the remains are too fragmented or too similar in size. Ethnographic evidence from Maghreb and the communities of the Rif Mountains show that wild boar is hunted and highly valued by some tribes who do not consider it as forbidden food, and have therefore a relaxed attitude towards its consumption (Moreno-García 2004, Simoons 1994).

Other type of meat could be consumed; however, meat was considered halal (lawful) only if the slaughtering of the animals was carried out with a clean cut to the throat while invoking the name of God (Insoll 1999:97).

Fasting occurs in the Muslim faith during Ramadan, a month-long abstinence from food and drink from sunrise to sunset, broken with a banquet each night, although no restriction was imposed on eating meat compared to Christian fasting (Insoll 1999:106, Zaouali et al. 2007:30). During the Middle Ages, and in contrast with modern Muslim observance, alcohol and intoxicating beverages were tolerated, although the degree of consumption and tolerance were dependent on the disposition of the ruling class (Armanios and Ergene 2018, Zaouali et al. 2007).

Christian dietary requirements did not include taboos for specific foods; however fasting and abstinence from meat and its products was central to the Christian doctrine of purification and atonement, although the degree to which people complied with is hard to determine (Woolgar 2003). Christian Portuguese sources mention that fasting during Lent included abstinence from meat, some fish, eggs, cheese, butter, animal fats and wine (Marques 1987). During the rest of the year fish was used as a common substitute for protein; however the less privileged strata of the society might have simply eaten cereals, legumes and vegetables without any animal protein (Adamson 2008:189). Certain members of society could be exempted from fasting including pregnant women, pilgrims, children, the sick and beggars (García-Marsilla 1993). The consumption of fish would have likely increased during fasting days which imposed a bigger demand onto market supply and research of late medieval sources suggested that worries existed among urban authorities in Portugal (Catarino 2002:58, Pereira 2012:14-15). The scarcity of fish during this period is portrayed in restrictions on Muslims and Jews buying fresh fish during Lent, with the aim of ensuring a steady supply for Christians only during periods of fasting (Glick 2005). Because of the difference in fish consumption portrayed in the sources, this thesis will explore this theme since marine and freshwater fish, especially from along the Atlantic coast, serve to increase the nitrogen isotope values, while marine fish specifically would increase the $^{13}$C values as well (Chapter 2).

### 3.8 Diet and gender

The ideology of separate roles for men and women is found in many sources; however assessing the extent to which a society stuck to these norms is disputed (Beattie 2006:213). The debate, for both Christian and Muslim societies, centres on the household as the key unit where conjugal and family life happened, and where food was most often prepared and consumed (Riddy 2006:222). Historical sources from as early as the 11th century describe specific spaces for women of all social status in the public and private sphere of life from household or palace to mosque and caravanserai (Díez Jorge 2002:159). Norms and regulations about the use of domestic space are reported, such as protecting women from unwanted gaze behind a curtain or with the creation of a restricted area in the house (Marín 2000:237). These regulations were more feasible in large, high status households with many rooms. This connection between family and domestic architecture has been studied in medieval Morocco. The centralized structure of the houses in Maghreb with equal cells surrounding a central space is said to reflect the family structure of its inhabitants: wives and children are relatively equal to each other but subordinate to the male head of the household (Fentress 2000). This hierarchy might also be reflected in terms of access to specific foods among those of higher social status. In the case of lower-status nuclear, one-room houses common across Islamic settlements, such as those excavated in Praça da Figueira (Díez Jorge 2002:161), it is probable that men and women were more likely to share space and food. In a similar vein, medium and lower-status women were less restricted in their daily activity, being free to wander in public spaces and use the public baths, unlike women of high status (Coope 2013, Lachiri 1993).

Scarce information is provided by historical sources on the women in Al-Andalus and their diet; however, medical recommendations on the consumption of specific food for women are given at specific times such as during pregnancy and breastfeeding (García-Sánchez 2006). Otherwise, uniquely gender-specific foods cannot be identified. Women were encouraged to consume high calorific food such as fats, sugars and carbohydrates in order to put on weight for aesthetic purposes (García-Sánchez 2006:217). The Kitāb al-Tabīj, an Andalusian cookbook compiled by an anonymous author in the 13th century, includes a couple of recipes called 'food for women' that had exactly this purpose (Martinelli 2012). In medieval Cairo men were said to eat street food very often because of its quality and because they did not like to eat what women cooked in the house (Lewicka 2011:120). One reason for this might have been the prejudice that menstruating women had a negative influence on the quality of the food. However, it seems that the allocation of food preparation in all its stages could vary considerably between different locations throughout the Islamic world. In Baghdad women are said to exclusively prepare meals for the household and are the only ones to undertake the traditional preparation of couscous in the Maghreb (Waines 1987). In terms of a typical high-status male diet, one could infer that the entirety of etiquette manuals and cookery books were actually intended for higher-status male individuals and are therefore a reliable source of information. The Arab-Islamic table, as much as its European counterpart, was dominated by men, and women were not taking part. They could watch the banquet from a shielded area or eat in their own part of the house (Visser 2012: 279, Lewicka 2011:401).

During the Christian period, women of middle and lower status are known to be economically active and performing a number of activities. Women worked in taverns, as shopkeepers, fishmongers and were cooking and selling *aletria,* a sweet vermicelli soup in late medieval

Murcia (Martínez-Martínez and Molina-Molina 2013:193) and couscous and rice every morning in the street of 16th century Lisbon (Fernandes 2002:138-139). In 14th century Coimbra, women were selling and making bread, which was apparently a strictly female task (Campos 2014:128), similarly to couscous making in the Maghreb (Waines 1987).

There are few explicit references in historic literature for culinary products shared by women and children. Women and children were considered of different physiological nature (children were hot and humid, while women were colder and drier), therefore similar food consumption is not associated with the humoral theories (Oliveira 2007:31). However, childcare is traditionally entrusted to women and it is likely that physical proximity would have prompted the consumption of similar meals.

Breastfeeding was considered by Christian and Muslim medieval societies of vital importance to a child development and health (Giladi 1998:108, Shahar 1990:57). Medical and historical sources from both the Muslim and Christian world suggested breastfeeding at least until two years of age (Baumgarten 2004; Fildes 1986). Breastfeeding has not been explored in this thesis because only a few non-adult samples are included in the two populations; however, breastfeeding practices have been widely documented in ancient populations with stable isotopes (Beaumont et al. 2015, Fulminante 2015, Tsutaya and Yoneda 2015).

A big part of the debate around gender-related food in the Middle Ages is centred around meat consumption. Meat consumption was associated with masculinity and some studies suggest that in time of scarcity meat was reserved for men, while women abstained from it and complemented their diet with other foodstuff (Medina 2005:159). Stable isotopes could inform on this debate since historical evidence for the medieval period is vague on this topic. As it is generally accepted that sex does not affect the tissues' isotopic values based on physiology (Schwarcz and Schoeninger 1991), higher nitrogen isotope values might correspond to higher trophic level protein being consumed by males compared to females. Although similar patterns have been recorded elsewhere in Muslim Spain with males consuming higher trophic level proteins (possibly riverine fish) in Tauste, for example (Guede et al. 2015), a sex difference in diet is not a common trend among isotopic datasets for Muslim populations from Spain (Fuller et al. 2010; Salazar-García et al. 2014, 2016; Alexander et al. 2015).

### 3.9 Summary

As was flagged earlier in this chapter, stable isotopes have the potential to elucidate some of the current debates on food consumption in the Middle Ages especially in regard to specific food groups ($C_4$ plants vs $C_3$ plants; meat vs fish; male vs female diet) that inform on economy, gender and status. In addition, variation in diet can also be assessed geographically including comparison between coastal and inland regions, urban and rural settlements or northern and southern regions. For example, secondary crops including $C_4$ plants might be more prevalent in rural areas, or in the north of Portugal compared to the south, while difference in fish consumption could be identified between coastal and inland populations. At the same time, gender and status-based difference can be explored to assess whether the most privileged group of the society accessed higher trophic level proteins or fish compared to less wealthy individuals. However, the limitation of the methodology must be borne in mind since isotopic analysis cannot discriminate the source of animal protein (e.g. animal species) and in what form it was consumed (e.g. meat or dairy). Similarly, differences in status, related to the type of crops and their preparations cannot be identified if plants are part of the same group; for example, isotopic analysis cannot tell apart if people have been eating white bread made of wheat or brown bread made of barley or rye, as all these are $C_3$ plants. These limitations should be kept in mind when exploring the research questions in this thesis and when interpreting the results.

In addition to these general lines of research that have been pursued on a number of medieval and ancient populations, there are specific questions that isotopic analysis can explore related to the particular social, cultural and religious Portuguese milieu during the period under study. Difference in food access between Muslims and Christians can be explored, questioning the idea that Christian fasting generally meant a higher reliance on fish. Similarly, a chronological approach could be used in order to assess the impact of the Christian conquest in the late medieval period on husbandry practices, agrarian regimes and food availability and supply among minority groups. This chapter provided a brief review on how isotopic studies can tap into historical and archaeological evidence and inform issues that have been previously tackled by both historians and archaeologists. Isotopic analysis rarely provides conclusive answers, but rather new avenues of investigation based on the holistic integration of different lines of evidence which will contribute to address the gap in our current understanding of foodways in Medieval Iberia and shape the direction of future research.

| Site | Period | Predominant species | Other species | Reference |
|---|---|---|---|---|
| Alcácer do Sal | End 9th-10th | Rabbit | Chicken, sheep/goat, cow, hare, fish. | Moreno García and Davis 2001 |
| Alcaria de Arge | 12th-13th | Rabbit and cow | Sheep/goat and chicken | Moreno García et al. 2008 |
| Alcaria de Odeleite | Mid 11th | Rabbit and cow | Sheep/goat and deer | Pereira 2012 |
| Alcaria Longa | End of 12th | Sheep/goat | Cattle, dog, deer | Antunes 1996 |
| Alcoutim - Castelo Velho | 9th-12th | Sheep/goat | Cow and rabbit | Catarino 1997 |
| Aljezur | 12th-13th | Rabbit | Horse, deer, sheep/goat | Mota and Cardoso 2016 |
| Castelo das Relíquias | 9th-10th | Sheep/goat | Rabbit and cow | Catarino 1997 |
| Cacela Velha – Poço Antigo | 13th | Sheep/goat, rabbit, cow | Chicken, cockle, oyster | Garcia et al. 2012, Valente et al. 2015 |
| Conimbriga | 7th-11th | Cow and sheep/goat | Pig, deer and rabbit | Detry et al. 2014 |
| Évora - Paço dos Lobos da Gama | 11th-12th | Sheep/goat | Cow, rabbit and horse. | Costa and Lopes 2012 |
| Lisbon – Castle | 11th-12th | Sheep/goat | Cow, rabbit and pig | Moreno-García 2008 unpublished |
| Lisbon- Largo da Severa | 12th-14th | Sheep/goat | Cow, pig | Valente and Marques 2017 |
| Lisbon - NARC | 10th-12th | Sheep/goat and cow | Horse, rabbit | Bugalhão et al. 2008, Moreno García and Gabriel 2001 |
| Lisbon – Sé (Cathedral) | End 9th-10th | Sheep/goat | Pig, cow, rabbit | Moreno García and Davis 2001 |

| Site | Period | Predominant species | Other species | Reference |
|---|---|---|---|---|
| Lisbon – western quarter | 11th-12th | Sheep/goat | Cow | Bugalhão et al. 2008 |
| Loulé – Casa das Bicas | 13th | Sheep/goat | Cow, rabbit, clams | Branco and Valente 2015 |
| Mértola – Casa II | Mid 12th-13th | Rabbit | Sheep/goat, cattle, chicken, partridge, barbell and clamshell. | Antunes 1996 |
| Mértola - Islamic house near the castle and Almohad neighbourhood | 10th-13th | Sheep/goat, rabbit | Hare, cow, pig | Moreno García and Pimenta 2012 |
| Mértola – Alcáçova | Islamic | Sheep/Goat, rabbit | Cow and hare | Morales Muñiz 1993 |
| Mesas do Castelinho | 9th-10th | Rabbit and sheep/goat | Deer and cattle | Cardoso 1994 |
| Paderne - Castle | 12th-14th | Rabbit and deer | Sheep/goat and galliformes | Pereira 2013 |
| Palmela – Castle | 11th-12th | Rabbit, sheep/goat | Deer, cow, pig | Fernandes et al. 2012 |
| Portela 3 | 10th-13th | Sheep/goat | Cow and rabbit | Pereira 2015 |
| Ribāt da Arrifana | 12th | Sheep and cow | Rabbit | Antunes 2011 |
| Salir – Castle | 12th-13th | Sheep/goat, deer | Chicken, cow and partridge | Martins 2013 |
| Santarém – Alcaçova | 9th-12th | Sheep/goat, cow | Rabbit, pig | Davis 2006 |
| Santarém - Convento de São Francisco | End 9th-10th | Sheep/goat and rabbit | Cow, deer, chicken and partridge. | Moreno García and Davis 2001 |
| Santarém - Convento de São Francisco | End 9th-11th | Sheep/goat | Cow, rabbit | Lopes and Ramalho 2001 |

| Site | Period | Predominant species | Other species | Reference |
|---|---|---|---|---|
| Silves | 8th-10th | Sheep/goat | Hare and rabbit | Antunes 1997 |
| Silves – east quarter | 12th-13th | Sheep/goat | Cow, rabbit | Davis et al. 2008 |
| Sintra – Castle | 10th-12th | Sheep/goat | Deer, cow, rabbit, pig | Coelho 2012 |
| Tavira – Almohad settlement | 10th-12th | Sheep/goat | Rabbit, hare and deer | Covaneiro, Cavaco and Lopes 2004 |
| Tavira – Parque das Festas | Islamic | Rabbit | Sheep/goat and pig | Covaneiro and Cavaco 2012 |
| Torres Vedras – Paço Concelho | 12th | Pig, sheep/goat | Rabbit and cow | Gabriel 2003 |

***Table 3-1** Summary of published zooarchaeological assemblages in Islamic Portuguese sites with indication of the predominant species at each location.*

# 4. METHODOLOGY

## 4.1. Human sample selection

This research includes both adult and non-adult individuals. Adult skeletons have been identified as having a biological age of over 18 years. At each site, every adult individual of determinable sex has been included in the research, based on the anthropological reports compiled for each site during the excavation. At the site of Beja adult individuals of undeterminable sex have been sampled as well, in order to perform an in-depth population study.

In relation to non-adult individuals, they have been included in this study only when the population was particularly small in number in order to increase sample size, reliability, and representativeness of the data set in Lisbon, Setubal and Loulé. For all the other site, adult skeletons only were analysed.

## 4.2. Sex and age estimation

Determining the age and sex distribution of a group of skeletons is the first step towards the reconstruction of the paleodemographic profile of an archaeological population. In addition, food consumption practices can vary according to sex and age categories, adding significant value to the study of a society and its relationship with food. Sexing and ageing methods are outlined and discussed in the following sections and tables are provided with the lists of methodologies applied at each site.

### 4.2.1. Sex determination in adult individuals

The difference between the female and male body is defined as sexual dimorphism. It is often identified as a systematic difference in the morphology of the two sexes that can be expressed by various skeletal traits. Sexual differences can be manifested in many tissues, including bone, as a tissue response to the level of hormones present in an organism.

Sex determination of human skeletal remains relies therefore on the existence and analysis of regular and recordable sexually dimorphic traits (Buikstra and Ubelaker 1994; Cox and Mays 2000). The greater the dimorphism, the more reliable will be the sex assessment of the skeletal remains. When assessing the sex of adult human remains it is essential to examine, if possible, the entire skeleton. The accuracy of the sex determination is not only contingent upon dimorphism but also the completeness of the skeletal remains, especially when the population under analysis exhibits low levels of sexual dimorphism.

The two areas of the skeletons that display higher levels of sexual dimorphism are the skull and the pelvis and, although the entire skeleton should be assessed, these two areas should have the most weight (White and Folkens 2005). In addition to the morphological assessment of the skull and pelvis, a series of metric analyses can also be performed. These methods are usually based on a regression formula, obtained from the study of known sex individuals and rely on the fact that sexual dimorphism usually provokes a difference in size between males and females. A great variability do however exists between population and the application of metric analysis is usually applied to complement the morphological assessment, or in case of poor preservation of pelvis and skull.

The sexually dimorphic feature predominantly examined on the os coxae are the subpubic concavity, the ventral arc, the inferior pubic ramus (Phenice 1969), the greater sciatic notch and the subpubic angle (Bruikstra and Ubelaker 1994) and the obturator foramen (Bass 2005). The combination of these traits provides 96-100% accuracy (Sutherland and Suchey 1991). On the skull the most sexually dimorphic regions are the supraorbital margins, nuchal crest, mastoid process, supraorbital ridge, mental eminence (Buikstra and Ubelaker 1994), and temporal lines (White and Folkens 2005). The observation of these traits can achieve 80-90% of accuracy (White and Folkens 2005:362).

Different methodologies applied at each site have been provided in Table 4-1. Despite the use of different scoring systems and techniques, the results on sex and age are considered to be comparable and reliable. This is because age ranges were not considered and skeletons have been grouped into adults or non-adults for the purpose of this work. Furthermore, skeletons' sex has been considered as reliable only in those individuals with a definite estimate and probable male or probable females were not included, or included as undetermined. This cautious approach was necessary in order to ensure that the results will be effectively portraying the diet of adult male and female individuals.

| Method | Type of observation | CIL | CDT | LOL | QDL | CAS | BEJ | SIL | SET | LU |
|---|---|---|---|---|---|---|---|---|---|---|
| Silva (1995) | Max length of astragals and calcaneus | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| Wasterlain et al. (2000) | Transversal and vertical diameter of the femur and humerus head. Max length of humerus, femur, tibia and radius. Epycondilar breadth of the humerus. | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ |
| Cardoso (2000) | Max length of humerus, tibia and radius. | | | | | ✓ | | | | |
| Ferembach et al. (1980) | Morphology of cranium, mandible and pelvis. | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| Bruikstra and Ubelaker (1994) | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Bruzek (2002) | | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | |
| | | | ✓ | ✓ | | | | | | |

*Table 4-1* *Methodologies applied at each site for sex estimation of skeletal remains. List of abbreviation: CIL (Cilhades – Bragança); CDT (Calçadinha do Tijolo – Lisbon); LOL (Largo das Olarias – Lisbon); QDL (Quarteirão dos Lagares – Lisbon); CAS (Castle of São João – Lisbon); BEJ (Beja); SIL (Silves); SET (Setubal); LU (Quinta do Lago – Loulé).*

### 4.2.2. Sex determination in non-adult individuals

The study of non-adult remains had a much slower development compared to the study of adult populations. This delay was caused by several factors such as the preservation issues of such delicate materials but also a different theoretical focus in the archaeological studies. Before the 1980's the non-adult remains were mainly studied to develop adequate techniques for sexing and ageing immature skeletal remains, drawing from medical studies. It is just with the development of gender studies in the 1990's that the study of children and childhood emerged and gradually increased its sophistication. Despite the amount of literature concerned with sexing methods for non-adult remains, universal and common methodologies holding good successful rate are yet to be defined. Although some studies have proven to be successful with specific populations, the methods failed when applied to different populations[1]. The scarce accuracy of the methodologies used so far might be a direct cause of the low level of scrutiny that these methods have received, affected by the assumption that morphological differences are not fully formed until reaching the pubertal hormonal stage (Stull and Godde 2013). Metrics and non-metric traits have been tested using several skeletal parts such as morphological traits of the pelvis (Cardoso and Saunders 2008; Halcomb and Konisberg 1995; Mittler and Sheridan 1992; Sutter 2003) and measurements of long bones (Coussens et al. 2002; Shutkowski 1993; Stull and Godde 2013) and teeth (Ditch and Rose 1972; Rösing and Schnutenhaus 1995; De Vito and Saunders 1990; Viciano et al 2015). While in some cases the reported rate of success in single case studies reaches 90% of accuracy (De Vito and Saunders 1990) and an exceptional 95.9% in Viciano et al. (2015), none of the above methodologies proves to have a consistent rate of success when applied to other populations. Because of the low reliability of these methodologies, sex estimation is not routinely performed on non-adult individuals and was never accounted for in the anthropological reports of the collections here analysed. In addition, only a handful of non-adults have been included in this thesis.

### 4.2.3. Human ageing methods in adult individuals

The real age of an individual is defined as the number of years that a person lived. It is impossible to establish the real age of an individual based on skeletal remains. Instead, what the osteological analysis assess is the biological or physiological age of an individual. The biological age is affected by several factors such as genetics, health status and the

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[1] For a full review of the literature dealing with non-adult sexing methods and recent development see Mays (2013)

environment, and, therefore, can not be always reflecting the real age of an individual (Cox and Mays 2000). Although it is necessary to take into account the limitations of skeletal biological age, ageing an archaeological population is a basic requirement in the reconstruction of the paleodemographic profile of a population, and it is a necessary step in any anthropological research.

The assessment of the biological age is based on the observation of the major development stages attained by an individual through life. The two main elements that are generally observed to identify the stages of childhood and adolescence are dental eruption and long-bones fusion. Once growth is completed, a series of morphological degenerative changes occurs through the skeletons such as dental ware and changes in bones structure. Scholars use these changes to estimate the age-at-death of adult individuals (White and Folkens 2005). Because these changes can display high rate of variability, and the ageing process is affected by several factors, as previously mentioned; osteologists usually assign age ranges to the analysed individuals. The most commons age categories in the recent literature are the ones suggested by Buikstra and Ubelaker (1994) identified as Young adult (20-34 years), Middle adult (35-49 years) and Old adult (50+ years). In the Iberian Peninsula, numerous studies follow the suggestions of Ferembach et. al (1980) drawing from the 'Complex method' of Acsádi and Nemeskéri (1970) that divides the age categories in five different groups. The values of these age groups can vary according to the number and type of traits analysed.

The high level of variability in the techniques used by different anthropologists to age the skeletons here analysed, called for a more conservative approach and the skeletons were divided in two age categories only: non-adults and adults. Adult individuals were defined as having a biological age over 18 years old. For comparative purposes, a table with the various methodologies applied during the study of each skeletal collection is provided in table 4-2.

| Method | Type of observation | CIL | CDT | LOL | QDL | CAS | BEJ | SIL | SET | LU |
|---|---|---|---|---|---|---|---|---|---|---|
| Ferembach et al. (1980) | Epiphyseal union | ✓ | ✓ | ✓ | ✓ |  | ✓ | ✓ |  |  |
| MacLaughlin and Bruce (1990) | Epiphyseal union at the sternal end of the clavicle | ✓ |  |  |  | ✓ |  | ✓ | ✓ |  |
| Scheuer and Black (2000) | Epiphyseal union |  | ✓ | ✓ |  |  |  | ✓ | ✓ |  |
| Krogman and Işcan (1986) | Ossification of thyroid cartilage |  | ✓ | ✓ |  |  |  |  |  |  |
| Işcan et al. (1984) | Sternal rib end |  |  |  |  | ✓ |  |  |  |  |
| Brooks and Suchey (1990) | Pubic symphysis degenerative changes |  | ✓ | ✓ |  | ✓ | ✓ |  |  | ✓ |
| Krogman and Işcan (1986) |  |  | ✓ | ✓ |  |  |  |  |  |  |
| Ubelaker (1989) |  |  | ✓ | ✓ |  |  |  | ✓ | ✓ |  |
| Katz and Suchey (1986) |  |  | ✓ | ✓ |  |  |  |  |  |  |
| Lovejoy et. al (1985) | Os coxae auricular surface degenerative changes |  | ✓ | ✓ |  | ✓ | ✓ |  |  | ✓ |
| Meindl and Lovejoy (1989) |  |  | ✓ | ✓ |  |  |  |  |  |  |

*Table 4-2 Age-at-death estimation for adult individuals at each site List of abbreviations: CIL (Cilhades – Bragança); CDT (Calçadinha do Tijolo – Lisbon); LOL (Largo das Olarias – Lisbon); QDL (Quarteirão dos Lagares – Lisbon); CAS (Castle of São João – Lisbon); BEJ (Beja); SIL (Silves); SET (Setubal); LU (Quinta do Lago – Loulé).*

### 4.2.4. Human ageing method in non-adult individuals

The age-at-death of a child is used in archaeology to infer about the mortality rate of a population, its demographic profile, growth and development as well as morbidity and weaning ages (Lewis 2007). Age estimation of non-adult individuals is based on dental development and skeletal growth and maturation. It relies, as for the adult individuals, on a correct conversion from biological to chronological age. However, as we already discussed for adult individuals, effects of the environment, disease, secular changes and genetics can affect the individual rate of growth and development (Agarwal 2016; Cardoso et al. 2014; Lewis et al. 2016).

Dental development has been proven to be the least affected by external factors and is therefore considered the most reliable methods for age estimation of immature skeletons (Cox and Mays 2000). This ageing technique is based on the observation of dental eruption and development that occurs in a rather regular pattern through several stages from deciduous teeth to the development of permanent dentition. One of the most popular macroscopic methods is based on the stage of dental eruption suggested by Ubelaker (1989:47).

In addition to dental development, the observation of macroscopic changes and measurements of long bones are applied to establish age-at-death in non-adult individuals. Specifically, diaphyseal length and fusion of the ephiphyses are the two most reliable methodologies. Regression formulae are applied to the measurements of the diaphyseal lengths in order to reconstruct the age of the individual (Scheuer and Black 2000), while the degree of ephiphyseal fusion is assessed following the guidelines provided by several authors. The most common are Buikstra and Ubelaker (1994), Cardoso and Saunders (2008), Ferembach et al. (1980), Scheuer and Black (2000).

Only three sites include non-adult individuals specifically Lisbon Castle, Setubal and Loulé. Since the sex and age-at-death has been established by several and different anthropologists on site, Table 4-3 presents a summary of the methodologies applied at each site.

| Method | Type of observation | CAS | SET | LU |
|---|---|---|---|---|
| Ubelaker (1989) | Dental growth and development | ✓ | ✓ | ✓ |
| Liversidge (1994) | Metric analysis of the deciduous crown | ✓ | | |
| Ferembach et al. (1980) | Epiphyseal union | | | ✓ |
| Scheuer and Black (2000) | | | ✓ | |
| Acsádi and Nemskéri (1970) | | | | |
| Cardoso and Saunders (2008) | | ✓ | | |
| Scheuer and Black (2000) | Diaphyseal length of long bones | | ✓ | |
| | Epiphyseal union | ✓ | ✓ | |

***Table 4-3.*** *Age-at-death estimation for non-adult individuals at Castle of São João – Lisbon (CAS), Setubal (SET) and Loulé (LU).*

## 4.3 Faunal sample selection

Faunal remains were assigned to species following morphological changes by the author with the help of zooarchaeological references (Schmid 1972; Barone 1986) during sample collections for the sites of Silves and Lisbon. Faunal remains from Laranjal (Bragança), Palmela (Setubal) and Quinta do Lago (Loulé) were studied by several zooarchaeologists and the sampling was based on the provided lists of species.

Sheep and goats were identified at the BioArCh lab with the application of Zooarchaeology by Mass-spectrometry (ZooMs) (Buckley et al. 2010), with the help of BioArCh technician Luke Spindler. Fish remains were kindly identified by Dr. David Orton and Dr. Laura Llorente-Rodriguez at the University of York.

### 4.3.1 Faunal ageing methods

Indication of the age of the animals was noted when possible. When in doubt, several pictures were taken of the specimen from which the sample was collected in order to assess the age a posteriori with the help of Dr. David Orton. The zooarchaeological reports seldomly included specific age indication and therefore adult individuals were generally preferred in the sampling process.

### 4.3.2 Sampling procedure

During the sampling of human skeletal remains, a Smart Weight SWS100 Elite digital pocket scale was used to collect ~1.5-2 g of bone. This method was preferred rather than collecting 3-4 cm of bone in the light of the state of preservation of the material. The majority of the skeletal remains were poorly preserved and therefore the weight of the bone was considered more reliable than its actual dimension. The sampling was carried out by hand or with a pair of clippers to minimise destruction.

Ribs were usually preferred as these bones are numerous per individual, tend to be very fragmented and are not the most useful during the anthropological assessment of the skeleton. Pathological ribs as well as rib ends, which might be used for age assessment, were excluded. Where ribs were not available, long bone diaphysis were sampled, prioritising broken elements in order to minimise destruction (Fig. 4-1).

When sampling animal skeletal remains, mandibles, metapodials and long bones were selected. Samples of ~3-4 g were collected. However in few cases cranium, pelvis and scapula were also sampled in absence of more suitable anatomical parts. In the case of fish remains, vertebrae and mandibles were sampled. Particular attention has been paid to the selection of the archaeological context to which the animal remains pertained. Only one element per species was collected from each stratigraphic unit in order to avoid multiple sample of the same individual. When the context or stratigraphy was confused, the same element from the same side of the same species was sampled.

*Figure 4-1. Osteological samples from a human rib bone(above) and long bone (below) from Beja.*

## 4.4 Laboratory procedure

In the following section, an overview of the techniques used in the laboratory is provided. The protocol for collagen extraction followed in this study is an established technique based on a modified Longin (1971) method and includes an additional ultrafiltration step as suggested by Brown et al. (1988). This additional step in the collagen extraction is performed in order to remove the mineral fraction of the bone, and as many contaminants as possible. The products obtained from this process is not pure collagen since traces of other bone proteins are retained, however it is referred in the literature and in this work as collagen (Ambrose 1990, van Klinken 1999).

The procedure includes the following steps:

1. Sample cleaning
2. Demineralisation in 0.6M HCl
3. Gelatinisation
4. Ultrafiltration
5. Free drying
6. Preparation of the samples for mass spectrometry

Health and safety regulations were followed throughout the entire procedures. Protective clothing such as lab coat, gloves and safety glasses were worn. A face mask was used during drilling of the animal bones.

The processing of the human and animal remains was carried out the at BioArCh facilities, Department of Archaeology, University of York. The first part of the analysis was performed in the old lab facilities of S-Block at the Department of Biology, while the second part of the analysis was undertaken in the new BioArCh facilities in the Environment building. The procedures remained exactly the same and no differences can be highlighted in the two phases of the work.

### 4.4.1 Sample cleaning

The samples were cleaned mechanically with the aid of a scalpel. Because of the fragility of the material in most instances, the scalpel was enough to remove the outer surface debris. When necessary, a burr attachment on a drill was used to clean the surface of the hardest specimens.

Once the outer surface was cleaned, the ribs were separated and the trabecular bone removed with the rests of soil and earth. Once the sample was entirely clean, long shards of bone or chunks were separated in order to speed up the dissolution in acid (Hajdas et al 2009). This method was preferred to bone grinding as this may result in lower C/N ratios and lower protein content as well as it may cause fragmentation and damaging of the collagen (Collins and Galley 1998; Nielsen-Marsh et al. 2000).

### 4.4.2 Weighing and demineralisation

Around ~300mg of bone was weighted out for each sample and transferred in 15ml glass screw top tubes. When the bone displayed poor preservation (e.g. highly mineralised bones, fragile, powdery and tendency to easily disintegrate when touched), larger samples of around ~400mg were collected. The weights were recorded in the lab book and in the dedicated lab spreadsheets.

Around 9 ml of diluted 0.6M HCl was poured into each test tube. The tubes were left in the fridge for an hour, covered in foil allowing the $CO_2$ gas to escape. Subsequently the caps were screwed on the test tubes and the samples stored in fridge with a constant temperature of ~4˚C. Demineralization at low temperature is suggested in order to minimise protein damage (Collins and Galley 1998). When the preservation appeared to be good, the samples were placed on a roller-rocker in order to make sure the acid would equally reach all parts of the sample. For the most damaged samples, the roller-rocker was generally avoided since it tends to speed up the reaction and may be too aggressive on the most degraded bone materials.

The length of the demineralisation process varied between a day to up to three weeks depending on the sample and its preservation. The acid was replaced every 48 hours to ensure the efficiency of the demineralisation. Samples were taken out of the acid when two of the following criteria were met: floating of the sample to the surface, pliability or flexibility of the bone, translucency of the sample, lack of effervescence indicating the cessation of reaction. When demineralised, the samples were rinsed three times with purified water and the spent acid was disposed of.

### 4.4.3 Gelatinisation

The aim of the gelatinisation is to solubilise the protein while avoiding dissolving any non-acid soluble contaminants. 8 ml of pH3 HCl were added to the samples in purified water. The pH was checked with pH strips in one sample per batch. The samples were then placed into the oven at a constant temperature of 80˚C for 48 hours.

### 4.4.4 Ultrafiltration

The gelatinised samples were filtered using Ezee® filters (Elkay Products 9 microns) to separate any residue like organic insoluble matter, from the gelatinised protein fraction.

The samples were then ultrafiltered with 30kDa ultrafilters (Fisher centrifugal filters) in order to isolate the higher molecular weight peptide molecules of the gelatinised proteins. The ultrafilters were initially conditioned with 0.1M NaOH and centrifuged for 9 minutes at 4000 rpm. Once the NaOH was discarded, three subsequent rinse of deionised water were performed at a speed of 4000 rpm for 9 minutes. The samples were then centrifuged ~4ml at a time until the gelatinised solution was reduced to the desired amount between the top of the filter and 500 µL.

At the end of this process two sections of sample are generated: the filtrate and the retentate fractions. Both filtrate and retentate were pipetted into pre-weighed clean plastic 15ml Falcon tubes labelled accordingly. The tubes were covered in parafilm which was pierced to allow the emission of gas during the freeze-drying process. The samples were then placed into a freezer kept at ~-20˚C and left at this temperature for at least 24 hours.

### 4.4.5 Freeze drying

The frozen samples were then loaded into a freeze-drier and lyophilised for 48 hours. This process aims to remove the organic solvents as well as water from the sample through sublimation. The result is collagen in a solid, candyfloss like form of various colours from white to tan. The tubes with the collagen are then weighed and the new weight is registered into the database in order to obtain the weight of the collagen. The collagen yield is then calculated following this formula:

$$\%\text{Yield}=\frac{\text{Collagen weight}}{\text{Original dry bone weight}}*100$$

After freeze-drying the samples can be stored at room temperature with the lids on to make sure no moisture enter the tubes.

### 4.4.6 Isotope ratio mass spectrometry

In order to prepare the samples for mass spectrometry, a fraction of collagen for each sample was weighed into a tin capsule. The optimal amount of collagen needed was between 0.9mg and 1.1mg. Each sample was weighed out in duplicates and the average of both duplicates was used for data analysis. Once the samples were weighed out, the tin capsule was closed and placed in an Eppendorf tube. A complete run includes 36 samples, 24 standards and three blank tin capsules. The samples were run at the Department of Archaeology at the University of York (BioArCh facilities) using a Sercon 20-22 Isotope Ratio mass spectrometer (IRMS).

The mass spectrometer is used to make a quantitative assessment of the sample, however its content has to be transformed into simpler chemical components in order to facilitate its analysis (Brand 2006:836). In the mass spectrometer the samples are combusted and transformed into gasses, separated in the gas chromatography column (GC) and then ionized prior to the measurement. The ions beam is separated by a magnetic field on the base of the ions mass. The ions are gathered in the collectors and measured by their mass to charge ratio (m/z).

The samples were placed in the autosampler carousel following the order of the electronic run spreadsheet. The tin capsules were dropped individually into the combustion chamber of the elemental analyser and combusted in oxygen. The combustion generates a series of gasses that are carried via a helium (He) stream in a reduction chamber with heated copper where nitrogen is reduced to $N_2$ and carbon to $CO_2$. After reduction, the gases undertook ionization whose result is a mass spectrum of each specific compound that gives a measurement of the raw ratio of the heavy to light isotope in analysis (Hoefs 2009:25). The raw measurements were converted into relative measurements (δ values ‰) in comparison to internationally accepted standard gas for the analysed isotope. The data were generated by the interface and downloaded in an electronic spreadsheet.

### 4.4.7 Standards, control samples and analytical error

Standards were run alongside samples to ensure the correct functioning of the procedure as well as the analyser. For each batch of samples, a modern bovine bone control was analysed alongside the archaeological samples in order to check the reliability and the quality of the collagen extraction process. The accuracy of measurements was monitored using international and in house standards with well-known isotopic composition (in-house Fish gelatine: $\delta^{13}C$ -

15.5±0.1, $\delta^{15}N$ 14.3±0.2; Cane sugar IA-R006: $\delta^{13}C$ -11.8±0.1; Caffeine IAEA 600: $\delta^{13}C$ -27.8±0.1, $\delta^{15}N$ 0.8±0.1; Ammonium Sulfate IAEA N2: $\delta^{15}N$ 20.4±0.2).

The analytical error for $\delta^{13}C$ and $\delta^{15}N$ was ± 0.2‰ as determined by analysis of internal laboratory standards coupled with every run. The Technical error measurement (TEM) for duplicate analysis of collagen samples was 0.2‰ for $\delta^{13}C$ and $\delta^{15}N$.

### 4.4.8 Collagen preservation

Collagen preservation was generally good at most sites; however, some samples did not provided sufficient collagen for mass spectrometry or did not meet quality standards such as atomic carbon to nitrogen ratio (C:N) which fell outside the range of 3.1 to 3.5 as recommended by van Klinken (1999). These samples are highlighted in Appendix B. Collagen yield across all sites ranges between 0.2% and 16.3% (average of 4.1%) and are presented in Table 4-4 and 4-5 for human and animal samples respectively. All carbon and nitrogen percentages in collagen samples were above the cut-off points suggested by Ambrose (1990).

| Site | Analysed individuals | Average Yield |
|---|---|---|
| Laranjal | 9 | 1.1 |
| Coimbra – São João de Almedina | 16 | 3.5 |
| Lisbon – Early medieval sites | 31 | 2.9 |
| Lisbon – Late medieval sites | 38 | 3.8 |
| Setubal | 9 | 5.0 |
| Beja | 54 | 3.0 |
| Silves | 65 | 2.6 |
| Loulé | 13 | 4.2 |

***Table 4-4*** *Average collagen yield in human samples per site*

| Site | Analysed individuals | Average Yield |
|---|---|---|
| Laranjal | 20 | 4.8 |
| Coimbra – Criptoportico | 18 | 4.7 |
| Lisbon – Praça da Figueira | 37 | 4.7 |
| Lisbon – Casa da Severa | 22 | 4.1 |
| Palmela | 22 | 6.5 |
| Silves | 17 | 5.0 |
| Loulé | 17 | 5.6 |

***Table 4-5*** *Average collagen yield in animal samples per site*

### 4.4.9 Statistical analysis

Dietary isotope studies in archaeology commonly employ t-test or Mann Whitney U-test to analyse their data set (Bourbou and Richards 2007; Richards et al. 2006; Salamon et al. 2008). The Mann-Whitney U test is a non-parametric statistical test that, unlikely the t-test, does not require the assumption of normal distributions. This test can be used to determine whether two independent samples were selected from population having the same distribution and is less likely to generate false positive results (Fay and Proschan 2010).

The Mann-Whitney U test can generate false positive results if a large difference in variance between two populations exists and the standard deviations of the two groups differs by a factor of 4 or above (Kasuya 2001). However, this rarely occurs in this thesis (Chapters 6 and 7). One of the limitation of this test is that it does not take into account population distribution but only assess the centrality of the data. To provide additional information on the distribution of the data, the Kolmogorov-Smirnov test will be used as well.

Statistical analyses of the isotopic data were conducted using SPSS with p values <0.05 considered significant.

# 5. ARCHAEOLOGICAL DATASET

## 5.1 Introduction

This chapter includes an overview of the archaeological context for each site. It provides a basic summary of the historical background of the sites, as well as specific information on previous archaeological research and excavations relevant to the medieval period. The location of the sites can be seen in figure 5-1 while tables 5-1 and 5-2 provide a breakdown of the assemblages with the respective number of individuals, dates and period. The sites included in this thesis follow a geographical and environmental transect, including inland and coastal locations as well as rural and urban populations. Whenever possible both Christian and Muslim groups were analysed for the same area.

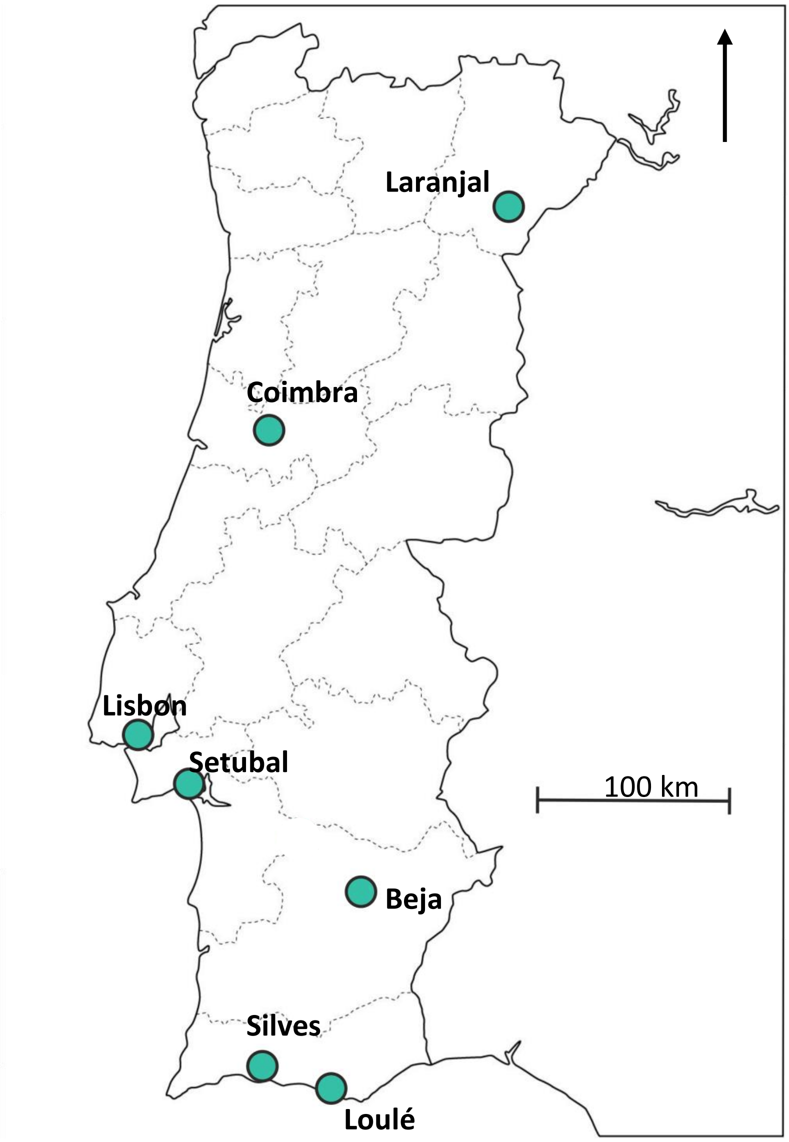

**Figure 5-1**: Location of the analysed sites within modern day Portugal.

| Region | Location | Site | Date | Faith | No. analysed individuals |
|---|---|---|---|---|---|
| Tras-os-Montes | Torre de Moncorvo-Bragança | Laranjal | $10^{th}$-$14^{th}$ | Christian | 9 |
| Coimbra region | Coimbra | São João de Almedina | $12^{th}$-$15^{th}$ | Christian | 16 |
| Lisbon Metropolitan Area | Lisbon | São Jorge Castle | $11^{th}$-$12^{th}$ | Muslim | 27 |
| | | Largo das Olarias - Mouraria | $10^{th}$-$15^{th}$ | Muslim & Christian | 48 |
| | | Quarteirão dos Lagares – Mouraria | $12^{th}$-$15^{th}$ | Muslim | 5 |
| | | Calçadinha do Tijolo - Alfama | $11^{th}$-$12^{th}$ | Muslim | 5 |
| Setúbal Peninsula | Setúbal | Rua Francisco Augusto Flamengo | $10^{th}$-$12^{th}$ | Muslim | 9 |
| Lower Alentejo | Beja | Escola Secundaria Diogo Gouveia | 9th-12th | Muslim & Christian | 54 |
| Algarve | Silves | Largo da Se | $13^{th}$-$15^{th}$ | Christian | 21 |
| | | Rua Miguel Bombarda | $13^{th}$-$15^{th}$ | Christian | 19 |
| | | Rua 25 Abril | $11^{th}$-$13^{th}$ | Muslim | 23 |
| | | Rua A | $13^{th}$ | Muslim | 2 |
| | Loulé | Quinta do Lago | 11-$13^{th}$ | Muslim | 13 |
| | | | | **Tot.** | **251** |

*Table 5-1: List of the analysed sites and individuals from north to south. Dates are in centuries.*

| Region | Location | Site | Date | No. analysed individuals |
|---|---|---|---|---|
| Tras-os-Montes | Torre de Moncorvo-Bragança | Laranjal | 10th-14th | 20 |
| Coimbra region | Coimbra | Criptoportico | 12th-15th | 18 |
| Lisbon Metropolitan Area | Lisbon | Praça da Figueira | 11th-13th | 56 |
| | | Casa da Severa - Mouraria | 12th-15th | 27 |
| Setúbal Peninsula | Palmela | Palmela castle | 10th-12th | 20 |
| Algarve | Silves | Largo da Se | 13th-15th | 1 |
| | | Rua Miguel Bombarda | 13th-15th | 1 |
| | | Rua 25 Abril | 11th-13th | 5 |
| | | Rua A | 13th | 13 |
| | Loulé | Quinta do Lago | 11-13th | 15 |
| | | | **Tot.** | **176** |

***Table 5-2**: List of the analysed faunal assemblages and number of individuals per site. Dates are in centuries.*

Each site included in the thesis is introduced in this chapter from north to south, providing details about historical and archaeological background as well as number and type of analysed individuals and the contribution to the research questions outlined in the introduction (Chapter 1).

## 5.2 Laranjal and the Sabor Valley

The site of Laranjal is a small plot of land within the now abandoned village of Cilhades, located on the shore of the River Sabor, in the Torre de Moncorvo *concelho*, Bragança district. This valley resides in the north-eastern corner of present day Portugal, crossed by the River Sabor, a main tributary of the River Douro that stretches for 120 kilometres providing a main route of communication through the valley. River crossing and navigation were systematically practised up until 1981. Although the village was abandoned at the end of the 19th century, seasonal frequentations of the site and the chapel of São Lourenço have been reported for agricultural works and ritual celebrations (AHBS 2012:3).

The area of Cilhades is of foremost importance to understand the settlement pattern in the Sabor Valley, since a continuous occupation of the site can be traced back to the Iron Age, concentrated in the elevated area overlooking the modern village, called Castelinho (AHBS 2012: 3). Amongst the most prominent evidences of frequentation and occupation of the site are a few engraved slabs and an anthropomorphic granite head dated to the Iron Age (Santos and Ladra 2016), two Roman votive altars with inscriptions (Pereira et al 2012, Santos and Ladra 2016:56) and a kiln, located underneath the cemetery, of probable Late Roman (2nd-3rd centuries) chronology (Santos et al 2016:56, Fig.4A). The recovery and the study of the pottery from the site confirmed the same chronological span for this site with abundant phases corresponding to the Imperial Roman, Late Antique and Medieval period (Rosselló Mesquida et al. 2016).

For the middle ages, Cilhades makes its appearance in the historical sources in a document dated 1200 AD in which King Sancho I (1185-1211) donated the village to the settlers of the nearby Mós Castle (Azevedo et al 1979:178). Located on one of the few accessible river crossings, it is mentioned in 16th-17th C local cartography as *Barca de Silhades* (Ferry of Silhades) (Santos et al. 2016:57).

The archaeological works were undertaken at this site because of the construction of the Sabor Dam, resulting in the submersion of the remains of the village (Fig.2).

***Figure 5-2*** *View over the now submerged village of Cilhades, following the construction of the Sabor dam (AHBS copyright).*

The excavation performed at the site of Laranjal (Fig. 5-3) allowed the identification of around 200 Christian burials, although only a part of it has been excavated. The inhumations were contained in graves made of slabs of schist with a NE-SW orientation.

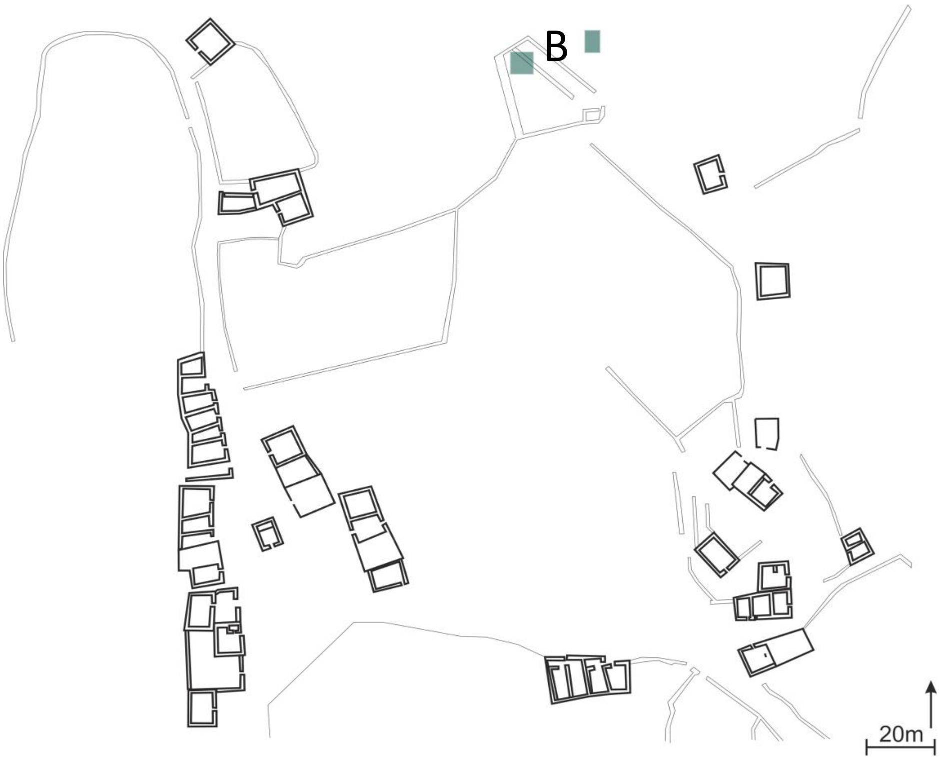

***Figure 5-3*** *Map of Cilhades. The main habitational space is known as Cemitério dos Mouros, while the green rectangular shapes identify the excavated burials within the location of Laranjal (B) (adapted from AHBS report, Cartografia 2).*

In addition, the remains of a small quadrangular building, identified as the previous chapel of São Lourenço, have been recovered and appear to be connected to the surrounding burials. The archaeological material in association with the inhumations gave a chronology spanning from the 10th to the 14th C (Santos et al. 2016b:17). During the excavation at the Cemitério dos Mouros, faunal remains were recovered and used as the animal baseline for the population buried at Laranjal. A breakdown of human and animal samples analysed for this site is provided in tables 5-3 and 5-4.

This site, with Coimbra, provide data on early medieval Christian diet in the north of Portugal, an area that was never under Islamic rule and could therefore offer a different perspective compared to the other Christian populations from southern Portugal. In addition, it is contemporaneous to the Islamic site included in this thesis while Coimbra is of late medieval chronology, potentially informing on different dietary practices across time. Furthermore the rural nature of the site complement the information given by the urban site of Coimbra, in order to shed light onto Christian diet in the north of Portugal.

| Adults | |
|---|---|
| Males | Females |
| 6 | 3 |
| **9** | |

***Table 5-3*** *Breakdown of the analysed individuals from the cemetery of Laranjal*

| Species | N |
|---|---|
| *Bos taurus* | 6 |
| *Ovis aries* | 1 |
| *Capra hircus* | 5 |
| *Sus* | 6 |
| *Gallus* | 2 |
| ***Tot*** | **20** |

***Table 5-4***.*Breakdown of the analysed faunal samples*

## 5.3 **Coimbra**

Coimbra is a riverfront town located in central Portugal. It is believed to be of Roman foundation (*Aeminium*); although, during Roman times, its importance was overshadowed by the bigger settlement of *Conimbriga* (modern Condeixa-a-Velha) (Alarcão 2004). The importance of Coimbra and its development during Roman times resided in its location on two main strategic routes: the River Mondego, a waterway that would connect the interior to the coast, flowing into the ocean at Figueira da Foz; and a main overland route that went from Roman *Bracara Augusta* (later Braga) to *Olisipo* (later Lisbon) (Alarcão 2004:14).

Despite the lack of evidence for the transition of the urban layout from Roman to Medieval times, the peculiar terrain topography influenced its first foundation and was maintained in the Visigothic and Islamic period, while the town underwent major changes during the later medieval period (Alarcão 2008).

The region of Coimbra was subjected to Islamic rule in 714-715, and between 987 and 1064, the year of its final Christian conquest. These seventy years of Islamic rule have left several open questions about the co-existence of Christian and Muslim groups in town, and historical sources provide discordant information on how the new establishment impacted the everyday life of the Christian communities (Alarcão 2004:27-28). The short period of Muslim occupation did not leave many traces behind but previous excavations identified several assemblages of Muslim pottery (Catarino et al 2009). In 1131 Coimbra hosted the main court, and this shift (from Guimarães) granted greater freedom of action to the king Afonso Henriques (1139-1185), focusing on the southern frontier. A few years later, and despite the Pope reluctance, in 1143, Alfonso VII and the Kingdom of Leon recognized Portugal's independence.

The beginning of the 13th C was a prosperous time for Coimbra, developing into one of the most important urban centres of Portugal. Few other places could be compared in terms of demographic and economic growth during this period (i.e. Lisbon and Santarém). Its central role as the main seat of the court paired up with the numerous successful campaigns against the Muslim rulers of the south by Afonso Henriques, prompted an all-round development of this urban centre: Coimbra became a prestigious royal city attracting noble families as well as religious orders bringing about a long-lasting alliance between Church and State (Gomes 1998:150).

The 14th C was highly affected by the epidemics of the Black Death that as soon as 1348 hit quite democratically people of both lower and higher status. Although there is a general assumption that the lower status would be more affected, several lines of research have shown how all levels of society were involved in the spreading of the disease and the number of testaments left by members of the elite testifies to their general concern (Coelho 1983:24). A series of poor and bad harvests additionally undermined the overall productivity of the city with obvious implications for the population and its nutritional status. Furthermore, the aggravated political situation with the Kingdom of Castile brought conflict during the reigns of Fernando (1367-1383) and João I (1385-1433) (Alvaro de Campos 2010).

The layout of the medieval town included two main areas: the walled citadel and the suburbs (*arrabaldes* in Portuguese) organized around extra-mural churches (Fig. 5-4).

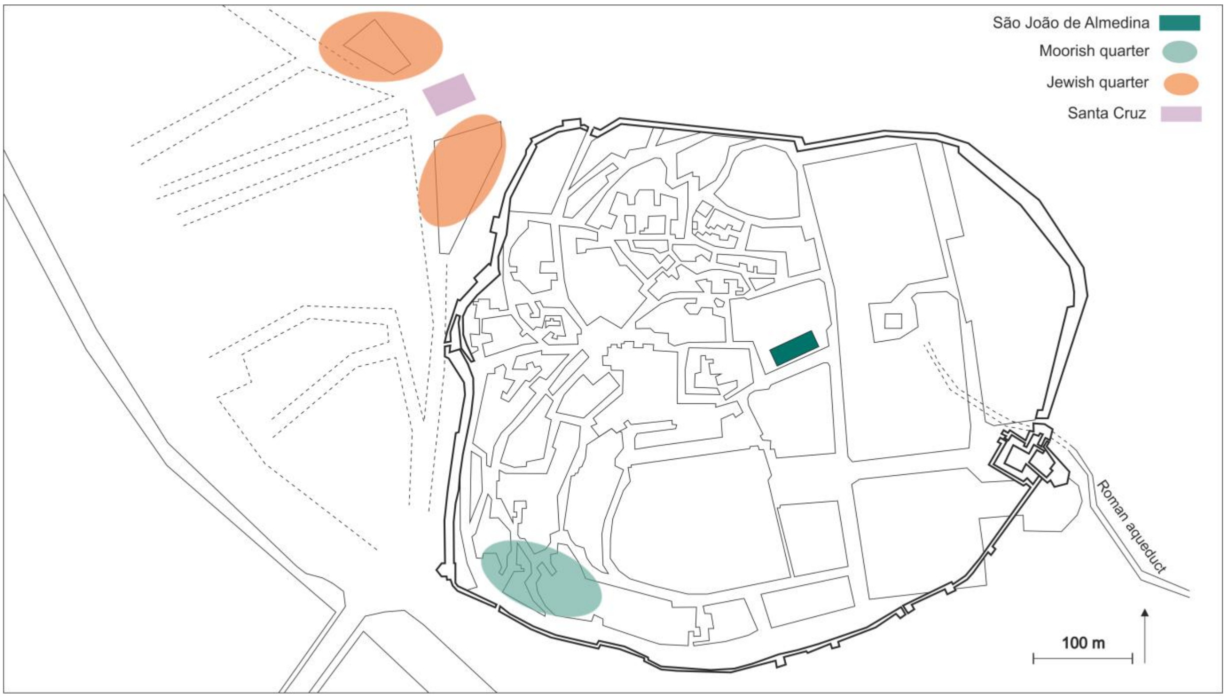

***Figure 5-4*** *Town of Coimbra with the layout of the medieval walls. The supposed locations of the Jewish and Moorish quarter, as well as the church of São João de Almedina, are highlighted in colours (redrawn and adapted from Alarcão 1999:8).*

The town is perched on a steep hill which has a more gentle side at its south-east corner, the location at which the Roman aqueduct entered the town and which was also the site chosen for the construction of the medieval castle near the Porta do Sol gate (Alarcão 1999:1). A stream surrounded the northern edge of the town hill (modern Avenida de Sá da Bandeira) and gave the name to this area, still called in the 12th C, Torrente dos Banhos

Reais (Royal Baths River). The stream would reach and pass through the Roman baths located at the site of the 12th C church of Santa Cruz (Fig. 5-4). Another example of the overlap of the Roman and Medieval town is the location of São João de Almedina church, built near the Bishop's Palace (current Museum Machado do Castro), situated on top of the Roman forum and meters away from the Roman theatre. The cryptoportico, supporting the Roman forum, is preserved and visible through the Museum. The citadel included all the main buildings of the religious and military power and from 1308, for a short period, the University; which was definitively reinstated in 1537 (Alvaro de Campos 2010:162; Coelho 1989). The suburbs differed from the citadel for hosting the majority of the workshops and manual labour and commercial activities, but this was also the more permeable area of the city to the influence of the surrounding rural world (Coelho 1990). Both inside and outside the walls, the urban houses were organised around a parish church. Historical sources and recent archaeological works identified the area in which the Jewish and Moorish quarters were located, outside the north-western part of the wall, where the Church of Santa Cruz was built in 1131 (Alarcão 2008: 151-153). The Church of Santa Cruz, with the Cathedral (Sé), became very influential in the late medieval period and administered a big part of the land surrounding Coimbra (Coelho 1988). Within the city walls four parishes were identified: Sé, S. Pedro, S. Bartolomeu and S. Joao de Almedina (Gomes 1998:153).

### 5.3.1 The church of São João de Almedina

The excavations performed around the church of São João de Almedina were incidental to the interest of the archaeologists in the Roman cryptoportico, mostly excavated in the 1940's. The human remains pertaining to the church burial ground were deposited in the Institute of Anthropology of the University of Coimbra; however no record of the first campaign of excavation has been kept. Further archaeological works identified more human remains that have being interpreted as part of the same cemetery (Silva et al. 2009). Documental evidence dating to 1083 showed the presence of a church in this same location dedicated to S. João and in Sisnando's will, another reference is found to a newly built church in 1087 (Silva et al. 2009:26). It is unknown when the church of São João de Almedina was founded but some early studies on the architecture of the city, proposed as a likely date the beginning of the 12th C.  It was in use until the late 15th C but the sources seems to be lacking for the following century and the parish registry started again only in the 18th C referring to the new church that was built on the site in the 17th C. It is possible therefore to assume that a minimal use of the church could have still happened in the 16th century, and was abandoned for a few years before the construction of the new church in addition to the Bishop palace still preserved today (Coelho 1989). Although some later individuals may be included in the cemetery, the majority of the samples can be ascribed to the 12th-15th C, following the Christian conquest of Coimbra in 1064. Regarding the social status of the population buried in the cemetery, some suggestions have been put forward regarding the presumed higher status of its components, however this is based on the idea that the people residing within the citadel held positions from the clergy, cathedral chapter and nobility and on the use of this burial ground for the bishops of Coimbra between 1088 and 1147 (Silva 2014). Because little is known on the foundation of the church and its use as burial ground, and because of the small sample size analysed from this site, this group is here intended as an urban Christian medieval population, and as a useful comparison to the contemporary Muslim and Christian populations from Southern Portugal (Lisbon, Silves and Beja).

### 5.3.2 The cryptoportico

A small assemblage of faunal remains have been analysed from Coimbra in order to provide a baseline for the human diet and food consumption, as well as providing some information on the animal husbandry practice of a Christian urban centre. The remains were recovered in a series of excavations that took place between 2006 and 2008 in the area of the Roman cryptoportico and forum, adjacent to the church of São João de Almedina, which later hosted the Episcopal palace (Fig. 5)(Silva 2009). Faunal remains were assigned to the medieval period (12th-15th C) following the stratigraphy of the site and the pottery typology (Silva 2014).

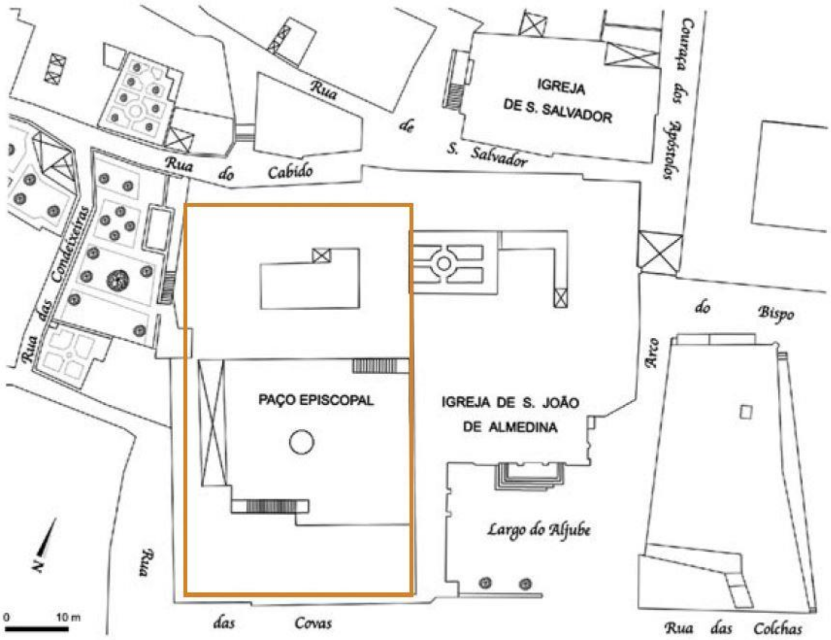

*Figure 5-5* *Excavated area of the cryptoportico and Claudian forum. Adapted from Silva (2009:27), taken from the map of Coimbra drawn by F. and C. Goulart in 1873-1874.*

A breakdown of the human and animal remains analysed from this site is provided in tables 5-5 and 5-6.

| Adults | |
|---|---|
| Males | Females |
| 8 | 8 |
| **16** | |

***Table 5-5*** *Breakdown of the analysed individuals from the cemetery of São João de Almedina*

| Species | n |
|---|---|
| *Bos Taurus* | 3 |
| *Capra hircus* | 5 |
| *Sus* | 5 |
| *Gallus* | 3 |
| *Anser* | 1 |
| *Equus* | 1 |
| *Tot* | **18** |

***Table 5-6*** *Breakdown of the analysed faunal samples from Criptoportico*

Coimbra is the only Christian urban site of the data set and provides a good comparison to the Islamic urban sites from Southern Portugal. Although it has been briefly under Islamic rule, the chronology of the human sample refers to the late medieval period and inform on the diet of an urban Christian population in a territory that even under Islamic rule, preserved a strong Christian identity. With the data from Laranjal, provides information on the Christian north and possibly offer an insight into different urban and rural dietary practices.

### 5.4 Lisbon and Central Portugal

Lisbon is located at the mouth of the River Tagus in central Portugal. The hilly terrain and its location on the estuary of an important river with direct access to the sea, made of this city a favourable site for settlement. The city of Lisbon holds traces of settlements from the Neolithic period. It was a very important trading post during Phoenician times; later conquered by the Romans as a consequence of the Punic wars, and then integrated into the Roman province of Lusitania whose capital was located in Emerita Augusta (present day Mérida). The city benefitted from a tax free status during Roman times, with a high level of autonomy over the urban and suburban area (Moita 1994:35-68). Following the fall of the Roman Empire and the arrival of barbarian tribes, the city was occupied by Sarmatians, Alans and Vandals in the 5th C. In the north, the Germanic Suevi settled in Gallaecia (modern day Galicia and northern Portugal), made Bracara Augusta (Braga) their capital and controlled the region of Lisbon until 586, when the Suevic Kingdom was included into the Germanic Visigothic Kingdom of Toledo, comprising the entire Iberian Peninsula (Collins 1994:507-68). The Islamic army took the city during its rapid first expansion in 711. Muslim families ruled the city until the Christian conquest in 1147. Lisbon has been long referred to as a major centre for Mozarabic people and culture (Marques 1993). One of the first account of its Christian conquest reports that a large part of the population was found to be Christian and was tolerated under Islamic rule. Muslim rulers, especially at the beginning of their reign, were well aware of the perils of highly restrictive religious policies and decided to amalgamate pre-existing customs and practices with their own. This fusion of culture and faith was more pronounced in the northern areas of the Islamic domain, in the so called Balata area (more or less modern day Portuguese Estremadura) located between the Mondego and the Tagus, including the main centres of Coimbra, Santarém and Lisbon (Malcolm 2007:16). Several Islamic sites have been uncovered in Lisbon as well as in the surrounding areas of the Portuguese Estremadura. However, the majority and the most important Islamic sites and materials come from the city itself and a couple of other important centres like Santarém and Setúbal. The centre of Portugal was very close to the Christian border and a reflection of the near threat is shown by the large number of fortifications and defensive structures in this region.

Lisbon was cited by Arabs authors mentioning its territory, fertility of its fields and produce. Al-Razi described Lisbon as being located west of Beja and Cordoba, and among its major economic activities, spoke of big spaces devoted to agriculture, fishing and hunting as well as the production of good honey (Sidarus and Rei 2001:40). Al-Idrisi described Lisbon as a perfect city on the River Tagus with a view onto the southern Almada region, provided with a defensive wall and a citadel (Sidarus and Rei 2001:49). Lisbon was an urban centre of relative importance for the western part of Al-Andalus, however it lacked political and administrative power, ousted by bigger political centres such as Cordoba, Badajoz, Seville and Mérida (Bugalhão 2009:379-380). The reasons of its growth to one of the main centres of the western Iberian Peninsula, are therefore to be sought in the economic and commercial role played by Lisbon during the centuries of Islamic occupation, thanks to its location on the River Tagus overlooking the Atlantic ocean (Bugalhão et al. 2008).

At the end of the 10th century a significant increase in population is witnessed by the expansion of the city outside the city walls with the creation of extra-mural neighbourhoods near the river where commercial, craftwork and fishing activities would have taken place (Bugalhão 2009:383, Bugalhão and Folgado 1997). The process of urbanization in any Islamic city tended to define a space for the political and religious power – the citadel (alcáçova); and an urban habitational space (medina) (Insoll 1999). These two parts of the city were both included in the surrounding fortified walls (Cerca Moura) that have been described by several historical authors. Al-Himari talks specifically of the layout of the wall in the 13th C and reports about the main gates of the city (Sidarus and Rei 2001:58). At the top of the Castle hill, nowadays Santa Cruz neighbourhood, the citadel was located, protected by defensive walls and in a privileged position to control access to the city by land and by sea (Matos 1999:80). The citadel hosted the governor and his court, including spaces to carry out administrative and military tasks such as tax collection and military recruitment, and providing habitational spaces for the families in charge of those duties (Amaro and Moita 1994).

In terms of religious and common spaces, the reuse of the Islamic structures during the later medieval period does not allow a clear identification of the mosques and the public baths. The medieval Christian cathedral (Sé) was excavated in the 1990's and although it has been proposed that it was built on top of a mosque, strong archaeological evidence is lacking. A second mosque would have being located near the Castle, in the modern day neighbourhood of Santa Cruz, underneath Santa Cruz church (Santana and Sucena 1994:841). A third mosque would have been located in the western suburb of the city, under the church of São Julião now hosting the Bank of Portugal, and would have served one of the most developed and populous suburbs of Lisbon. Archaeological interventions in Praça da Figueira (Banha da Silva et al. 2011), Rua Augusta (Bugalhao and Folgado 1997), Rua do Ouro (Bugalhao 2009:387) and Rua de S. Nicolau (Sepulveda et al. 2003) confirmed the extension and intense activity of this residential and industrial neighbourhood, central to trading, fishing practices and pottery making.

The eastern neighbourhood, Alfama, is believed to take its name from the existence of a public bath (al-hamma, in Arabic hot fountains or baths) and is mentioned by the Arab traveller Edrici, as the heart of the Islamic city of Lisbon (Matos 1999:81). Archaeological excavations in this area allowed an estimation of the size and vocation of this suburb and identified another residential quarter dating to the period of the Christian conquest (Bugalhao 2009).

In Lisbon six sites have been analysed for this study: human skeletal remains from São Jorge Castle, Calçadinha do Tijolo in Alfama, Largo das Olarias and Quarteirão dos Lagares in Mouraria and in conjunction with two animal assemblages from Praça da Figueira and Casa da Severa in Mouraria (Figure 5-6). These sites, of different chronology, provide an invaluable source of information on one of the main urban centre in medieval Portugal, both under Islamic and Christian rule. The assemblage from the castle, offers an insight into the diet of population of higher-status which has rarely being assessed before, due to the lack of hierarchical organization in Muslim cemeteries or grave goods. The second early medieval site, Calçadinha do Tijolo, although it is composed on only five individuals, inform on the diet of the urban population and is contemporaneous to the caste assemblage. The two late medieval sites, Largo das Olarias and Quarteirão dos Lagares, excavated in the Muslim quarter of Lisbon, are of significant importance to this thesis as they represent the community of Muslims living under Christian rule, after the Christian conquest, shedding light upon the dietary practices of religious minorities but also providing a comparative data to assess the chronological evolution of Muslim diet along the entirety of the Medieval period. In addition, Largo das Olarias, being a multi-faith burial ground, provides the opportunity to compare the diet of contemporaneous Muslim and Christian individuals from the same location.

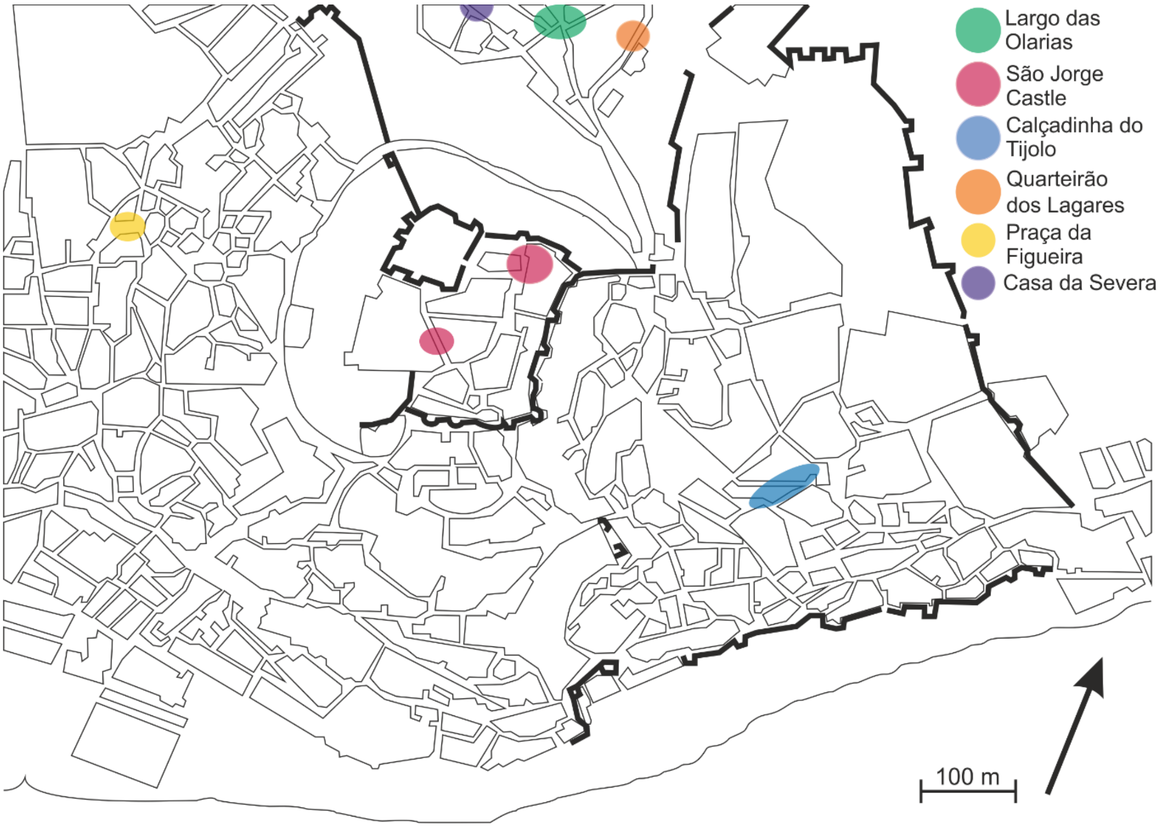

*Figure 5-6 Map showing the location of the analysed sites in Lisbon (the smaller circles indicates the animal assemblages). The layout of the remaining medieval walls is highlighted. Redrawn from Google Maps.*

### 5.4.1 São Jorge Castle

The excavation of these two sites (Fig.5-7) took place within a larger archaeological intervention that involved a big portion of the citadel to rehabilitate some of the old structures, but also to follow some of the road works in the area (Gaspar and Gomes 2001).

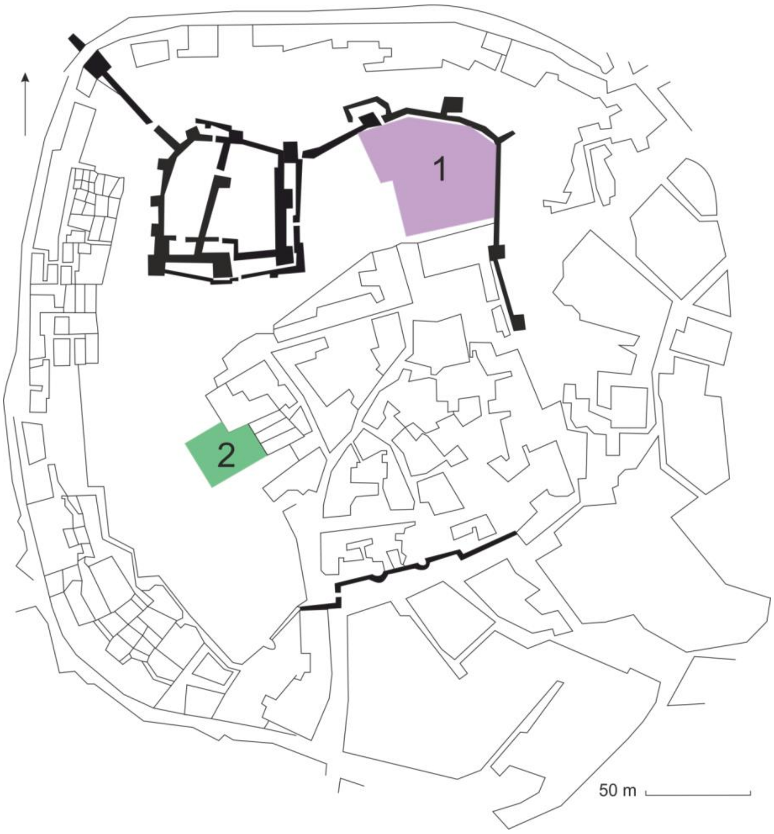

***Figure 5-7*** *Map of São Jorge Castle. The highlighted areas represent the location of the human burials: purple area (1) Praça Nova, and green area (2) Palacio das Cozinhas (adapted from Gomes et al 2003:Fig.1).*

Although both sites provided Muslim burials, little is known on the archaeology of the Palácio das Cozinhas, while the results from the excavations that took place in Praça Nova, with a specific focus on the Islamic period of occupation, have been published (Gaspar and Gomes 2001; Gomes et al. 2003). The area seemed to have had a residential use through the Islamic period confirmed by the recovery of several layers of occupation and re-use of previous walls in the earlier period and the uncovering of a proper neighbourhood with well-defined streets and blocks of houses, dated to the 11th century (Gomes et al. 2003:219). The layout and location of the houses, their size, and the internal decoration of walls and floors point towards a higher status settlement, especially when compared to similar dwellings outside the city walls (i.e. Praça da Figueira) in which the modular house with one or two rooms was the norm (Banha da Silva et al. 2011). In the eastern part of Praça Nova, some Islamic structures were found, however their use seem to cease with the Christian conquest, and in the later medieval period, gardens are mentioned in this area (Gaspar and Gomes 2001:96). The individuals that have being analysed, both adults and non-adults, are presented in table 5-7.

| **Adults** | | | **Non adults** |
|---|---|---|---|
| Males | Females | Indeterminate | |
| 3 | 5 | 1 | 18 |
| | **27** | | |

**Table 5-7** Breakdown of the analysed individuals from São Jorge Castle

### 5.4.2 Alfama

The excavation at Calçadinha do Tijolo took place in 2014 following the refurbishment of a building and its courtyard. Four trenches were excavated to assess the archaeological impact of the construction works, leading to the recovery of 5 individuals buried following the Muslim ritual (table 5-8).

| **Adults** | | | **Non adults** |
|---|---|---|---|
| Males | Females | Indeterminate | |
| 1 | 2 | 1 | 1 |
| | **5** | | |

***Table 5-8*** *Breakdown of the analysed individuals from Calçadinha do Tijolo (CDT)*

Because of the small size of the excavation and the reduced number of individuals, it is hard to put forward an interpretation for this site in relation to the wider urban setting of Islamic Lisbon. However, it is likely that these burials are part of the Islamic cemetery that served the eastern suburb of Lisbon that is mentioned in the historical sources as being located outside the eastern gate, near the hot springs (Sidarus and Rei 2004:58).

### 5.4.3 Mouraria

This neighbourhood of Lisbon probably already existed under Islamic rule; however it was formally recognised and given to the Muslim community still living in Lisbon after the conquest, in an official royal document dated to 1170 (Barros 2015). It has being described as a poor area devoted to agriculture, small scale trading and pottery production. Toponymic references to the pottery workshops in this area are retained in the name of the streets (Rua das Olarias, Largo das Olarias) and in this area was located one of the main clay sourcing site of the city of Lisbon (Bugalhão 2009). Recent ongoing excavations that started in 2015 brought to light several burials and identified what it is thought to be one of the main Islamic cemeteries of Lisbon. This recovery is significantly changing what was known of Lisbon under Islamic rule, since the only Muslim burials until then were recovered in the castle and are not representative of the urban population because of their small sample size and peculiar location.

The excavations at the site of Largo das Olarias are still on-going and therefore an in-depth study of the chronology and the use and development of the site is underway. However the complex stratigraphy of the site, and archaeological finds such as coins and pottery, suggest a late chronology for the main part of the cemetery (13th-15th C). The majority of the burials followed Muslim ritual, however 3 burials in the oldest layer of use of the cemetery were buried following Christian customs. A breakdown of the individuals analysed for this site is provided in table 5-9.

| Muslim | | | Christians | |
|---|---|---|---|---|
| Males | Females | Indeterminate | Males | Females |
| 9 | 9 | 1 | 6 | 10 |
| | | 35 | | |

***Table 5-9*** *Breakdown of the analysed individuals from Largo das Olarias (LOL)*

The excavation at the Quarteirão dos Lagares were performed by the archaeological unit ERA in 2013 and uncovered a total of seven individuals, although only five have being sampled for analysis (table 5-10). Because of the location of the burials, it is possible that they are part of the same cemetery excavated in Largo das Olarias; however the reduced size of the trenches in this excavation, did not allow a comprehensive assessment of the relation between these two burial grounds. The individuals were buried on their right side, oriented N-S and facing East, following the Muslim ritual. Because of the materials associated with the excavation, a later medieval chronology has been hypothesised for this assemblage (ERA-Arqueologia 2014).

| Adults | Non adults |
|---|---|
| Females | |
| 3 | 2 |
| 5 | |

***Table 5-10*** *Breakdown of the analysed individuals from Quarteirão dos Lagares*

In 2010 and 2012-2013, archaeological works were performed at Casa da Severa, located in the heart of the Mouraria, just over a hundred meters from the Muslim cemetery of Largo das Olarias. The archaeological intervention was part of a wider project for the requalification of the entire neighbourhood and specifically to renovate this property to host a cultural and social hub for the Mouraria. The excavation identified several level of frequentation with early and late medieval pottery as well as faunal remains dating between the 12th and the 17th C. The faunal remains sampled for this study were chosen from the medieval period 12th-15th C (table 5-11) (Antonio Marques personal communication).

| Species | n |
|---|---|
| *Bos Taurus* | 10 |
| *Ovicaprid* | 1 |
| *Ovis aries* | 6 |
| *Capra hircus* | 1 |
| *Sus* | 1 |
| *Gallus* | 2 |
| *Canis* | 1 |
| *Pagrus pagrus (seabream)* | 1 |
| *Tot* | **23** |

***Table 5-11*** *Breakdown of the analysed faunal samples*

### 5.4.4 Praça da Figueira

This square in central Lisbon was one of the first locations to be archaeologically explored in the 1950s and in later years, archaeological works continued, bringing to light several levels of occupation from Roman times until the post-medieval period. Of particular importance is the recovery of a part of the Roman cemetery with remains of funerary monuments, which highlighted its importance during the imperial period and a subsequent change in its use for the later Roman period with the reduction of the cemetery to a small area. During the Late Antique period, this area seem to be abandoned and traces of human activity are scarce. In the western part of the excavation, a main road structure has been found and identified as one of the main axes of the medieval town exiting the urban centre (Banha da Silva et al 2011). In the south-western quarter, a residential area has been found, with at least 14 individual units organised in four blocks of houses with clearly marked streets and passageways. The period of major frequentation and use of these blocks seems to point toward the 11th-12th C, based on the amount and typology of the pottery in situ (Banha da Silva et al 2011:22). The faunal remains analysed from this site are presented in table 5-12.

| Species | n |
|---|---|
| *Bos Taurus* | 11 |
| *Equus* | 1 |
| *Ovis aries* | 5 |
| *Capra hircus* | 3 |
| *Sus* | 6 |
| *Gallus* | 5 |
| *Canis* | 2 |
| *Felis catus* | 2 |
| *Oryctolagus cuniculus* | 1 |
| *Corvus corax* | 1 |
| *Merluccius merluccius (Hake)* | 1 |
| *Galeorhinus galeus* | 1 |
| *Tot* | 39 |

***Table 5-12*** *Breakdown of the analysed faunal samples*

## 5.5 Setúbal and Palmela

Setúbal is located about 30 km south of Lisbon, in the middle of a bay functioning as a natural port, where the River Sado estuary and the Atlantic Ocean meet (Fig. 5-8). The coastline is very flat and for this reason dangerous in time of conflict, however the plain meets the Arrábida massif at its western side, providing shelter and naturally defended hilltop locations. In addition, marine and fluvial ecosystem played a significant role in food supply and economic activities such as salt production, as well as providing easy accessibility to the interior. Gold mines are also mentioned in the area as well as gold being found in the River Sado by Roman authors (Fernandes 2004). These peculiar characteristic made Setúbal peninsula a particularly favourable place for human settlement that left traces from the Middle-Late Paleolithic to the Roman period (Fernandes 2004:46).

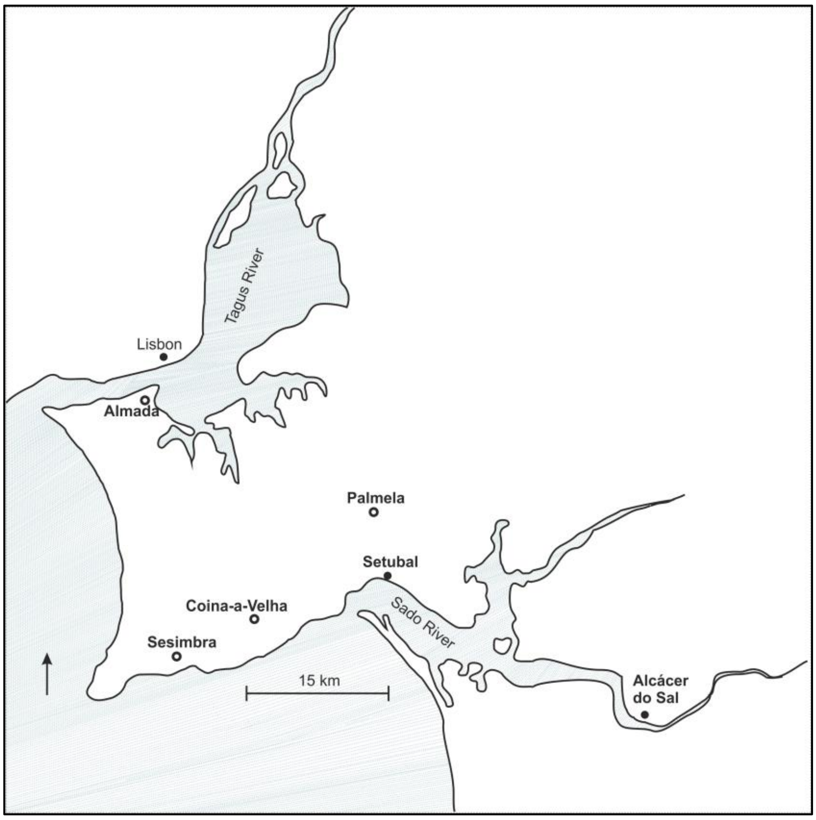

***Figure 5-8*** *Setúbal Peninsula. The location of the four Islamic castles are shown (Almada, Sesimbra, Coina-a-Velha, and Palmela) as well as the location of important centres such as Lisbon, Setúbal and Alcácer do Sal (adapted from Fernandes 2004, fig 24).*

During peaceful times, thanks to its naturally protected port, Setúbal was a perfect harbour for all maritime transit, with links, under Islamic rule, to Alcácer do Sal (Silveira 2008). The Setúbal peninsula gave access to a series of centres located on main traffic arteries, both waterways and overland roads, such as Almada, Lisboa and Alcácer, as well as regulating the connection between Lisbon and the southern part of Portugal (Silveira 2008). However, the vulnerability of the centres in the plain can be seen from the scarce archaeological finds dating to transition periods such as Late Antique to Islamic and Islamic to Christian (Silva et al. 2014). The strategic location of the peninsula played an important role in the Christian conquest of the Islamised south. The richness of water and rivers in this area has also being widely exploited in the past for different economic activities testified in the documents of the Order of Santiago including watermills, lime kilns, and the cultivation of oranges, which has been known in this area up until modern times (Fernandes 2004:187).

The archaeology of Setúbal has been the object of interest and continuous research by the local Museu de Arqueologia e Etnografia do Distrito de Setúbal (MAESD) since its foundation in 1974. The oldest occupation of Setúbal can be traced back to the Bronze and Iron age, about 8th C BCE (Soares and Tavares da Silva 1986, Correia 1995). During Roman times, the settlement looked like a small village mainly devoted to maritime and fishing activities focusing on the processing of fish into several products as well as pottery and amphorae production (Tavares da Silva and Coelho-Soares 2014,2016). Excavations in the city centre have highlighted a continuous occupation throughout the Roman period from the 1st to the 5th century. Significant traces of occupation exist for the Islamic and later medieval period (Silva et al 2014).

The site from Setubal represent a small rural settlement on the seashore. This small Muslim community was probably subjected to the influence of Alcácer do Sal and Palmela and offer an insight onto the dietary practice of a small coastal settlement, potentially informing on marine versus terrestrial resources exploitation, while providing a comparison to the urban population of Lisbon.

### 5.5.1 Rua Francisco Flamengo

This site, in the centre of Setúbal, was excavated during a rescue archaeology intervention in 2008/2009. This central area of Setúbal, has been investigated widely and has given proof of human frequentation as early as the Iron Age, however the most significant findings date back to the Roman Imperial period and the Islamic period (Silva et al 2010:18). Roman walls and pottery have been found as well as five Muslim inhumations dating between 980 and 1150 CE (Beta-256936:1000±40 BP) (Figure 5-9).

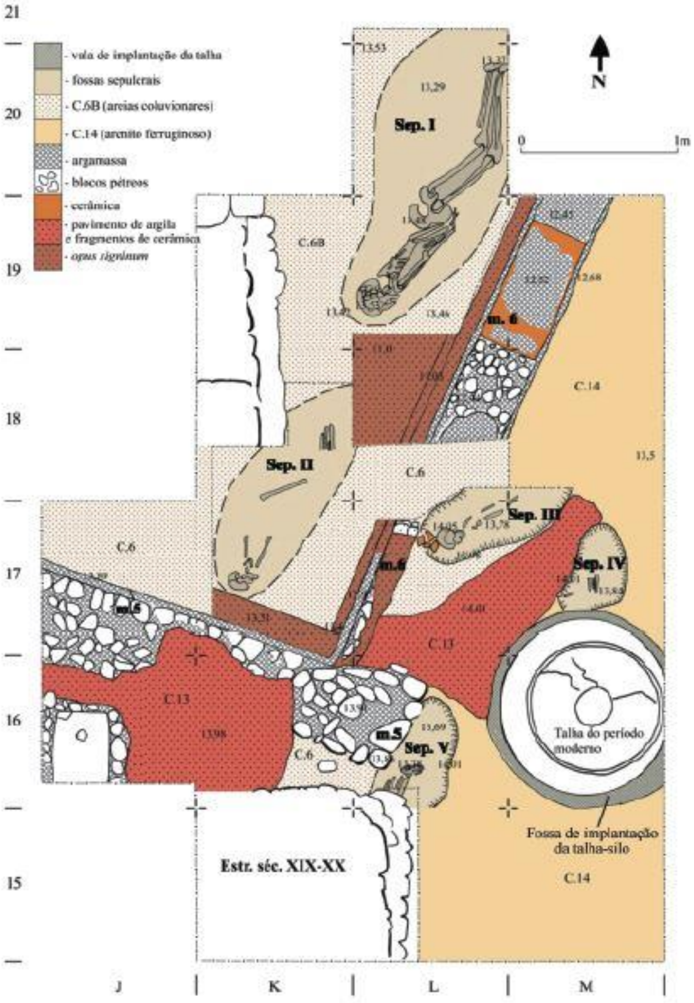

***Figure 5-9*** *Rua Francisco Flamengo 10-12, trench C. Map showing the Islamic burials and the Roman wall (adapted from Silva et al. 2014).*

A follow-up campaign in 2010 further identified 15 primary Muslim burials (left lateral decubitus, SW-NE orientation) with few more burials visible in section, suggesting the cemetery expanded beyond the limit of the trench (Silva et al 2014:188). These are the first Muslim remains uncovered in Setúbal and are of early chronology, suggesting that the cemetery must have been abandoned in the late medieval period after the Christian conquest. The individuals analysed from this site are presented in table 5-13.

| Adults | | | Non adults |
|---|---|---|---|
| Males | Females | Indeterminate | |
| 0 | 3 | 1 | 5 |
| | 9 | | |

***Table 5-13*** *Breakdown of the analysed individuals from Rua Francisco Augusto Flamengo (FAF)*

### 5.5.2 Castle of Palmela

The castle of Palmela is located on a high promontory overlooking a wide area over Setúbal peninsula, at the junction of the plain and the Arrábida massif (Figure 5-10).

***Figure 5-10*** *View from Palmela Castle to Setúbal and Troia peninsula (Alice Toso 2015).*

The high visibility of the place, allowed it to be a stronghold of the Islamic power, especially during conflictual times when it sheltered the population of the villages in the plain, Setúbal being one of them. Palmela was included in a defensive system of four castles with Sesimbra, Almada, Coina-a-Velha, and several watch towers along the territory. After the first Christian conquest, a large number of Muslims continued in Palmela and this is testified by a royal document, dated 1170, that allowed them to remain. Palmela was the object of intense conflicts and battles during the Almohad attacks in 1184 and 1191 but, after the final Christian conquest, was used as headquarter of the Order of Santiago, preparing the conquest of Alcácer in 1217. Another royal document granted permanence to the Muslim community until the 15th C (Fernandes 2004:188).

Archaeological works in the castle since 1992 have uncovered much of the past of this fortification. The stratigraphy of the site identified a continuous Muslim settlement and use of the site from the Emiral period (8th C) to the 12th C. Unfortunately the most recent layers have been disturbed by the construction of later buildings and the stratigraphy is less clear for the later phases of the occupation of the castle, which saw the coexistence of both Muslims and Christian at the same site (Fernandes et al. 2012). Zooarchaeological research has been performed on animal remains from the castle, leading to significant insight into the dietary habits of the communities of both Muslims and Christians living here across the century (Cardoso and Fernandes 2012). The results revealed a strong prevalence of ovicaprids in all periods of Muslim settlement as well as during the Christian period, however a high number of bovines was also found suggesting the plain area surrounding the castle was used for pastures. In terms of wild animals, deer and possibly wild boar are present. Similar frequencies of wild boar have been found also in the Almohad castle of Mesas do Castelinho (Cardoso 1994), although discriminating wild boar from domestic pig is often challenging and stable isotopes could provide useful insight on the diet of these specimens. A large number of domestic pig/wild boar belonged to immature individuals, evidence that has been used to support the idea of a military elite living in the Castle during the Muslim rule, since the consumption of juvenile animals is associated with higher strata of society (Cardoso and Fernandes 2012:232). Analysis of the butchery marks revealed that the preparation involved larger anatomical parts, usually cut at the joints and used for substantial stews, ideally to feed a large military garrison, both in the Muslim and Christian period. Burned patches on the bone suggested the use of grilling as cooking alternative (Cardoso and Fernandes 2012:233). A more comprehensive study of a larger number of faunal remains from the same sites, highlighted a significant consumption of molluscs (60% of the determined remains) and rabbit/hare during the Islamic period (Fernandes et al 2012:115). The previously highlighted general trends of consumption have also being confirmed with a higher reliance on bovines and ovicaprids throughout the entire Islamic period, with wild species such as rabbit/hare, wild boar and deer. The Christian period is characterised by a sudden increase in domestic pig consumption, followed by ovicaprids. The faunal remains analysed from this site are presented in table 5-14.

| Species | n |
|---|---|
| *Bos Taurus* | 5 |
| *Ovis aries* | 2 |
| *Capra hircus* | 4 |
| *Sus* | 4 |
| *C. elaphus* | 2 |
| *Equus* | 1 |
| *Gallus* | 4 |
| *Tot* | **22** |

***Table 5-14*** *Breakdown of the analysed faunal samples*

## 5.6 Beja and the Lower Alentejo

Beja is located in the heart of the Alentejo plain in Southern Portugal. It is the capital of its own district that extends from the western Atlantic coast to the Spanish border (Figure 5-11). Beja was the main functional centre of Lower Alentejo from Roman times until the present day, reaching its economic and political apogee during Roman times and in the Caliphal period (10th-110th centuries).

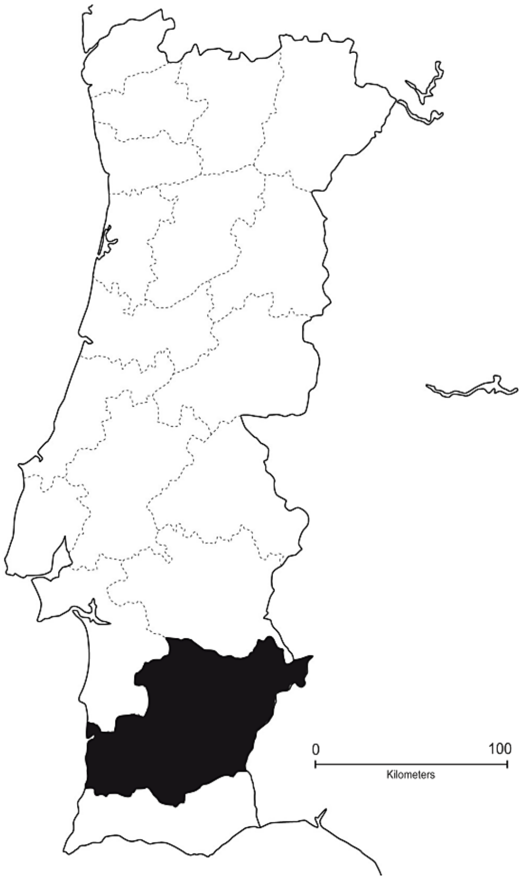

***Figure 5-11*** *Map of Portugal and the District of Beja in Lower Alentejo.*

The importance of Beja and its district during Roman times is reflected by the preservation of its original borders as well as the mention of this area with the Roman name (*Conventus pacensis)* in both Late Antique and early Islamic sources (Macias and Lopes 2012: 305). Previous studies on settlements strategy during the transition between the Late Antique and the Islamic period have shown rather scattered evidence for a number of smaller *villae,* acting as satellites of the main urban centre of Beja. Despite the lack of in-depth archaeological research on the evolution of the settled landscape in Southern Portugal during this transitional period, Macias and Lopes (2012:315) suggested that several centres in the Lower Alentejo showed a prolonged and continuous occupation between Late Antiquity and the Islamic period. The supporting archaeological record is identified in a series of Islamic fortifications; pottery assemblages; and as well as a Muslim necropolis dating 8th-12thC and spread across the entire district (Figure 5-12). The type of settlement during the Late Antique–Islamic transition period was characterized by several small rural settlements. It is hard to monitor the evolution of such a dispersed landscape but, although scattered, the density of the villages and towns may have been rather high, as suggested by the results of a survey undertaken in the area of Alcaria Longa by Boone et al. (2002). The survey, aiming at documenting the transition between the Tardo-Roman and Islamic period, mapped 22 Roman sites while the number of recovered Islamic sites was 157 indicating that a much more dispersed type of settlement and landscape use was introduced with the Islamic conquest (Boone 1995:25, see Fig. 2 and 3).

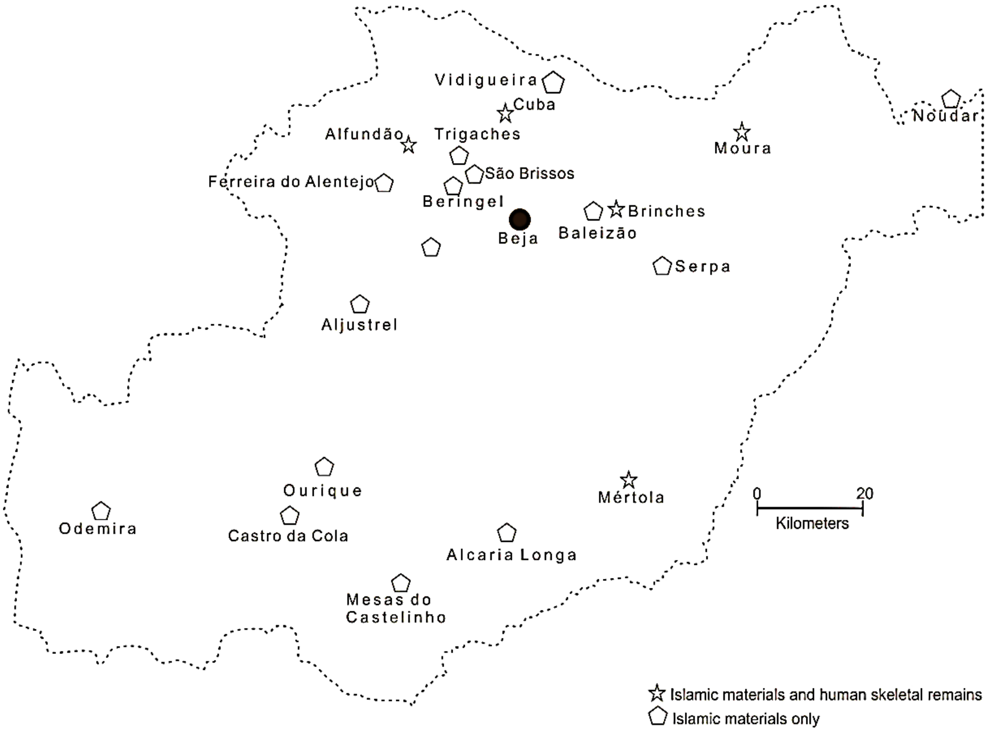

***Figure 5-12*** *Distribution of the main Islamic sites in the district of Beja (8th-12th C)*

Although rural villages and *alquerias* certainly prevailed as the main form of settlement in Lower Alentejo, a few towns showed a more urban character, acting as the main focus points for the economic, political and military apparatus of the newly formed Islamic power, such as Beja, Moura, Serpa, Alcaria Longa and the fortified port town of Mértola (Macias 2006). The route from Mértola to Beja, passing through Serpa and leading to Évora, was one of the most important commercial arteries of the region, thanks to the important contacts that Mértola maintained with the Mediterranean ports (Fig. 5-13). The town, through its fluvial port on the River Guadiana, had direct access to the sea and established long-term commercial relations with other ports of Al-Andalus. A second important route in crosses the region from the west to the east, connecting Alcácer do Sal to Seville, passing through Beja and Aroche. Both roads existed during Roman times and were still used in the 13th C (Macias 2006:83).

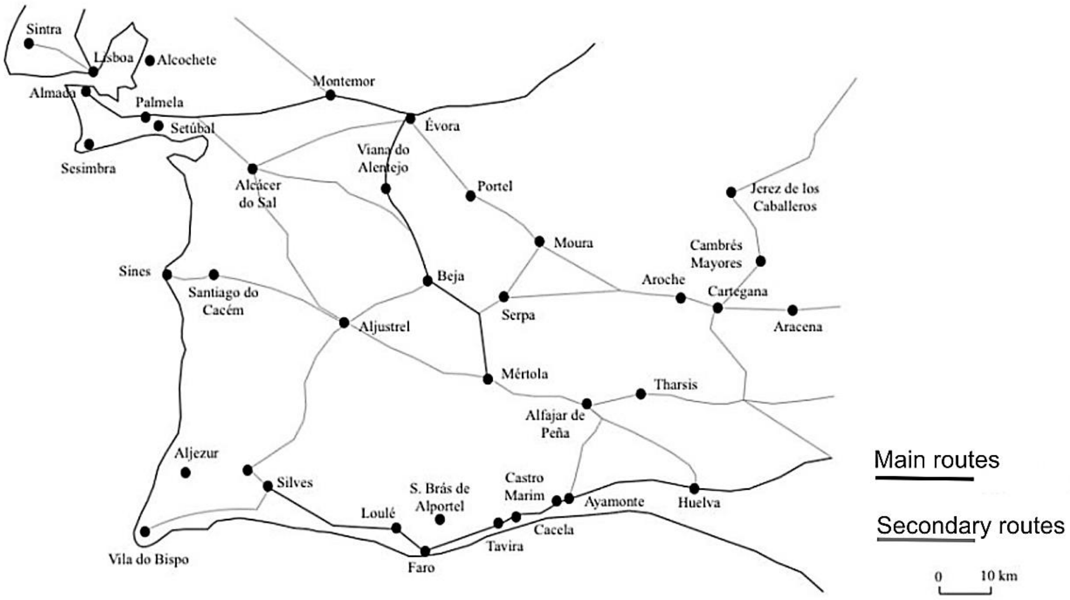

*Figure 5-13* *Main routes of communication during the Islamic period in southern Portugal (adapted from Torres 1997:353).*

### 5.6.1 Islamic Beja : historical context

The Islamic conquest of Beja is reported by Islamic sources to have happened around 712-714 in conjunction with the conquest of the town of Ossónoba-Faro (Catarino 1993). Although the majority of the Islamic and Christian historical sources post-dated the events of the Islamic conquest of Portugal, providing some uncertainty regarding its exact chronology, broad consensus has been reached on the strategy adopted to take the town of Beja. No armed conflict was reported; instead Beja was taken following peaceful negotiations (Chalmeta 1994:179). As per the usual customs, the town was subjected to the payment of a capitation tax (*jizya*) as well as asked to provide several buildings and properties for the new ruling autarchy (*kharáj*) (Sidarus 1996). Once the Islamic power was established, the emir left Beja in the hands of the governor Abd al Jabbar Ibn Salama al Zuhri (Macias 2006:29-30; Marques 1993:121). In 742 a second wave of Arab soldiers and families settled in Beja. These groups of people, originally military conscripts from Syria-Palestine and Egypt, arrived in the Peninsula to handle the animosity which had arisen among groups of Berbers already residing in Al-Andalus (Chalmeta 1994: 312-35; Manzano-Moreno 1993, Taha 1989: 132-50). These groups of soldiers decided to settle in the Peninsula, and successfully claimed part of the territories in exchange for their military support. Three districts were assigned to them: Murcia in the east and Beja and Ossónoba in the west. The ethnicity of these groups have been described in the sources and interpreted by modern authors as Yemeni (Sidarus 1996:30, Taha 1989:148). During the following years, and for the rest of the 8th century, the political climate of Beja, but not only there, was characterised by a series of tensions between the different Islamic groups and clans (*yund*) trying to gain power. Because of this period of political instability, the majority of the historical sources of this period are concerned with the upheavals, leaving a lot to the imagination in terms of the social dynamics that took place in a newly formed multi-faith society. However in one instance Christian groups are mentioned to have taken part in one of these protests, supporting a rebel named 'Urwa ibn al-Walid' against the legitimate governor in 750. The archaeological record is somewhat elusive on the presence and importance of the Christian groups living in Beja. Christians living under Muslim rule were called Mozarabs and sources are often elusive regarding their presence and lifestyle. However, a few funerary stelae have been recovered in Beja, Castro de Cola and Mértola dating to 8th-9th C, which suggests that up until that point, at least a part of the Christian community was wealthy enough to request this production[1] (Torres 1993; Torres et al. 2006; Torres et al. 1991). During the 8th and the 9th century, the importance of the city in terms of administrative power was accompanied by increasing waves of uprisings and in 929 the emir al-Rahman III had to act himself on behalf of the governor of Beja to re-establish his power over the city and its territory. The establishment of a new governor and influential families loyal to the central power was necessary to prevent future instability (Macias 2006:47). The 10th century saw the decline of Beja which at this point is rarely mentioned in the historical sources and was under the control of the governor of Ossónoba – Faro, suggesting that these two regions could have been administered quite easily at this point in time and there was no need for two political functionaries (Marques 1993:127-128; Macias 2006:51).

During the Almoravid (11th – 12thC) and Almohad periods (12th – 13thC) the kūra of Beja lost most of its original importance as well as much of its land, with the secession of main centres like Évora and Alcácer do Sal, which created their own districts. Mértola held at this stage a stronger economic and military role than Beja. During this period Beja is only mentioned again in the historical sources during the insurrection of Ibn Qasi from Silves, a Sufi political leader who guided the revolt against the Almoravid power in the al-Gharb. Beja returned to Almohad control after Ibn Qasi's death in 1151. The second half of the 12th C saw the first victories of the Christian armies in the south of Portugal and following the conquest of Santarém in 1147, groups of Christians took Beja for a short period of time in which they destroyed its defensive system and abandoned it (Garcia Domingues 1971:250; Macias 2006:61-62). Between 1172 and 1175 three Christian invasions happened in Beja with no particular attempt by Islamic forces to counter the Christian attack, which is another element that suggests the lack of importance that this centre held in the final stages of Islamic rule in Portugal. In 1175 Christian troops definitively entered the town, but for the following 60 years several incursions of both armies took place in the wide territory of the kūra of Beja and a stable political control over the entire region was not established until the beginning of the 13thC. In 1232 the western margin of the River Guadiana was secured, forcing the Islamic army to retreat. In the following years several victories of the Christian army caused a progressive contraction of the Islamic power in al-Gharb, until the final conquest in 1238 (Macias 2006:65).

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[1] For a review of the Portuguese scholarship and an updated bibliography of the Mozarab presence in the al-Gharb see Sidarus (2005) and Gomez Martinez (2015).

### 5.6.2 Islamic Beja: archaeological context

The archaeological record for the medieval Islamic period of Beja is rather scarce, especially if compared to the important role that the town played during the first centuries of Islamic control. Despite pioneering works in the 40s and 50s in the archaeology of the region by Abel Viana and Fernando Branco Correia, Islamic material was rarely found. This was also the case in the sporadic excavations of the 70s and 90s. It was only in 2003 that a systematic approach to the urban archaeology of Beja was considered under the scheme POLIS-Beja. In 2006 Isabel Ricardo undertook the drafting of the Carta Arqueológica of the district to gain an insight into the preserved archaeological sites of the region (Ricardo and Grilo in press). The results of the archaeological research in combination with historical source permitted an accurate reconstruction of the main lay-out of Islamic Beja (Figure 5-14). The town appeared to have had five gates and the layout of the Christian walls is believed to reflect the Islamic one. As already mentioned, one of the first acts of the Christian army during the Reconquest was to destroy the defensive system of the town, making it hard to assess how much of the original layout was preserved following the reconstruction of Beja under Christian rule.

*Figure 5-14 Layout of the medieval town of Beja. The dark teal rectangle is the secondary school Diogo Gouveia, where the main Islamic necropolis of Beja has been uncovered.*

After the Christian conquest, the Muslim population settled in the Mouraria quarter and the main Islamic necropolis of the town was believed to be near this area, outside the city walls and in proximity to the eastern gate (Torres and Macias 1998: fig 107). However in 2006, the Archaeological Unit Palimpsesto under the direction of Miguel Serra, started the archaeological assessment of Rua de Mértola and Rua Gomes Palma following the remodelling of the modern public water supply system of the town. Four interventions were carried out, recovering a total of 19 skeletons, buried following Islamic customs. The location of a burial area outside the city walls and in proximity to one of the city gates follows the general characteristics of Islamic burial grounds. In addition, in the entire Peninsula, the same burial grounds from Roman times were often re-used during the Islamic period (Torres and Macias 1998:35). This could have been the case also in Beja where a Roman grave was found in close proximity to the Muslim graves. Although the extensions of the trenches limited the possibility of further investigating the layout of the necropolis, it is important to report that some of the Muslim burials cut through Roman pavement levels made of *opus signinum*, suggesting that the town was bigger and more densely populated during Roman times and decreased in size during the Islamic period (Serra 2009:649). Radiocarbon dating has been performed on one of the individuals from this excavation giving the following dates: 1σ 903-914 cal CE; 969-1019 cal CE (Serra 2012:242). Broadly speaking this individual can be situated between the 10th and the beginning of the 11th century, when Beja was already losing her power in favour of the nearby centres of Évora and Alcácer do Sal; however a long-lasting use of this necropolis may be hypothesised since it is the only Muslim burial ground found so far.

### 5.6.3 Secondary School Diogo Gouveia

The human individuals that have been sampled for this research derive from a new series of archaeological works carried out at the secondary school Diogo Gouveia between 2009 and 2011 by the archaeological unit Neoepica (Figure 5-15). The works followed six phases of excavations that allowed the identification of a further extension of the Muslim necropolis, whose northern fringe was detected during previous excavations in 2006 by Palimpsesto. The excavation recovered a total of 276 primary burials, 255 of whom were Muslims and 21 Christians. The individuals were buried in shallow graves and no specific pattern is followed in the layout of the burials. Christian and Muslim burials share the same space and no segregation of either group can be appreciated from their distribution (Gomes et al. 2014).

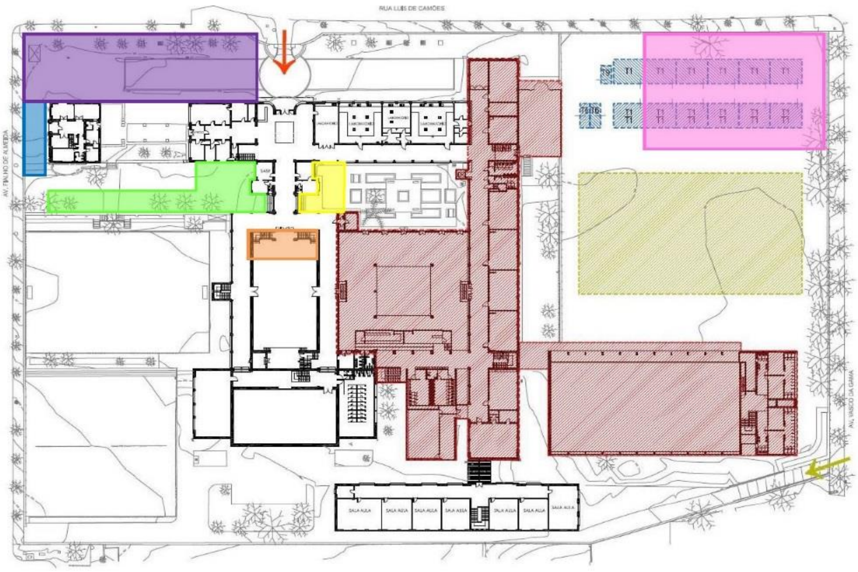

*Figure 5-15* The six phases of the archaeological works carried out at the Secondary school Diogo Gouveia by Neoepica Lda. (Gomes et al. 2014:10).

One of the main limitations of this excavation is the almost complete lack of stratigraphy, which highly limits the chance to investigate the development of the burial ground. There are some cases of Muslim burials intersecting each other as well as Christian ones, and in a couple of cases Christian and Muslims burials cut each other; however no real stratigraphy is shown in any part of the excavation (Figure 5-16).

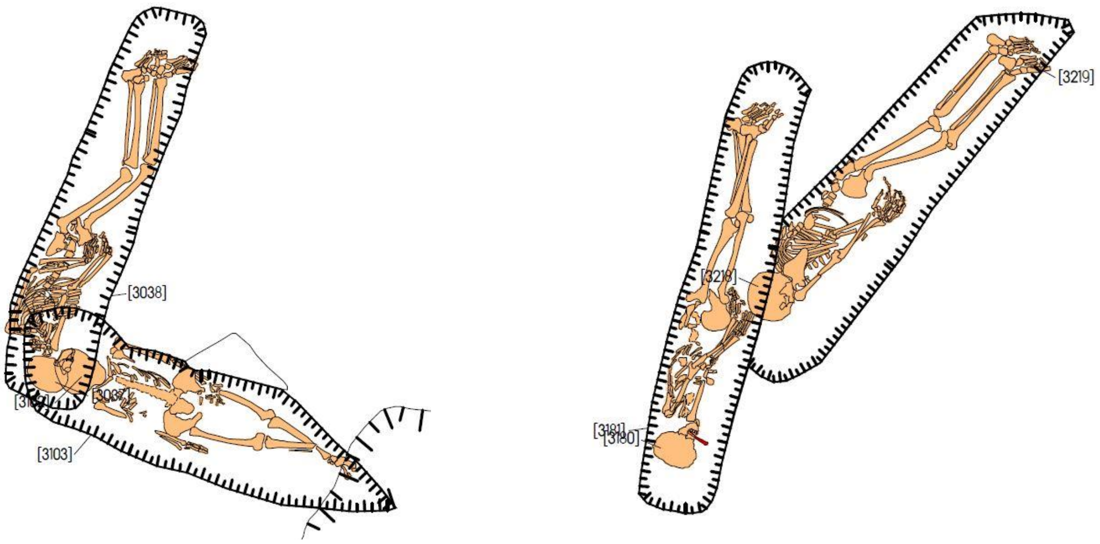

*Figure 5-16* Examples of a Muslim and Christian burial cutting each on the left; and two Muslim burials intersecting on the right (Gomes et al. 2014).

No objects were interred with the individuals following Muslim customs while one Christian individual was buried with three bronze rings. Unfortunately, the location of the cemetery of Beja had previously been unknown and was never mentioned in historical sources leaving little space to infer about its use and development, especially in the light of the co-existence of Muslims and Christians in the same burial ground. The analysed individuals from this necropolis are shown in Table 5-15.

| Christians | | | Muslims | | |
|---|---|---|---|---|---|
| Males | Females | Undetermined | Males | Females | Undetermined |
| 4 | 6 | 2 | 19 | 21 | 1 |
| 12 | | | 41 | | |

***Table 5-15*** *Breakdown of the analysed individuals per faith, sex and age*

This site has a significant relevance to the research questions of this thesis. It offers the unusual possibility to analyse the diet of Muslims and Christians from the same burial ground, similarly to the late medieval site in Lisbon. These two populations of potential contemporaneous chronology can inform on faith-related difference in diet and can be compared to other important urban centre during the Islamic period in Portugal such as Lisbon and Silves.

### 5.7 Silves, Loulé and the Algarve

The Algarve is the southernmost region of Portugal and despite its contained size, presents a diverse climate and environment between the interior and the coastal areas. Three different geomorphologic bands can be identified: a mountain range in the northern part, a second band of crags and hills (i.e. Barrocal) and a third band including the coastline. As a result the environment and both flora and fauna of these areas present significant differences. Silves is located in the Barrocal area which is characterised by calcareous hills in which oak trees are predominant as well as wild olive, myrtle, carob, almond and fig trees. Thanks to the irrigation of the valleys, these hills have also being used to cultivate citrus fruit trees. The area hosted a range of species such as eagles, owls, sparrows, wolf and Iberian lynx (Gomes and Ferreira 2005:40).

The coast is the true strategic platform of this region and the strong attraction of the sea is manifested in the settlement distribution across centuries with a strong preference for seaside locations. The first anthropic activities in the Algarve have been recently identified in a series of shelters and seasonal site use thanks to a survey project led by the University of the Algarve (Cascalheira et al. 2013). These territories have been exploited since the first half of the 8th century BCE by the Phoenicians first and the Greeks later, who came in contact with Southern Iberian populations (Brito 1992). The Greeks introduced a number of agricultural species that shaped the traditional food system of the region including fava beans, green peas, lentils, lupin beans and grass pea. In addition, fig and almond trees appear to be also introduced by the Greeks during this time in the Peninsula (Gomes and Ferreira 2005:40). The process of Romanization in this area has been affected by the natural landscape, especially on the coast. The environmental difference between the eastern side characterised by sandy beaches and lagoon systems is in stark contrasts with the rugged, high and rocky western coast. Communication with the Gaditan Bay in modern day Spain were favoured by proximity as well as easy navigation and harbouring (Bernardes 2010:357). Two main Roman urban centres – for which exist both literary and archaeological evidence - were identified in the eastern part: Balsa (near Tavira) and Ossonoba (Faro). Historical sources mention at least another important urban centre for the western side whose existence would be also justified by the vastness of the area; however there is no agreement on the site and no supporting archaeological evidence. Smaller towns were recognised in Ipses (Alvor), Cilpes/Cilpis (Cerro da Rocha Branca near Silves), Laccobriga (Monte Molião near Lagos) (Bernardes 2010, Arruda et al. 2008). Trading with the Gaditan bay and Italy is attested during this period with import of fish products, olive oil, wine and fine pottery ware (Viegas 2011:581). The archaeological data available for the late Roman period and up to the 5th century show that the political turmoil, characterising the rest of the Iberian Peninsula, did not affect the economic relations between this region and the rest of the Mediterranean. Although the Suebi took Mertola in 440, the Algarve is somehow forgotten during this period of conflict (Viegas 2011:588).

The Algarve has been the first Islamised part of modern day Portugal and also the region where the Islamic rule was established for longer and therefore produced the highest concentration of sites and materials dating to the Islamic period (Gómez Martinez 2015).

Although some sites documented better than others the transition from Roman to Islamic rule – i.e. Cerro da Vila (Matos 1994), Milreu (Teichner 1994), Serra de Monchique (de Meulemeester et al. 2006) Alcoutim (Catarino 2005) and Cacela Velha (Garcia et al. 2006) -

the majority of the excavations focused on later period, detecting the urban expansion of the 12th century. Despite the number of studies on domestic urban spaces, little archaeological evidence has been produced for public spaces, with the exception of Loulé, where the Islamic bath and part of the hydraulic system have been excavated (Luzia 2006, 2009).

The two locations analysed for this region are one of the main urban site during this period, Silves, and a small rural site, Quinta do Lago – Loulé, located on the coast and linked to fishing and weaving industries. The diverse nature of these sites inform on different economic strategies as well as dietary preferences between the 10th and the 13th century in both a rural and urban environment. In addition, the study of Christian burials from Silves allow a chronological as well as a faith-related assessment of diet in one of the most important centres of the Al-Gharb and can be compared to Beja and Lisbon similar data set.

### 5.7.1 Silves

Silves is located on top of a small hill, reaching about 50m above the sea level, on the shores of the River Arade. Silves is located in the modern day region of Algarve at about 10 km from the coast, however during the Middle Ages the distance would have been smaller and the River Arade provided a navigable waterway to the Atlantic ocean (Gonçalves 2009:491). The earliest archaeological evidence of human activity date back to the Bronze Age in the locality called Rocha Branca, a small elevation at the entrance of the town of Silves (Varela Gomes 1993:79). The settlement of this early community in this area would be driven by the resource wealth of the region, specifically copper (Varela Gomes 2002:88). The Romanization of the Algarve brought about a new political and administrative system as well as a new type of economy, creating settlements along the coast and small villages in the surroundings to exploit both agricultural and marine resources. One of the most successful industries for this period is without doubt the one dedicated to fish preservation with a series of sauces and condiments such as *garum* and *liquamen* (Fabião 1992 :248-249). The urban area of Silves would host in the 2nd century AD an important Roman temple, as suggested by two marble capitals, stelae and some dispersed material recovered in the city centre (Varela Gomes 2002:93-96). The late antique period is hardly identified in the archaeological record of Silves. The list of materials that can be dated to this period are a few pieces of pottery, a marble funerary stone and rare architectural elements such as a couple of capitals (Dias and Gomes 1992:180). At the site of the Castle, beneath the Islamic wall, a series of late antique vessels have been found, dating to the 6th-7th C and suggesting a continuity of occupation until the Islamic period (Gomes and Gomes 1990:60-62). After the Islamic conquest of Silves in 713, the city acquired a prominent role in the region and between the 10th to the 13th century, it is mentioned as one of the most important centres of the Gharb al-Andalus (Coelho 1989; Lévi-Provençal 1982). Its importance was partly a consequence of its strategic location at the confluence of two main roads, one from the north and another longitudinal road, crossing the region from the western coast, parallel to the sea. Following some texts (Lévi-Provençal 1982:130) the first inhabitants of Islamic Silves were of Yemeni origin, as at Beja, and the Arab origins of this centre were cited quite consistently as a reason for its prestige, sophistication and importance. In 846, the port of Silves hosted a meeting between Abd al-Rahman II representatives and a Viking leader to negotiate a peace treaty between the two powers (Picard 2000:67). The taifa period was rather favourable for Silves, dependent on Seville. It was chosen by king Al-Mutamid to be administered by his son and heir Al-Mutamid, who lived there for a few years and wrote a poem about his nostalgic feeling towards Silves once he left (Coelho 1989:300-302). During the second taifa period, Silves minted coins from 1146, in both gold and silver, being the only centre with a mint in the modern Portuguese territory. The city was also known for its poets, historians and philosophers (Coelho 1989). In 1189 Silves fell under the first Christian attack, was destroyed and burned down, and remained under Christian rule for two years before it was then reconquered by Islamic forces. A general reorganization of the town took place after that, including the construction of a new and enhanced defensive system (Varela Gomes 2002:112). Silves was finally conquered by the Christians in 1248.

Extensive archaeological works have been carried out since the 1980's in Silves, allowing us to reconstruct fairly confidently the layout of the Islamic city. Its defensive system was composed of at least four towers and defensive walls with four gates (Figure 5-17).

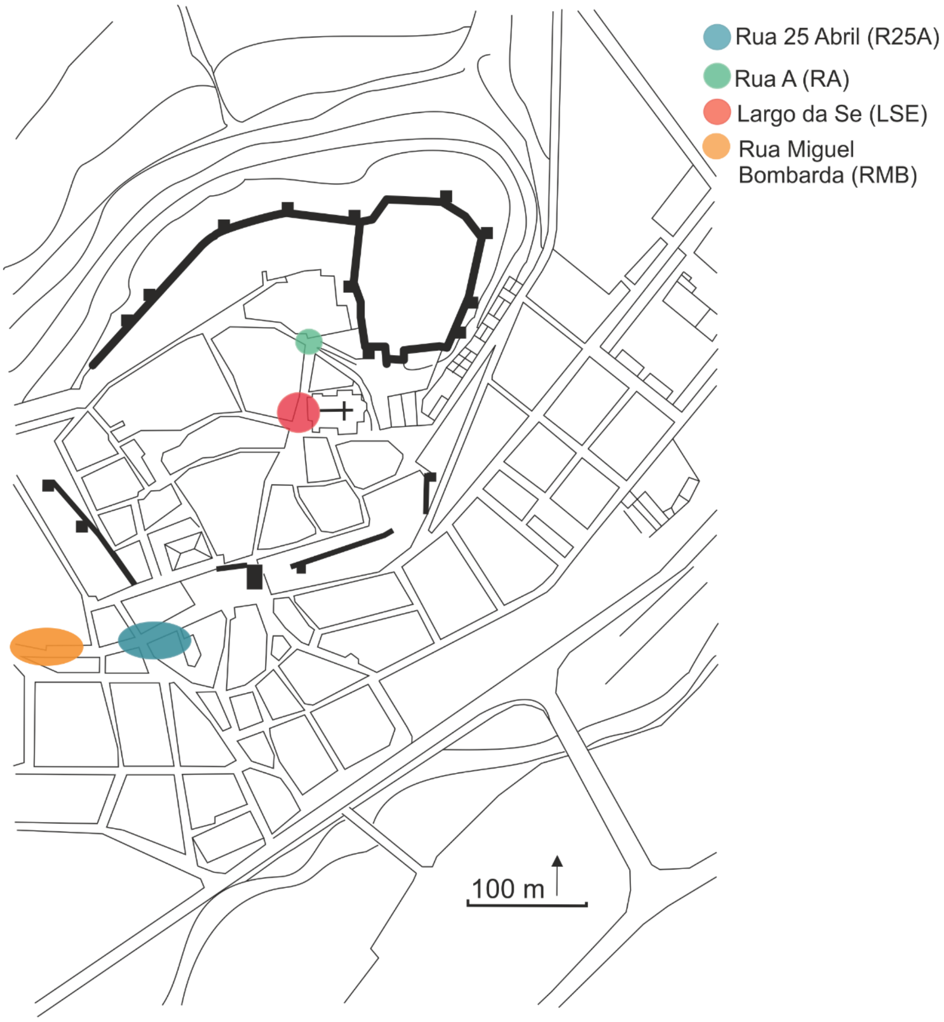

***Figure 5-17*** *Layout of the medieval walls of Silves with the location of the analysed sites. Rua 25 Abril and Rua A are Muslim burial sites while Largo da Sé and Rua Miguel Bombarda are Christian cemeteries. Redrawn from Gonçalves (2009).*

Little is known about the places of worship of the city that have not been recorded archaeologically, however two sources, refer to mosques located outside the city walls, while it is believed that the main mosque would have been located beneath the Christian cathedral (Gonçalves 2009:493). The city benefitted from a complex water supply system, composed of several underground channels and cisterns, four of which have been excavated. The biggest and most remarkable example is the cistern located in the space adjacent to the castle, followed by another underwater tank located a few meters away from the first one and a third one was excavated in a house nearby the gate that led to the citadel, hosting today the archaeological museum of the city (Gomes 2006). A fourth cistern was excavated between the castle and the cathedral, whose use might have been related to the mosque (Gamito 2003:240).

In terms of the residential areas, both the area inside the city walls and the suburbs have provided examples of domestic architecture for the Islamic period (Figure 5-18). Although not all of them have been completely excavated, more than 30 houses have been identified. Apart from the one excavated in the castle of clear higher status and wealth, possibly hosting more than one nuclear family (Figure 5-18a), the houses within the urban centre follow the pattern of Islamic houses with a patio and one or two rooms overlooking onto it. The main room usually presents several alcoves, which helped to divide the functions of this room used to receive guests, work and sleep. A second room, of usually smaller size, would host ovens, fireplaces and other type of workshops. When this secondary space is missing, the patio was used for all the activities that could not have been carried on indoors (Gonçalves 2009:504).

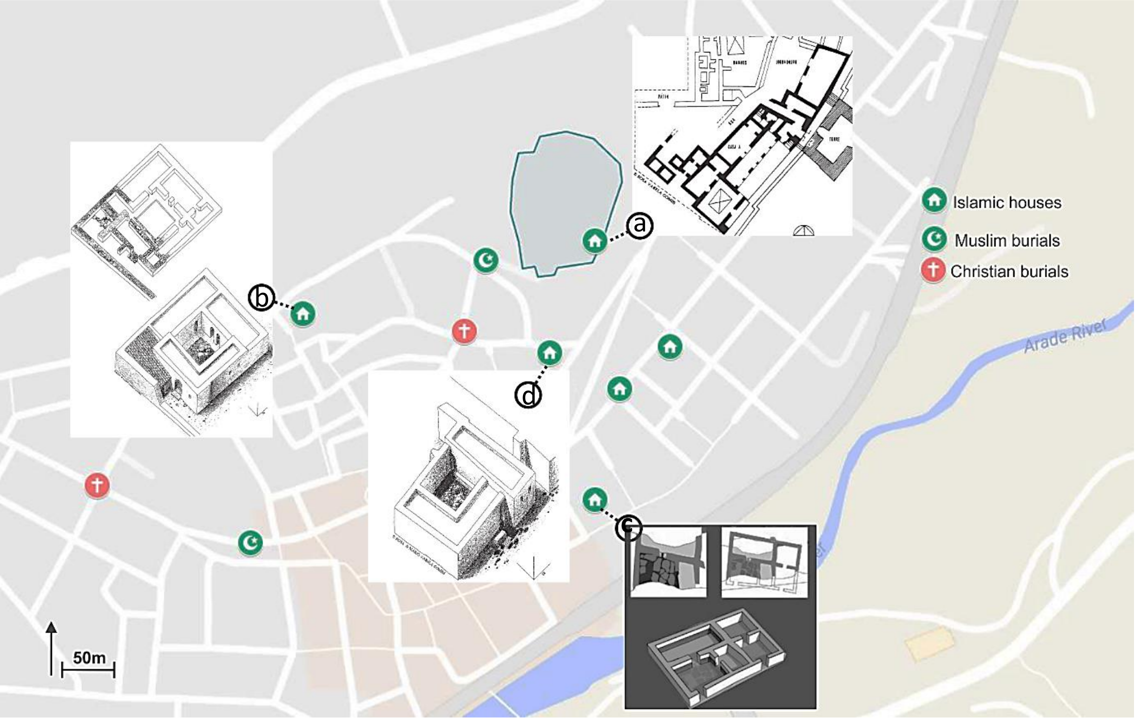

***Figure 5-18*** *Examples of excavated Islamic houses and burials sites: a (Varela Gomes 2002:Fig.38), b (Gomes 2011: Fig. VI.23), c (Gonçalves 2009:Fig. 9), d (Gomes 2006:Fig. 2.23).*

In terms of burial sites, a recent work summarised both the recovering of scattered human remains as well as cemeteries dating to medieval times (Gonçalves et al 2010). Two main Muslim burial sites have been identified respectively Rua A and Rua 25 Abril, while two main Christian cemeteries have been excavated surrounding the Cathedral (Largo da Se) and in Rua Miguel Bombarda.

### 5.7.2 Rua A

This burial site was excavated in 2007, where 20 Muslim burials were recovered (Santos et al 2008). The quadrangular space was walled on at least three or the four sides and presented mostly juvenile individuals. Because of its location in the centre of town, therefore against the usual convention of placing the cemetery outside the city wall, this space was interpreted as an early burial site, dating to the first Islamic settlement, when Silves could have been much smaller. However the materials associated with the excavation dated to the 12th-13th century (Gonçalves 2009:495). A second interpretation provided by the archaeologist in charge of the excavation, Ana Vieira, suggested this site might have been used as a cemetery during the siege in 1189. This idea is reinforced by the high number of juvenile individuals, likely to have been more vulnerable to the lack of water and poor food supply. In addition an intra-mural cemetery is reported in the Islamic world as a solution in times of conflict (Gonçalves 2009:496). The analysed individuals from this site are presented in table 5-16.

| Muslims | |
|---|---|
| **Males** | **Females** |
| 2 | 0 |
| **2** | |

***Table 5-16*** *Breakdown of the analysed individuals from Rua A (RA)*

### 5.7.3 Rua 25 Abril

This Muslim burial site has been identified as the main cemetery of the people living in the walled city (Santos et al 2008). Almost 200 individuals have been recovered and radiocarbon dating on one of the individuals in the oldest layers of the cemetery provided a date of 869-1030 cal CE (Sac 2208 2σ). The burials were generally excavated in simple graves, however a few cases presented a more complex layout with a platform made of stone slabs and a cylindrical plaster structure on top (Gonçalves 2010: Fig.10). The individuals sampled from this site are presented in table 5-17.

| Muslims | |
|---|---|
| Males | Females |
| 17 | 6 |
| 23 | |

***Table 5-17*** *Breakdown of the analysed individuals from Rua 25 de Abril (R25A)*

### 5.7.4 Rua Miguel Bombarda

This Christian cemetery surrounded the chapel Ermida de Nossa Senhora dos Mártires outside the city walls. The first mention of this church is in relation to the two years of Christian rule between 1189 and 1191, when the troops of King Sancho I (1185-1211) took the city. Apparently some members of his army were buried in this cemetery; however the materials recovered during the excavation dated to the 13th-14th century (Casimiro et al. 2008). A total of 300 individuals have been recovered. Some of the individuals preserved traces of textiles that resulted to be very similar to white linen. In addition a few pins have been found suggesting the treatment of the body followed the Christian ritual of burying the body naked, in a shroud. Eight burials provided coins of wide chronology spanning from the 13th to the 16th C (Casimiro et al 2008:274). The individuals analysed from this site are presented in table 5-18.

| Christians | |
|---|---|
| Males | Females |
| 6 | 13 |
| 19 | |

***Table 5-18*** *Breakdown of the analysed individuals from Rua Miguel Bombarda (RMB)*

### 5.7.5 Largo da Sé

The excavation at this site took place as did the previous ones, within the intervention Polis Silves, which lasted between 2004 and 2006. In this area 141 Christian individuals were recovered. During the Islamic period, the northern and western area surrounding the Cathedral would be occupied by houses, whose structure was re-used to host the burials during the Christian period (Casimiro et al. 2008). Although, it is believed that the Cathedral was built on top of the Mosque, archaeological excavation failed to prove a cultural continuity for this space. Its construction started in the 13th century but because of political tension over the possession of the Algarve between the Kingdom of Portugal and the Castilian king, not much attention was given to the settlement and urban organization of the area after the conquest. In the 14th century, the church was still to be finished and the only major construction that can be identified in the gothic style of the church date to the 15th century (Gamito et al 1997). The use of the cemetery can be therefore ascribed to the period between the 13th and the 15th C. The individuals analysed from this site are presented in table 5-19.

| Christians | |
|---|---|
| **Males** | **Females** |
| 12 | 9 |
| **21** | |

***Table 5-19*** *Breakdown of the analysed individuals from Largo da Sé (LSE)*

### 5.7.6 Faunal remains from Silves

Faunal remains were uncovered at all four sites in Silves, however the rubbish pit in which the animal remains were found did not allow the identification of a specific chronology. All remains were classified as medieval and could be from both the Islamic and Christian period. Therefore, although they are not informative about possible changes in husbandry practices between the two faith groups, provide a solid baseline to interpret the human diet at all sites.  A breakdown of the analysed samples is provided in table 5-20.

| Species | n |
|---|---|
| *Bos Taurus* | 7 |
| *Ovis aries* | 4 |
| *Capra hircus* | 3 |
| *Sus* | 1 |
| *Canis* | 2 |
| *Dicentrarchus labrax* | 1 |
| *Galeorhinus galeus* | 1 |
| *Tot* | **19** |

***Table 5-20*** *Breakdown of the analysed faunal samples*

### 5.7.7 Quinta do Lago, Loulé

This site is located in the modern day natural park of Ria Formosa, 1600 meters from the current coastline, at the most elevated area (between 8.3 and 9.8 meters a.s.l.). Archaeological research in the region provided evidence of dense human activity from the Roman period to the end of the Islamic rule ($1^{st}$-$12^{th}$ centuries) and two main settlements have been uncovered in subsequent campaigns between 1984 and 2002 (Arruda et al. 2004). One occupation dated to the Roman period and included both domestic and industrial buildings, while the second settlement, dated to the Islamic period, was characterised by houses and a cemetery (Figure 5-19). Although the material culture has confirmed a continuity of human activity throughout the centuries, the two settlements are not associated. The Roman settlement was a production site specialising in garum and fish products, as well as amphorae (Fabião 1992). Thanks to archaeological work undertaken in the estuarine area of São Lourenço, a number of similar sites have been recovered, all specialised in amphorae production and fish processing (Bernardes et al. 2007). Some surface material at the roman settlement dated to the $8^{th}$-$9^{th}$ century suggesting that a frequentation of the site during the Islamic period might have took place. However, the Islamic settlement of Quinta do Lago developed separately and the majority of the material culture dated between the $11^{th}$ and the $13^{th}$ century. The excavation uncovered five different domestic structures, two shell middens and two big rubbish pit. The structure of the houses is similar to other Islamic settlements (i.e. Praça da Figueira, Lisbon; Mertola). The urban domestic architecture can be more articulated like in Silves, however a number of similarities are shared, including the L or U shape; the opening of the rooms onto the patio while no internal communication is seen between rooms. A number of materials were recovered including a thimble and weaving tools, suggesting this activity was rather common at the site and usually carried out outside. Several fireplaces have also been found and have been associated with both domestic use and small production activities (Arruda et al. 2004).

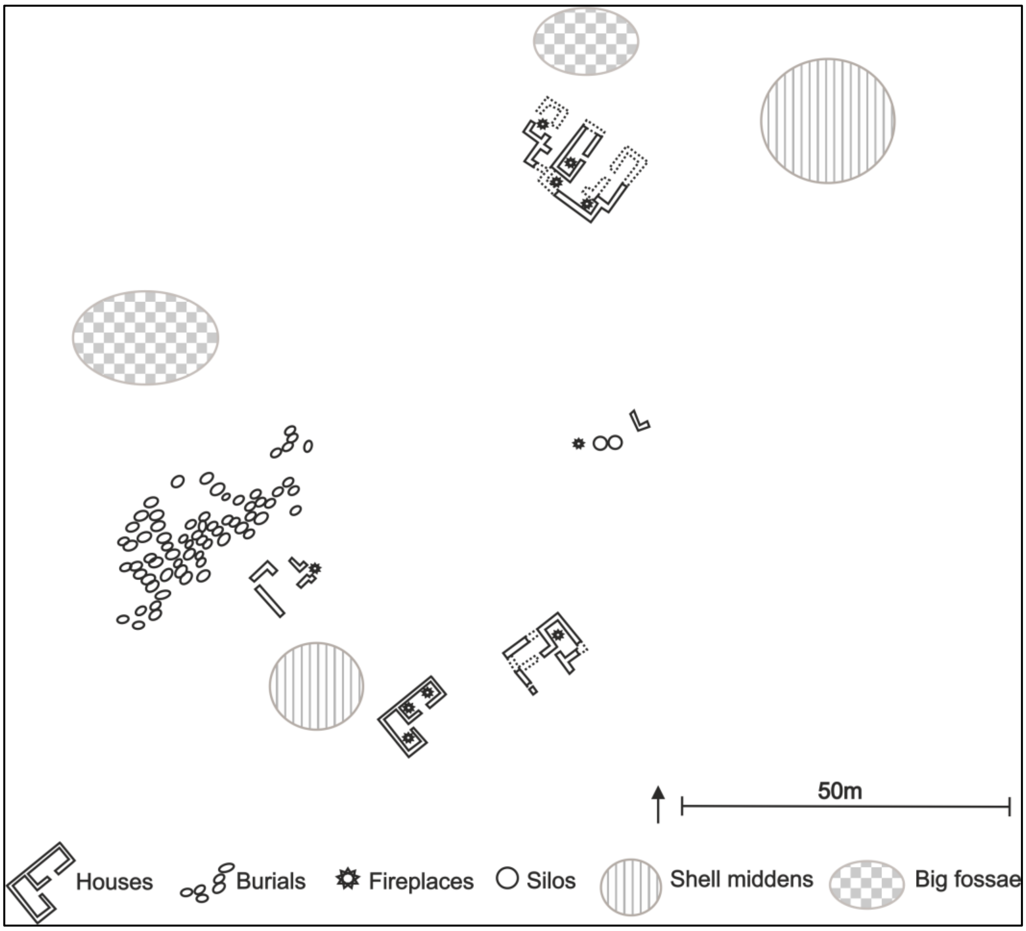

*Figure 5-19* *Layout of the Islamic settlement at Quinta do Lago (10th-12th c)*

The shell middens testify the big reliance of this population of both the sea and the river for their protein intake, however some domestic mammals has also been recovered and both are currently under study (Branco and Valente 2015).

The cemetery included 76 individuals excavated in 1984 and 22 individuals recovered in 2001/2. The chronology is further confirmed by radiocarbon dating undertaken on two individuals dating respectively 981-1160 cal AD (2σ Sac-1821) and 983-1159 cal AD (2 sigma; Sac-1892) (Vilhena de Carvalho et al. 2005). Although the chronology fits with the one provided by the material culture, the marine diet of these individuals - suggested by the amount of shells recovered at the site, and its coastal location – might have affected their carbon values producing an older chronology.

The trajectory of this assemblage after the excavation has been troubled and neither the bones or the osteological report could be located. The sex and the age of the sampled individuals is based on a more recent revaluation of a small selection of the individuals (Vilhena de Carvalho 2003). This accessibility issue affected the sampling strategy and finally only 13 individuals could be sampled for this thesis (table 5-21). A selection of animal remains have also been sampled and analysed (table 5-22).

| Adults | | Non adults |
|---|---|---|
| Males | Females | |
| 5 | 2 | 6 |
| | **13** | |

***Table 5-21*** *Breakdown of the analysed individuals from Quinta do Lago – Loulé (LU)*

| Species | n |
|---|---|
| *Bos Taurus* | 4 |
| *Ovis aries* | 1 |
| *Capra hircus* | 5 |
| *Oryctolagus cuniculus* | 1 |
| *Equus* | 1 |
| *Gallus* | 4 |
| *Canis* | 1 |
| *Pagrus pagrus (seabream)* | 2 |
| *Tot* | **19** |

***Table 5-22*** *Breakdown of the analysed faunal samples*

## 5.8 Summary

The chosen sites satisfy the research aims outlined in Chapter 1. Regional and local trends in dietary practices and resource exploitation can be explored by this dataset. Four major sites from north to south (i.e. Coimbra, Lisbon, Beja and Silves) allow the assessment of diets in an urban setting both under Islamic and Christian rule. In addition, smaller rural sites in close proximity to the bigger settlements, have been included to inform on potential differences between these two environments including Laranjal, Setubal and Loulé. Sampling of a rural location close to Beja was not possible since there is a lack of excavated cemetery for such area.

Geographical trends can be explored thanks to sites spreading from north to south and in inland and coastal location. Each site provides sizable numbers of human individuals to explore sex, status and faith related intra-population variation in diet.

In addition, the chronology of the sites allows to explore possible variations in diet along the medieval period, with a specific focus on the consequences of the Christian conquest onto food access and availability for the majority of the population as well as religious minorities.

The large number of animal remains from several locations provide a faunal baseline that is used to interpret the human data, while allowing a direct assessment of husbandry practices at each site and evaluate intra-species variations. Some of the faunal assemblages have been dated by stratigraphic analysis to the medieval period and it is not known if the remains belonged to a Christian or Muslim household. This can be true also in the case of pits of specific chronology since both faith groups co-existed under Islamic and Christian rule, however it would have been preferable to have a mixture of contemporaneous samples from both periods of secure chronology. Radiocarbon dating would be required if a specific assessment of fodder strategy under differing political rule is to be undertaken; however it was beyond the scope of this work. For the purpose of this thesis, the medieval chronology of the faunal remains was considered to provide a reliable baseline to interpret the human data and caution is used when interpreting the isotopic results of the animal remains (Chapters 6-7).

# 6. RESULTS: NORTH AND CENTRAL PORTUGAL

This chapter and the following one (Chapter 7) present the isotope results for each site, grouped per geographical area and presented from north to south i.e. Northern, Central, Southern interior and Southern coastal Portugal. Full breakdown of the results from all sites is provided in Appendix B. In this chapter a description and a brief discussion of the results is undertaken focussing on patterning within each site, while an inter-site comparison is provided in Chapter 8 following a theme-based discussion exploring variation due to faith, sex, and chronology. This organization of the results reflects the different climate and environment of the sites across Portugal and thus aids in the exploration of any geographical and ecological patterning.

Each site is described separately including animal and human data. The inclusion of a reliable animal baseline is a fundamental step in dietary reconstruction because $\delta^{13}C$ and $\delta^{15}N$ values of the baseline are likely to be affected by local environment (Chapter 2). At Beja, it was not possible to locate contemporaneous faunal remains and therefore the animal baseline was derived from published data of Late Antique/Early Medieval chronology from a nearby site (Monte da Cegonhas, Saragoça et al. 2016). The samples of marine fish included in this thesis are from Lisbon, Silves and Loulé; however, they are common marine species (shark, hake, seabream and sea bass) and would have been available along the entire coast of Portugal. Therefore, marine fish values have been included in all plots regardless of the site of recovery. The applicability of these values is further confirmed by recently published data of fish remains isotope ratios from Galicia, Spain, dating to the Roman and Late Roman period. They exhibit similar values to the fish samples included in this thesis confirming the reliability of the samples as a representative marine fish population for the Atlantic Iberian coast (López-Costas and Müldner 2016). Unfortunately, freshwater fish were not available from any site.

In this chapter (Ch. 6), the isotopic data generated from Northern Portugal and Central Portugal, including Laranjal, Coimbra, Lisbon (São Jorge Castle, Praça da Figueira, Calçadinha do Tijolo, Largo das Olarias), Setubal and Palmela are presented and discussed. In chapter 7, the results for Southern Portugal, including Beja, Silves and Loulé, are presented and discussed.

## 6.1 Northern Portugal: Laranjal

Carbon and nitrogen isotope data for both human and animal samples are plotted in Figure 6-1, while summary statistics are provided in Table 6-1. The preservation at this site was rather poor and out of 26 samples, only 9 produced good quality collagen (35% success rate of collagen extraction). This was by far the site with the lowest success rate for human remains, although faunal remains from the same site, had better preservation, suggesting that the burial environment was hostile to collagen preservation.

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **No.** | **Min** | **Max** | **Range** | **Mean ±1σ** | **Min** | **Max** | **Range** | **Mean ±1σ** |
| Human | 9 | -22.8 | -17.1 | 5.7 | -20.1±1.8 | 8.1 | 12.0 | 3.9 | 9.6±1.2 |
| Cow | 6 | -20.6 | -19.5 | 1.1 | -20.2±0.4 | 3.4 | 9.3 | 5.9 | 6.1±1.9 |
| Sheep | 1 | - | - | | -20.5 | - | - | | 6.7 |
| Goat | 5 | -20.6 | -19.3 | 1.3 | -19.9±0.4 | 3.9 | 5.6 | 1.7 | 4.7±0.6 |
| Chicken | 2 | -20.3 | -20.2 | 0.1 | -20.2 | 6.6 | 9.9 | 3.3 | 8.2 |
| Pig | 6 | -21.1 | -20.1 | 1 | -20.6±0.4 | 4.7 | 7.7 | 3 | 6.5±1.3 |

***Table 6-1:*** *Summary isotopic data for humans and animals from Laranjal. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

Goats predominate over sheep at this settlement and show very similar values for $\delta^{13}C$ with similar standard deviation compared to cattle; however, they differ slightly in their $\delta^{15}N$ values, with cattle showing higher and greater range of values (~6‰). The variation between sheep and goats across the whole dataset is explored in the Discussion (Chapter 8). The two chickens show similar $\delta^{13}C$ values but are separated by their $\delta^{15}N$ values, by a 3.3 ‰ difference. Pigs have very similar $\delta^{13}C$ values to the other faunal samples and exhibit a wide range in $\delta^{15}N$ values as all the other species (~3‰).

Considering the size and rural nature of the site, the isotopic variation shown by animals at Laranjal is surprising, where most species exhibit a range of at least 3‰ in their $\delta^{15}N$ values. In an urban environment, this spread of data could reflect a varied origin of livestock; however, it is rather unlikely it is the case for Laranjal, which was a small rural village. All individuals were adults, which excludes the possibility of a persistent suckling signal. A great variability in $\delta^{15}N$ is seen in all faunal remains from all the sites in this thesis (excluding the Muslim quarter in Lisbon) but also at other Iberian medieval sites including urban and rural sites under Christian or Islamic rule (Alexander et al. 2015; Guede et al. 2017; Lubritto et al. 2017). Since there is usually no species-related patterning, it is likely that this trend is a result of the great diversity of the Iberian climate and environment influencing stable isotope values. A number of environmental and anthropogenic factors such as different feeding practices or manuring may cause enrichment in $\delta^{15}N$ values (Chapter 2). Regarding the comparatively little variation in $\delta^{13}C$ values, these animals are feeding on $C_3$ plants with no input from $C_4$ plants.

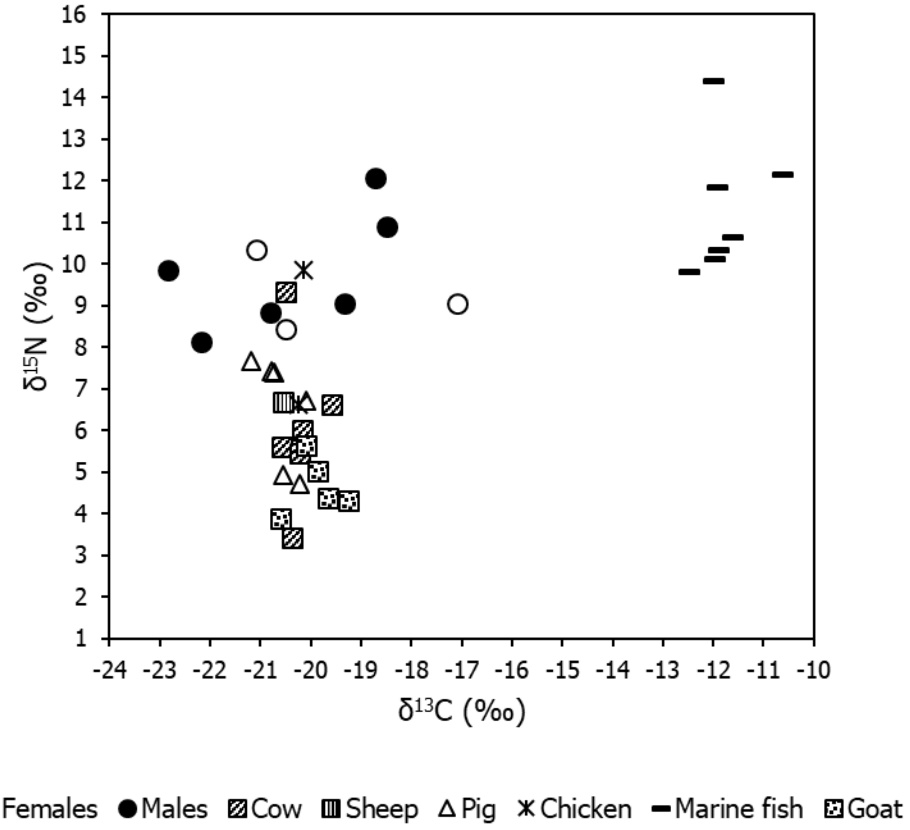

***Figure 6-1**: Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of humans (n=9) and animals (n=20) from Laranjal, Cilhades (10th-14th C). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

Omnivores, especially pigs have the same range of values as the herbivores. Pigs are therefore consuming a predominantly herbivorous diet at Laranjal. However, there is evidence of a mix of husbandry practices for pigs in the medieval period and this is discussed in Chapter 8.

The two chicken samples from Laranjal have similar $\delta^{13}C$ values but differing $\delta^{15}N$. One individual plots within the herbivore range while the second one has higher nitrogen values (>9‰) and plots within the human population showing an omnivorous diet. Patterns of omnivorous diet and chickens across all sites are discussed in Chapter 8.

The nine human individuals sampled from Laranjal exhibit a wide range in $\delta^{13}C$ values (5.7‰) and $\delta^{15}N$ values (3.9‰). The mean value of $\delta^{15}N$ for humans is ~3.2‰ higher than the mean value for all terrestrial animals suggesting that this population had a mixed diet of plants and low trophic level proteins, with no appreciable consumption of fish (marine or freshwater).

Because of the riverine location of this site, it is notable that none of the human individuals show a freshwater signature. Freshwater fish might have complemented the diet of these individuals, but its contribution might have been under the threshold of identification for bulk isotopes of collagen and therefore not a major dietary component (less than 20%) (Hedges 2004; Milner et al. 2004). In addition, freshwater resources vary in their isotopic values depending on the freshwater source (Chapter 2) but the range of variability is hard to ascertain with no freshwater samples for this site.

The wide range of $\delta^{13}C$ values (5.7‰) is unusual for a single population and especially for a small rural site where diet tended to be more homogeneous than in an urban environment with access to a large market of foods. However, the majority of the individuals are within the range of $C_3$ plants with the exception of one female individual (LAR52) showing an enrichment in $^{13}C$ suggesting the inclusion of $C_4$ resources in the diet. Since the faunal baseline show a $C_3$ diet, the $C_4$ signal shown by this individual is likely to have been produced by directly consuming $C_4$ plants, such as millet, and not through the consumption of products from $C_4$-fed animals. As the diet at the site based on $C_3$ resources, this female may come from elsewhere where $C_4$ crops were routinely consumed (see section below and females from Coimbra). However further analysis with mobility isotopes would be needed to gain further evidence. The general reliance of the Laranjal population on $C_3$ resources differs from the data from northern Spain and specifically Galicia, where an increasing reliance on marine and $C_4$ resources can be seen in the post-Roman population (López-Costas and Müldner 2016).

A breakdown of the values by sex is provided in Table 6-2. There is no significant statistical difference between males and females for both carbon and nitrogen values (Mann Whitney U=7.0, p=0.714; Mann Whitney U=10.0, p=1.000). However, because of the small sample size of this population, it is possible that different dietary patterns would have been identified with a larger dataset.

| | | $\delta^{13}C$/‰ | | | $\delta^{15}N$/‰ | | |
|---|---|---|---|---|---|---|---|
| Sex | No. | Min | Max | Mean ±1σ | Min | Max | Mean ±1σ |
| Females | 3 | -21.1 | -17.1 | -19.5±2.1 | 8.4 | 10.3 | 9.3±0.9 |
| Males | 6 | -22.8 | -18.5 | -20.4±1.8 | 8.1 | 12.0 | 9.8±1.4 |

***Table 6-2:*** *Summary isotopic data per sex groups of human individuals from Laranjal. Standard deviation is calculated where the sample number is at least 3.*

## 6.2 Northern Portugal: Coimbra

Carbon and nitrogen data for both human and animal samples are plotted together for comparison in Figure 6-2, while summary statistics is provided in Table 6-3. Figure 6.2 includes isotopic data from Luxton (2015), (an unpublished master's dissertation) who analysed part of the same cemetery of São João de Almedina church. These results indicate that domestic herbivores (goat, cow and horse) have a wide spread in $\delta^{15}N$ values (range of 5.3‰), similar to Laranjal. Pigs again exhibit values within the herbivore range, although at least one individual exhibits higher $\delta^{15}N$ values in line with humans, reflecting an omnivorous diet. Goose and chicken, however, show enriched nitrogen values, similar to the human population. Nevertheless, while the goose shows a diet based on $C_3$ resources, chickens have higher $\delta^{13}C$ values, strongly suggesting the inclusion of $C_4$ plants in their diet and a different management strategy for these two species in Coimbra. A similar pattern has been seen in the Anglo-Saxon site of Flixborough, where although both animals were feeding on $C_3$ plants, a species-related difference could be seen in their diet and chickens showed increased $\delta^{13}C$ and $\delta^{15}N$ values (Colonese et al. 2017). Other medieval sites in Germany, however, indicate homogeneous feeding practices for poultry (including chicken and goose) (Olsen 2013). Domesticated geese are mainly herbivorous, but the Greylag goose (*Anser anser*), the most common wild goose in Europe today, and the ancestor to domesticated geese in Europe, can consume snails, slugs, and small aquatic animals that have enriched nitrogen isotope values. Medieval sources from Italy and UK suggests that geese were kept separately because of the high level of attention required for these animals compared to chickens, and barley (a $C_3$ crop) was suggested as a fodder to fatten them (Slavin 2010).

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **No.** | **Min** | **Max** | **Range** | **Mean ±1σ** | **Min** | **Max** | **Range** | **Mean ±1σ** |
| Human | 16 | -19.2 | -14.3 | 4.9 | -16.8±1.3 | 8.3 | 11.0 | 2.7 | 10.1±0.7 |
| Cow | 3 | -21.8 | -20.8 | 1 | -21.1±0.5 | 5.0 | 6.5 | 1.5 | 5.7±0.7 |
| Goat | 5 | -21.2 | -19.9 | 1.3 | -20.5±0.2 | 3.1 | 7.0 | 3.9 | 5.4±1.5 |
| Horse | 1 | - | - | | -22.2 | - | - | | 1.7 |
| Chicken | 3 | -16.7 | -12.6 | 4.1 | -15.2±2.3 | 8.1 | 9.0 | 0.9 | 8.5±0.5 |
| Goose | 1 | - | - | | -21.1 | - | - | | 10.4 |
| Pig | 5 | -22.0 | -20.3 | 1.7 | -21.2±0.7 | 3.6 | 8.9 | 5.3 | 6.4±2.0 |

***Table 6-3:*** *Summary isotopic data for humans and animals from Coimbra. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

In Coimbra, chickens were evidently kept at different diet rich in $C_4$ resources, and one individual show values that would suggest a diet based on almost 100% $C_4$ proteins. Interestingly, but not surprisingly, chickens show a very similar diet to the human population, and it is likely that they were purposely fed $C_4$ plants, or that they had access to domestic waste and food scraps, similar to what has been observed at Benipeixcar (Alexander et al. 2015). The human population consumed a terrestrial diet based on low trophic level proteins as suggested by the relatively low nitrogen values. Their $\delta^{13}C$ values indicate a reliance on $C_4$ plants. The difference between animal and human mean values of $\delta^{15}N$ is ~4‰ and within the expected range of trophic level enrichment. The offset in $\delta^{13}C$ is larger than would be expected (~4‰) and indicates that human values have been shifted by $^{13}C$-depleted resources, thus suggesting that the inclusion of $C_4$ resources is the expression of a human dietary preference rather than the influence of the animal diet. This is the only population in this study with clear signal of $C_4$ resources in its diet, probably in the form of millet.

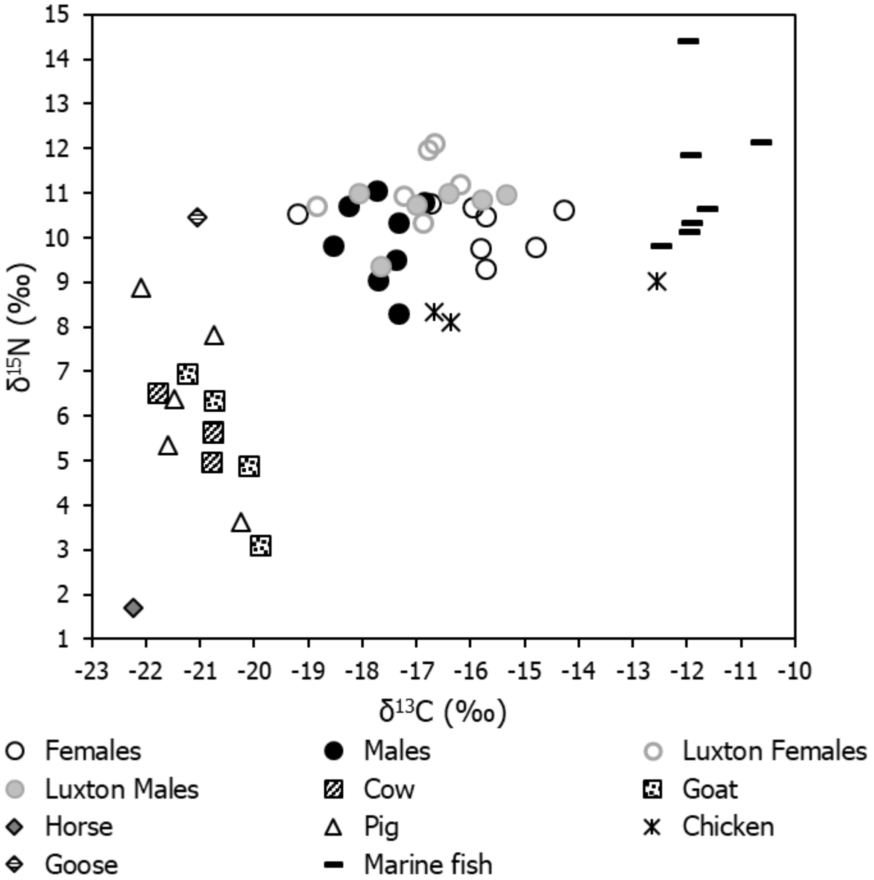

***Figure 6.2*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of humans (n=16) from São João de Almedina church, Coimbra (12th-15th C) and animals (n=18) from the Criptoportico of Coimbra (9th-11th C). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C). The individuals in grey are part of São João de Almedina cemetery. They were analysed by Luxton (2015) and are here included to aid the assessment of sex-related dietary patterns.*

Summary statistics for the human dataset divided by sex is provided in Table 6-4 including the individuals from Luxton (2015). During an initial visual and statistical assessment of the data from this thesis, a sex-related difference in δ$^{13}$C values was revealed. A statistically significant difference in δ$^{13}$C values was retained when the data from Luxton (2015) became available and were added to provide a larger dataset (Mann Whitney U=53.5, p=0.041), although the data for males and females were visually slightly less differentiated (Fig. 6.2). No statistical significant difference is found in δ$^{15}$N values (Mann Whitney U=90.5, p=0.744). The implications of this sex-related access to C$_4$ resources is discussed in Chapter 8.

| | | δ$^{13}$C/‰ | | | δ$^{15}$N/‰ | | |
|---|---|---|---|---|---|---|---|
| Sex | No. | Min | Max | Mean ±1σ | Min | Max | Mean ±1σ |
| Females | 8 | -19.2 | -14.3 | -16.0±1.5 | 9.3 | 10.8 | 10.2±0.5 |
| Males | 8 | -18.5 | -16.9 | -17.6±0.5 | 8.3 | 11.0 | 9.9±0.9 |
| Females (Luxton 2015) | 6 | -18.8 | -16.2 | -17.1±0.9 | 10.3 | 12.1 | 11.2±0.7 |
| Males (Luxton 2015) | 6 | -18.1 | -15.4 | -16.7±1.1 | 9.4 | 11.0 | 10.7±0.6 |

Table 6-4: *Summary isotopic data per sex groups of human individuals from São João de Almedina, Coimbra. Standard deviation is calculated where the sample number is at least 3.*

## 6.3 Summary of trends in Northern Portugal

Altogether the isotopic results presented here seem to support the historical evidence discussed in Chapter 3 of a Christian pheasant diet based on cereals (wheat, millet and rye) with a variable amount of meat and fish that would complement the diet depending on local availability and price. Although in the north of Portugal it was common to substitute wheat with millet for human and animal consumption, this seems to be true only for the human population in Coimbra, suggesting that historical sources provide only general statements that are not applicable to all populations in the North of Portugal. In addition, the only animals whose values are in accordance to C$_4$ resources are chickens in Coimbra, suggesting that different livestock practices were in place at these sites. In terms of human diet, there is a sex-related access to C$_4$ resources in the human population in Coimbra. The one individual from Laranjal with enriched carbon isotope values is also a female, however the small sample size hinder further speculation.

## 6.4 Central Portugal: Lisbon

In this section, the results obtained from a number of sites in Lisbon are presented. Animal and human populations under Islamic and Christian political rule are considered separately.

### 6.4.1 Early Medieval sites

Results for Islamic period sites, both humans and animals, are plotted in Figure 6-3. Data and summary statistics for the human and animal datasets are provided in Table 6-5. A breakdown per sex of the early medieval sites is shown in Figures 6-4 and 6-5 and summary statistics in Table 6-6. Weaning age in relation to the $\delta^{15}N$ mean value of the female population is plotted in Figure 6-6.

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| SJC Human | 27 | -19.4 | -16.5 | 2.9 | -18.4±0.6 | 8.7 | 13.1 | 4.4 | 10.5±1.1 |
| CDT Human | 5 | -18.9 | -18.6 | 0.3 | -18.7±0.1 | 9.3 | 10.0 | 0.7 | 9.5±0.3 |
| Cow | 11 | -21.8 | -20.2 | 1.6 | -21.1±0.5 | 4.9 | 11.1 | 6.2 | 6.3±1.9 |
| Sheep | 5 | -21.6 | -20.0 | 1.6 | -20.8±0.6 | 4.5 | 9.9 | 5.4 | 6.6±1.0 |
| Goat | 3 | -20.6 | -20.0 | 0.6 | -20.2±0.4 | 4.0 | 10.6 | 6.6 | 6.5±3.6 |
| Horse | 1 | - | - | | -18.4 | - | - | | 6.0 |
| Chicken | 5 | -19.9 | -18.4 | 1.5 | -19.0±0.6 | 8.0 | 10.7 | 2.7 | 9.4±1.3 |
| Pig | 6 | -21.0 | -18.9 | 2.1 | -20.0±0.8 | 4.9 | 7.7 | 2.8 | 6.6±1.0 |
| Cat | 2 | -19.0 | -18.5 | 0.5 | -18.7 | 6.9 | 8.9 | 2 | 7.9 |
| Dog | 2 | -18.4 | -15.6 | 2.8 | -17.0 | 9.4 | 14.1 | 4.7 | 11.8 |
| Rabbit | 1 | - | - | | -21.6 | - | - | | 5.2 |
| Raven | 1 | - | - | | -19.4 | - | - | | 8.6 |
| Marine fish | 2 | -12.0 | -11.9 | 0.1 | -12.0 | 11.9 | 14.4 | 2.5 | 13.1 |

**Table 6-5**. *Summary of isotopic data for humans from São Jorge Castle (SJC), Calcadinha do Tijolo (CDT) and animals from Praça da Figueira. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

Despite the uncertainty related to the long chronology of the faunal remains, husbandry practices for the main domestic species seem to be constant in Lisbon between the 3rd and 14th centuries. The majority of the domestic species show an herbivorous diet based on $C_3$ plants. Notably, a few individuals (two cows, two sheep and one goat) have higher $\delta^{15}N$ values.

Animals that are reared near urban centres are more likely to show enriched $\delta^{15}$N values (Hedges et al. 2005; Reitz et al. 2016) and the variation in herbivores' values can also indicate a wider provisioning area. From historical sources, it is known that animals consumed in urban areas were not always reared near the settlements (Catarino 1998:39). Toponyms in the surrounding of Lisbon, with particular mention of the areas upstream of the river Tagus for the Islamic and Christian periods, suggest the existence of pastures (Gomes Barbosa 1994:20; Catarino 1998:34). Thus, these differences in herbivore diet suggest distinct management strategies and/or provenance for these individuals. However, as it has been already mentioned for the northern sites, this wide range of values in the nitrogen isotope is common in Iberian datasets, and throughout this thesis, and will be discussed in Chapter 8. Lastly, two dogs have been analysed from Lisbon and show a very different diet. While one individual has the same diet as the majority of the human population, showing a diet based on terrestrial proteins, possibly scrap food from domestic waste, the other individual (PF 8510M) has high $\delta^{13}$C and $\delta^{15}$N values suggesting a mainly marine diet.

| | | $\delta^{13}$C/‰ | | | $\delta^{15}$N/‰ | | |
|---|---|---|---|---|---|---|---|
| Sex | No. | Min | Max | Mean ±1σ | Min | Max | Mean ±1σ |
| SJC Females | 6 | -19.1 | -18.5 | -18.8±0.2 | 8.7 | 9.9 | 9.4±04 |
| SJC Males | 3 | -19.4 | -18.7 | -19.0±0.4 | 10.0 | 11.2 | 10.8±0.7 |
| SJC undetermined | 1 | - | - | -18.8 | - | - | 9.9 |
| SJC non-adults | 17 | -18.8 | -16.5 | -18.1±0.6 | 8.8 | 13.1 | 10.9±1.2 |
| CDT Females | 2 | -18.7 | -18.6 | -18.6 | 9.6 | 10.0 | 9.8 |
| CDT Males | 1 | - | - | -18.7 | - | - | 9.3 |
| CDT undetermined | 1 | - | - | -18.9 | - | - | 9.6 |
| CDT non-adults | 1 | - | - | -18.6 | - | - | 9.3 |

Table 6-6: *Summary of isotopic data per sex and age groups of human individuals from São Jorge Castle (SJC) and Calçadinha do Tijolo (CDT), Lisbon. Undetermined individuals are adult individuals of unknown sex. Standard deviation is calculated where the sample number is at least 3.*

The human diet is rather similar at both sites regardless of social status and there is no statistically significant difference in both $\delta^{13}$C and $\delta^{15}$N values between the two populations (two-samples Mann Whitney U=47, p=0.31 and U=33, p=0.07). Their diet is prominently terrestrial and based on $C_3$ plants. Although $C_4$ plant consumption has been found in isotopic studies of medieval Muslim populations from Valencia (Salazar-Garcia et al. 2014; Alexander et al. 2015) and at Coimbra (this thesis), there is no indication of their inclusion in the diet of the humans or animals from Lisbon. This is despite historical records indicating that they were available (Chapter 3). As crops such as millet and sorghum may have been considered to be low-status crops (García-Sánchez 1996:223; Alexander et al. 2015), the lack of evidence for them in the diet, especially among the CDT individuals, may reflect a different local economy or the relatively easy access of this population to more desirable crops.

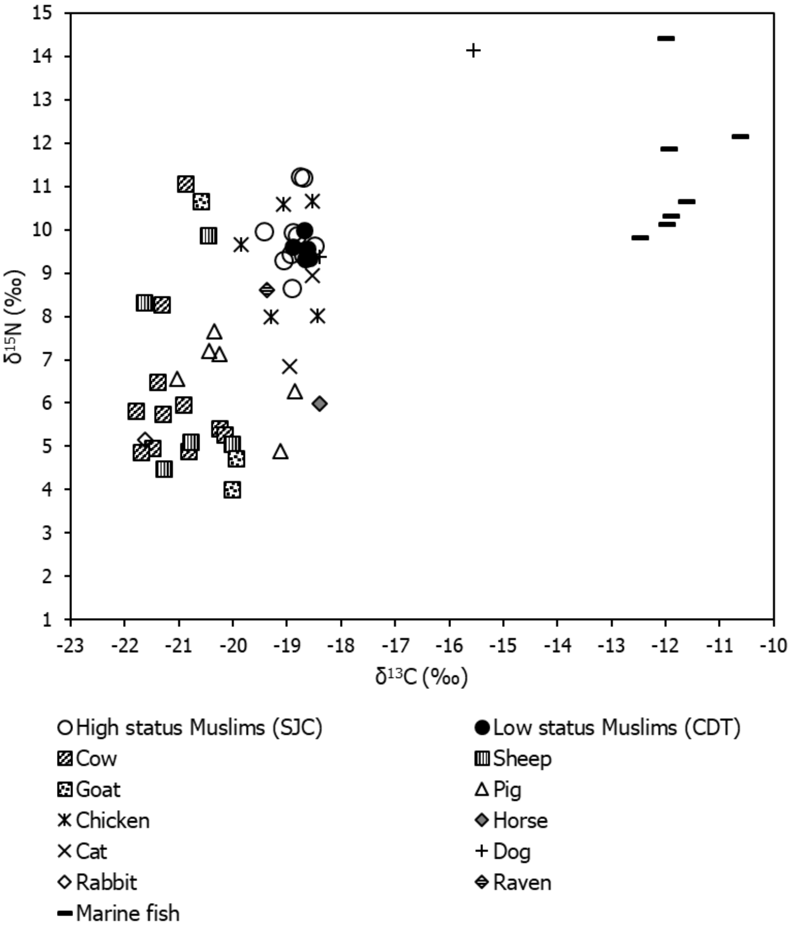

***Figure 6-3*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of humans from São Jorge Castle (SJC) (n=27), Lisbon (10th-11th C), Calçadinha do Tijolo (CDT) (n=5), Lisbon (10th-11th C) and animals (n=37) from Praça da Figueira (3rd-12th C). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

In terms of animal protein, given the aforementioned wide range in nitrogen values, it is difficult to pin down specific species that were consumed. It is likely that herbivores played a significant part in the diet of these individuals, with omnivores like chickens supplementing the diet of some, particularly those with higher nitrogen values. The isotopic evidence indicates that marine fish were not a significant part of the diet. This is surprising given the location of Lisbon and its intrinsic relationship with the sea. However, limited consumption (less than ~20%) of low trophic level fish would not be detected by isotopic analysis as previously discussed. Cultural and religious preferences should also be considered. The Quran does not prohibit the consumption of fish; however, some sections of Islam did consider it unlawful, mainly in the Eastern Shia tradition (Pellat et al. 2012). Fish recipes are also very scarce in medieval Andalusian cookbooks, usually accounting for 4-10% of the presented recipes (García-Sánchez 1986:264-265). The only medieval Portuguese cookbook available unfortunately dates to the late medieval Christian period (Manuppella 1987). A lack of zooarchaeological data also hinders the assessment of the consumption of marine resources in Islamic Lisbon. Sieving is not routinely carried out due to the time constraints that recovery processes impose on rescue and commercial archaeology.

When the two population are assessed separately, a sex- and age-related difference in diet can be observed in the high status SJC population but not in the lower status one (CDT). Women and men display a different diet at SJC, with males generally possessing higher $\delta^{15}N$ than females. The difference is significant for $\delta^{15}N$ but not for $\delta^{13}C$ (two samples Mann-Whitney U test, p= 0.02 and p= 0.89 respectively). This could indicate that males consumed higher trophic level proteins from chickens or potentially freshwater fish, which would also serve to enrich $^{15}N$ values (Hedges and Reynard 2007). Women were encouraged to consume high calorific food such as fats, sugars and carbohydrates in order to put on weight for aesthetic and fertility purposes (García-Sánchez 2006:217). The Kitāb al-Tabīj, an Andalusian cookbook compiled by an anonymous author in the 13th century, includes a few recipes referred to as ‘food for women’ that had exactly this purpose (Martinelli 2012). In this case, the diet shown by the SJC women could fit this scenario with lower trophic level protein consumed and a potentially higher consumption of carbohydrates and vegetables (although the latter will not show up in bone collagen if sufficient animal protein was consumed, as is likely the case here).

When patterns related to sex are compared between the high and low status populations, female individuals from SJC have a very similar diet to both males and females at CDT, although the sample size is very small in this population. This sex-related difference does not seem to affect the urban population in Lisbon (Fig. 6-4). Therefore, rather than the high-status females from the castle exhibiting a unique diet, it appears that high status males are more distinctive in their eating habits compared to the rest of the urban population of the time. This difference for the high status male individuals could be linked to their activities taking place outside the home and them potentially having access to a wider range of foodstuffs. Although similar patterns have been recorded elsewhere in Islamic Spain with males consuming higher trophic level proteins (possibly riverine fish) in Tauste, for example (Guede et al. 2017), a sex difference in diet is not a common trend among isotopic datasets for Muslim populations from Spain (Fuller et al. 2010; Salazar-García et al. 2014, 2016; Alexander et al. 2015). The small sample sizes from Lisbon hamper any definite conclusions regarding diet and sex. At São Jorge Castle, adults and non-adults display a significant difference in both their $\delta^{13}C$ and $\delta^{15}N$ values (two-sample Mann-Whitney U test, p= 0.00 and p= 0.04 respectively). Interestingly, three weaned non-adults (older than 2 years) of the SJC population share a similar diet to the female individuals (Fig. 6-5).

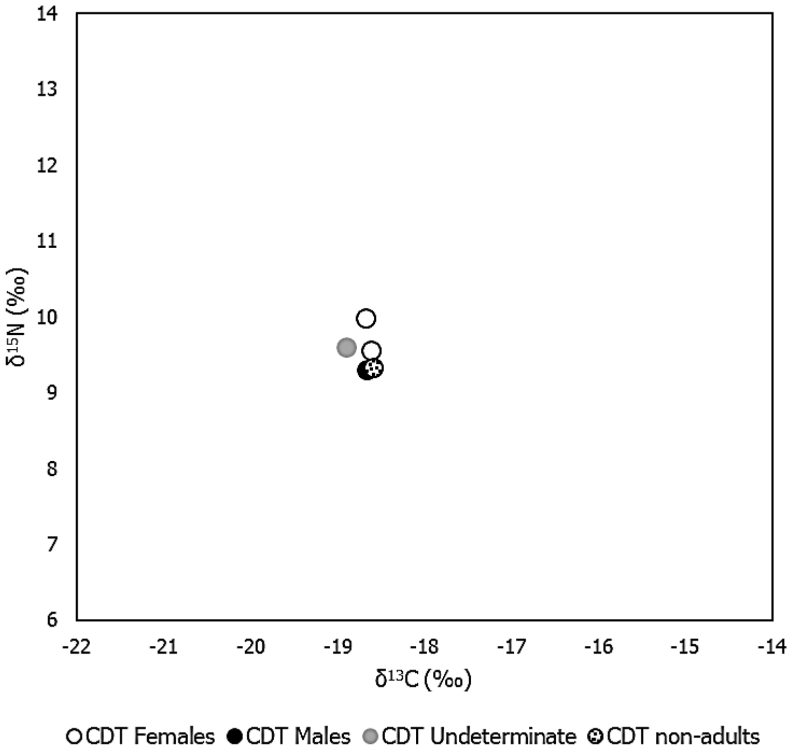

*Figure 6-4* *Scatter plot of* $\delta^{13}$*C and* $\delta^{15}$*N ratios (‰) of humans (n=5) from Calçadinha do Tijolo (CDT), Lisbon (10th-11th C).*

There are few explicit references in historical literature for culinary products shared by women and children. Women and children were considered of different physiological nature (children were hot and humid, while women were colder and drier, although not as warm as adult men), therefore this similar food consumption is not associated with the humoral theories (Oliveira 2007:31). However, childcare is traditionally entrusted to women and it is likely that physical proximity would have prompted the consumption of similar meals. Breastfeeding, although sometimes performed by wet-nurses among high status families, was considered by Christian and Islamic medieval societies of vital importance to child development and health (Giladi 1998:108; Shahar 1990:57; Winer 2008). The results show that the majority of the non-adults under the age of two were still breastfed in accordance with medical and historical sources from both the Islamic and Christian world, which suggested breastfeeding at least until two years of age (Baumgarten 2004; Fildes 1986). When compared to other archaeological medieval populations, the non-adult individuals from SJC appear to follow a similar pattern of enriched nitrogen values compared to the females' mean value of their respective populations (Fig. 6-6). This is the expected signature for breastfeeding and weaning.

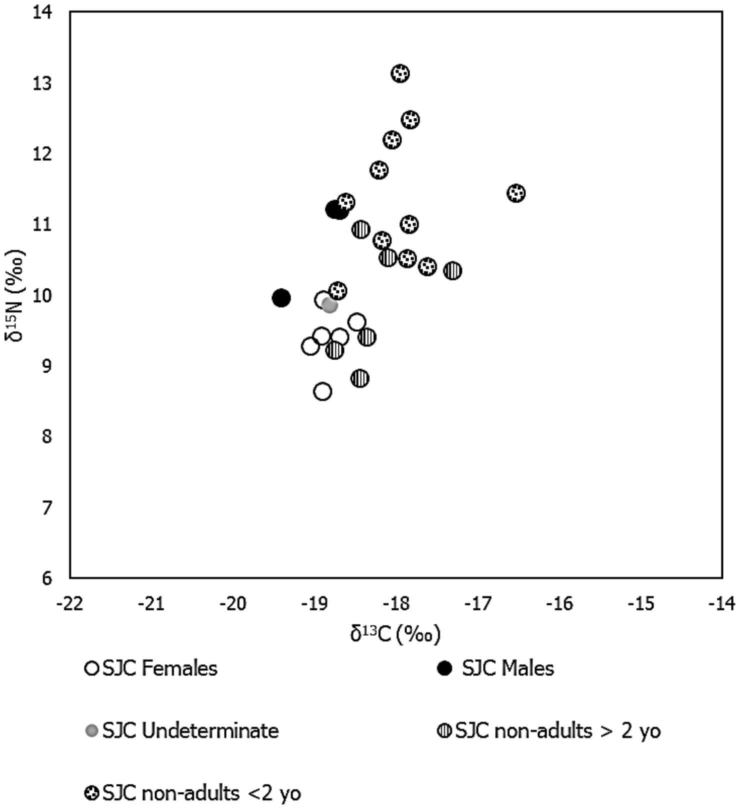

***Figure 6-5*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) per age and sex groups of the population from São Jorge Castle (SJC), Lisbon (10th-11th C). SJC non-adults > 2 yo (n=6), SJC non-adults < 2 yo (n=11).*

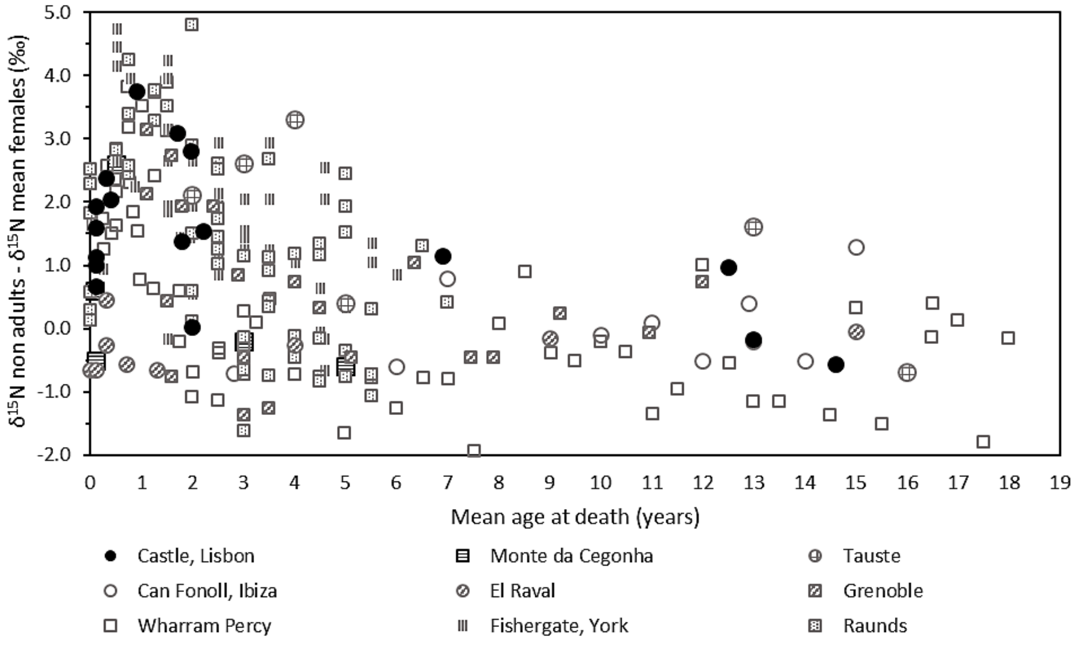

***Figure 6-6*** *Breastfeeding and weaning pattern of non-adult individuals from SJC, Lisbon and Monte da Cegonha compared to other Muslim and Christian populations from Spain, France and UK. The comparative sites are Monte da Cegonha, Portugal (Saragoça et al. 2016), Tauste, Spain (Guede et al. 2017), Can Fonoll, Ibiza, Spain (Pickard et al. 2017), El Raval, Spain (Salazar-García et al. 2014), Grenoble, France (Herrscher 2003), Wharram Percy, UK (Richards et al. 2002), York, UK (Burt 2013), Raunds, UK (Haydock et al. 2013).*

### 6.4.2 Late Medieval sites

Results for the late medieval sites, including humans and animals, are plotted in Figure 6-7 and summary statistics are provided in Table 6-7 by faith and species. The two faith groups are plotted separately per sex in Figure 6-8. As it has been described in Chapter 5, the late medieval individuals have been excavated at different sites by different archaeological units; however, they are considered to be part of the same cemetery and for this reason are treated in this thesis as one assemblage. Animal remains come from Casa da Severa site (12th-14th), a residential area within the Islamic quarter.

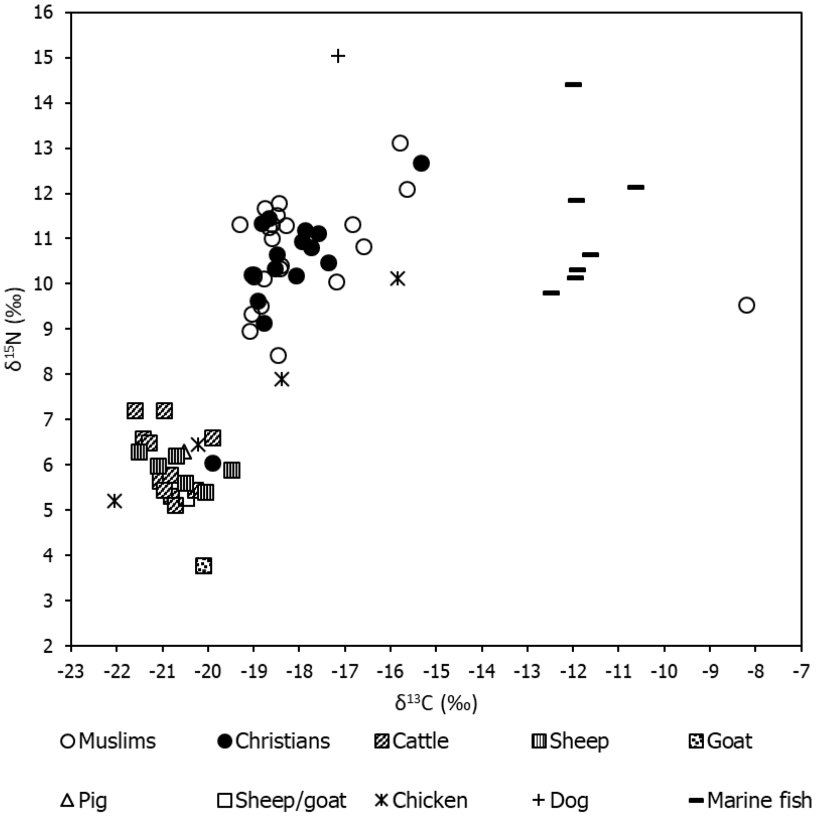

*Figure 6-7* *Scatter plot of* $\delta^{13}C$ *and* $\delta^{15}N$ *ratios (‰) of Christians (n=15) and Muslims (n=23) from the Islamic Quarter (Mouraria)'s cemetery, Lisbon, and animals (n=20) from Largo das Olarias, Lisbon. Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

The majority of the domestic species show an herbivorous diet based on $C_3$ plants. All animals, except for two chickens, cluster together quite tightly. Ranges of both $\delta^{15}N$ and $\delta^{13}C$ values are more contained than other sites which is interesting, especially for $\delta^{15}N$, which shows considerable variation in all species at all sites. This relatively homogeneous rearing practice that seem to take place in the Islamic quarter in Lisbon might suggest a change in provision strategies for this urban population compared to the earlier medieval sites. Historical sources mention the existence of an Islamic corral within the Islamic quarter, where the animals were kept before being slaughtered. In addition, because of the specific slaughter norms respected by Muslims, this quarter had an Islamic slaughterhouse and butcher that provided *halal* meat (Oliveira and Viana 1993:199).

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Muslims | 23 | -19.3 | -8.2 | 11.1 | -17.8±2.3 | 8.4 | 13.1 | 4.7 | 10.7±1.1 |
| Christians | 15 | -19.9 | -15.3 | 4.6 | -18.2±1 | 6.1 | 12.7 | 6.6 | 10.4±1.5 |
| Cow | 11 | -21.6 | -19.9 | 1.7 | -20.9±0.5 | 5.1 | 7.2 | 2.1 | 6.1±0.8 |
| Sheep | 6 | -21.5 | -19.5 | 2 | -20.6±0.7 | 5.4 | 6.3 | 0.9 | 5.9±0.3 |
| Goat | 1 | - | - | - | -20.1 | - | - | - | 3.8 |
| Sheep/goat | 1 | - | - | - | -20.5 | - | - | - | 5.3 |
| Chicken | 4 | -22.0 | -15.8 | 6.2 | -19.1±2.6 | 5.2 | 10.1 | 4.9 | 7.4±2.1 |
| Pig | 1 | - | - | - | -20.5 | - | - | - | 6.3 |
| Dog | 1 | - | - | - | -17.2 | - | - | - | 15.0 |
| Marine fish | 1 | - | - | - | -11.6 | - | - | - | 10.7 |

Table 6-7. *Summary of isotopic data for humans from the Islamic Quarter (Mouraria)'s cemetery, Lisbon, and animals (n=20) from Largo das Olarias, Lisbon. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

Provisioning of meat might have occurred through a reduced number of suppliers and in lower quantities compared to the early medieval period. Backyard rearing cannot be ruled out since historical sources mention the existence of rural areas in the vicinity of the Islamic quarter or within the quarter itself. In this case the data seem to match the historical record and the reduced autonomy given to this faith group under Christian rule, might have had an impact on herding management practices.

Although the majority of the domestics have similar values, two chickens show higher nitrogen and carbon isotope values and especially one individual (LS96B) show an enrichment in $\delta^{13}C$ values of over 4‰ compared to the mean values of the other chickens suggesting a diet based on $C_4$/marine resources. Similar values have been seen for chickens at Coimbra and Loulé and this trend is further explored in Chapter 6. The only dog of this dataset shows significantly higher values of $\delta^{13}C$ and $\delta^{15}N$ compared to the rest of the animals and also the human population, suggesting a high reliance on marine resources. This is interestingly seen in one dog included in the early medieval period dataset, although of Roman chronology. At present no information can be found in historical sources about the food given specifically to dogs in Portuguese antiquity; however, the coastal and riverine location of Lisbon might have supplied dogs with an easy access to fish and fish remains.

The human diet is rather similar for both faith groups (Fig. 6-7) and there is no statistical difference between the two populations. Their diet is variable and while some individuals display a diet based on terrestrial and $C_3$ resources, the general trend of the population show increasing $\delta^{13}C$ and $\delta^{15}N$ values in both faith groups. This trend suggests a growing reliance on marine resources for both Muslims and Christians at this site during the late medieval period. This is the only site where different faith groups show the same diet and particularly is the only site where Muslim individuals show a diet based on high trophic level marine proteins (see below other multi-faith sites such as Beja and Silves). Further discussion of this chronological trend is undertaken in Chapter 8; however these first results are suggesting that faith is not the only factor to be considered when assessing the diet of urban medieval dwellers in Portugal, as chronology and the political shift brought about by the Christian conquest might have played an equally important role in defining food access and resource availability. This is especially true for the urban environment which seems to be more sensitive to the changes in political climate than the rural sites throughout this thesis. In addition to marine resources, $C_4$ plants cannot be ruled out as a complementary resource in the diet of some of the late medieval individuals from Lisbon. This is applicable to the individuals with higher $\delta^{13}C$ and lower $\delta^{15}N$ which could be consuming $C_4$ resources or low trophic level fish. As it has been discussed (Chapter 2), stable isotopes cannot always discriminate between these two protein sources and therefore is not possible to ascertain which food group is responsible for such values in Lisbon. As seen above, two chickens have enriched $\delta^{13}C$ values compared to the other animals and could indicate the presence of $C_4$ plants on site. However, chickens are omnivores and are likely to be reared near the house, likely scavenging on domestic waste, including fish, or being fed $C_4$ plants and terrestrial protein. A similar scenario with chickens kept on $C_4$ (presumably millet) has been found in Coimbra (this thesis) and in Valencia, in a Muslim population of similar late medieval chronology (Alexander et al. 2015). Notably, one Muslim woman (QDL 104) who was found interred with a couple of beads from a necklace and a ring (ERA Arqueologia 2014), exhibits $\delta^{13}C$ and $\delta^{15}N$ values that suggest a diet based almost exclusively on $C_4$ plants. These lines of evidence are not necessarily in contrast and the diet of this late medieval population seem to be more varied than the population from the early medieval period with a number of resources complementing their diet including marine fish, $C_4$ plants and terrestrial resources. What is striking is the higher reliance on high trophic level fish for some of the Muslim individuals at this site. None of the early medieval Muslim population show the same trend, suggesting that high trophic level fish might have become a normal part of the Islamic diet only in the late medieval period.

A sex-related difference in diet has not being found in either faith group in late medieval Lisbon (Figure 6-8), similarly to what has been seen in other multi-faith sites within this thesis (i.e. Beja and Silves).

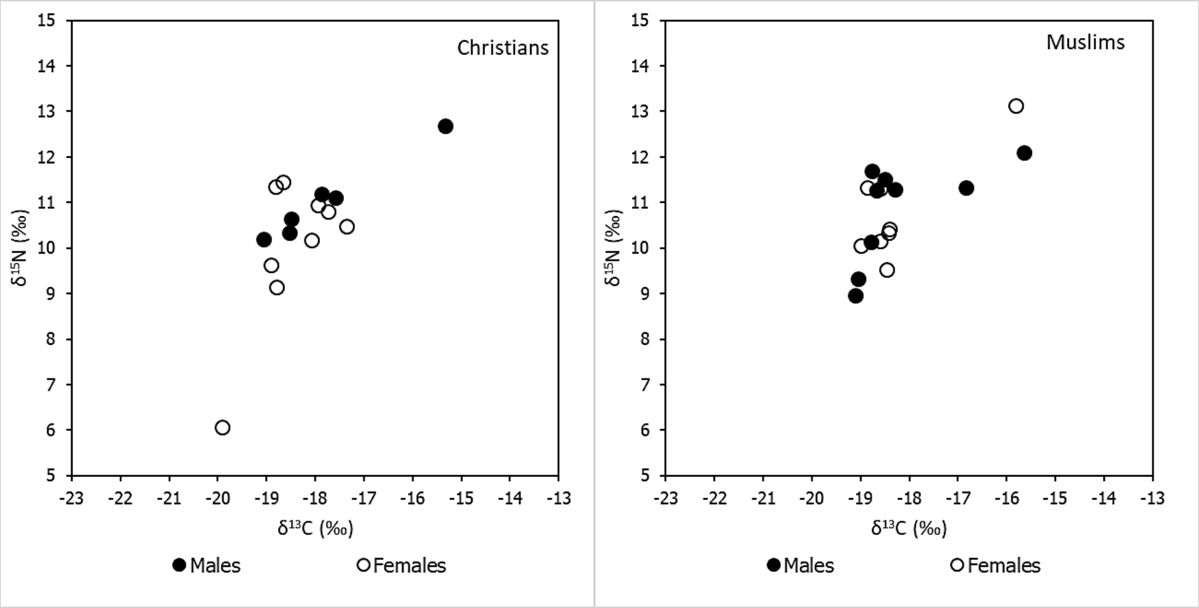

**Figure 6-8** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of Muslims and Christians per sex. One outlier individual (QDL 104) has been omitted from the Muslim population for scale purposes.*

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Samples | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Christians (F) | 9 | -19.9 | -17.4 | 2.5 | 18.5±0.8 | 6.1 | 11.4 | 5.4 | 10.0±1.7 |
| Christians (M) | 6 | -19.1 | -15.3 | 3.7 | -17.8±1.3 | 10.2 | 12.7 | 2.5 | 11.0±0.9 |
| Muslims (F) | 11 | -19.3 | -8.2 | 11.1 | -17.4±3.2 | 8.4 | 13.1 | 4.7 | 10.5±1.2 |
| Muslims (M) | 9 | -19.1 | -15.6 | 3.5 | -18.2±1.2 | 9.0 | 12.1 | 3.1 | 10.8±1.1 |
| Muslims (U) | 1 | - | - | - | -18.4 | - | - | - | 11.8 |
| Muslims (J) | 2 | -19.0 | -16.6 | 2.4 | -17.8 | 10.2 | 10.8 | 0.6 | 10.5 |

***Table 6-8*** *Summary of isotopic data for humans from Muslim quarter cemetery, Lisbon by faith, sex (F=females, M=males, U=undetermined) and age (J=juveniles). Standard deviation is calculated where the sample number is at least 3.*

### 6.5 Central Portugal: Setubal

In this section, the data of the Muslim individuals from Rua Francisco Augusto Flamengo (FAF), Setubal, are presented and discussed and compared to contemporaneous animals from the nearby fortress of Palmela. Results for both human and faunal data are plotted together in Figure 6.9. Summary statistics for the dataset are provided in Table 6-8. Breakdown of the human population values by sex and age groups is provided in Table 6-9 and plotted in Figure 6-10.

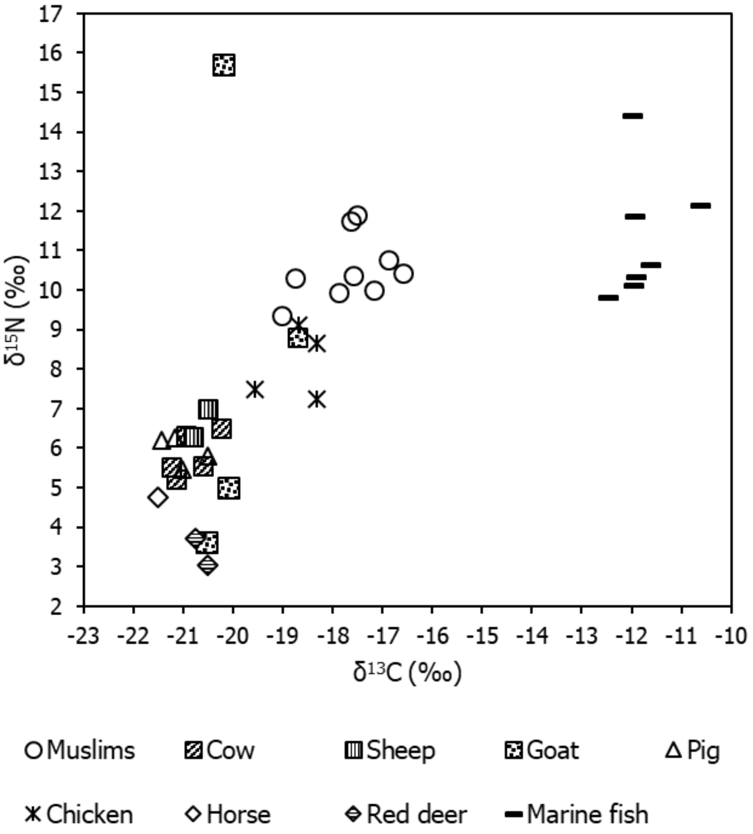

***Figure 6-9*** *Scatter plot of δ13C and δ15N ratios (‰) of humans from Rua Francisco Augusto Flamengo, (FAF) (n=9), Setubal (10th-12th C), and animals (n=22) from Palmela Castle (8th-12th C). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

With the exception of two goats (sample CP1 and CP5), herbivores and pigs form a tight group for both $\delta^{13}$C and $\delta^{15}$N values, indicating $C_3$ based diets. Chickens show higher values of both carbon and nitrogen and bridge the gap between animal and human diet values. Chickens were likely kept within or around human settlements and fed scraps.

The two goats stand out in terms of their nitrogen values. One individual (CP5) has enriched values compared to the other herbivores. The other goat (CP1) has an unusually high nitrogen isotope value (15.7‰). Such high nitrogen isotope values have been reported for herbivores from arid areas e.g. antelope from Egypt (Thompson et al. 2005). The Palmela area is rich in water, surrounded by vegetation and close to the coast and the estuary of the Tagus River. Zooarchaeological assessment of the assemblage revealed that animals were procured and brought to the castle for processing (Fernandes et al. 2015:117). Because of the climatic conditions in Palmela, and since no other animal sampled in this dataset from Portugal exhibits such high nitrogen isotope values, it is suggested that this animal derived from another, extremely arid, geographic area with $^{15}$N-enriched soil, possibly North Africa. Movement of livestock into Iberia from the East and North of Africa has been recorded in both written and archaeological sources especially for dromedaries (Morales Muñiz et al. 2001). Two fragments (scapula and humerus) of a young camel were found at Palmela with butchery cut marks (Fernandes et al. 2015:118). This is a rare finding in the Iberian zooarchaeological record, although camel scapulae were used in the East as writing support to practice the Arabic alphabet (Doménech-Belda and López-Seguí 2008).

Zooarchaeological studies of sheep bones from southern Portugal indicate a marked size increase during the Islamic period that may reflect an improvement of this animal, resulting from human management or incoming stock from elsewhere (i.e. merino sheep) (Davis 2008). A modern DNA study on Portuguese sheep breeds found an influence of maternal lineages from the Middle East and Asia, especially in southern Portuguese breeds (Pereira et al. 2006). The study of pottery (fine ware and common ceramic) from Palmela suggested the presence of a governor/elite living in the castle together with a lower status garrison (Fernandes et al. 2015:126). Altogether, this evidence suggests some influx of goods and animals from other parts of the Islamic world during the permanence of this military branch in Palmela.

| | | $\delta^{13}$C/‰ | | | | $\delta^{15}$N/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Human | 9 | -19.0 | -16.6 | 2.4 | -17.7±0.8 | 9.4 | 11.9 | 2.5 | 10.5±0.8 |
| Cow | 5 | -21.2 | -20.2 | 1 | -20.8±0.4 | 5.2 | 6.5 | 1.3 | 5.8±0.6 |
| Sheep | 2 | -20.8 | -20.5 | 0.3 | -20.8 | 6.3 | 7.0 | 0.7 | 6.7 |
| Goat* | 3 | -20.5 | -18.7 | 1.8 | -19.9±0.8 | 3.6 | 8.8 | 5.2 | 5.8±2.7 |
| Horse | 1 | - | - | | -21.5 | - | - | | 4.7 |
| Chicken | 4 | -19.6 | -18.3 | 1.3 | -18.7±0.6 | 7.2 | 9.1 | 1.9 | 8.1±0.9 |
| Pig | 4 | -21.4 | -20.5 | 0.9 | -21.0±0.4 | 5.5 | 6.3 | 0.8 | 5.9±0.4 |
| Red deer | 2 | -20.8 | -20.5 | 0.3 | -20.6 | 3.0 | 3.7 | 0.7 | 3.4 |

Table 6-8 *Summary of isotopic data for humans from Rua Francisco Augusto Flamengo (FAF), Setubal and animals from Palmela Castle. Standard deviation is calculated where the sample number is at least 3. Where a*

*species is represented by one sample, the raw value is given. *The goat group does not include individual CP1 as it is considered an outlier. Values for this individual can be found in Appendix A.*

The human population shows a diet based on low trophic level proteins, as indicated by the relatively low nitrogen isotope values with input of $C_4$ plants and/or of low trophic level fish. The reliance on $C_4$ plants rather than low trophic level fish is challenging to detect from stable isotope values in some regions because of their similar $\delta^{15}N$ values. Although the $\delta^{15}N$ values are relatively low (max of 11.9‰), the large offset in N (~5‰) and C (~3‰) between herbivores and human values suggests an input of higher trophic level protein such as chickens or marine fish into the diet. The archaeological context of the site, a small settlement on the beach of Setubal, would make the hypothesis of fish consumption more convincing, and the zooarchaeological evidence of the site could be used to corroborate the tentative trends in the isotopic data. An intensive fishing industry was active in Setubal during the Roman period as testified by the numerous factories excavated along the coast (Soares and Silva 2012; Tavares da Silva and Coelho-Soares 2016). The industry and the intensive processing of fish products ended towards the 5th century when all the factories were abandoned or repurposed. Visigothic historical sources mention the abundance of fish in Portugal; however, sources are scarce for the Islamic period and it is only in the Anglo-Norman account of Lisbon's siege that fish is mentioned again as one of the main resources for Lisbon and the Tagus River (Cunha 1972:7).

Because of the small sample size, it is not possible to indulge in further speculation about age- and sex-related diet; however as it is shown in Figure 6-10, all adults have a similar diet, as well as non-adults older than 2 years (ranging between 5 and 11 years old). The only two non-adult individuals younger than 2 years of age have higher (~2‰) nitrogen isotope values in comparison to the adult mean, suggesting they are still retaining the breastfeeding signal, similar to what has been shown in the population of São Jorge Castle, in Lisbon.

| | | $\delta^{13}C$/‰ | | | $\delta^{15}N$/‰ | | |
|---|---|---|---|---|---|---|---|
| Age/Sex | No. | Min | Max | Mean ±1σ | Min | Max | Mean ±1σ |
| Adult females | 3 | -17.9 | -16.9 | -17.5±0.5 | 9.9 | 10.8 | 10.4±0.4 |
| Adult undetermined | 1 | - | - | -16.6 | - | - | 10.4 |
| Non-adults > 2 y | 3 | -19.0 | -17.2 | -18.3±1.0 | 9.4 | 10.3 | 9.9±0.5 |
| Non-adults < 2 y | 2 | -17.6 | -17.5 | -17.6 | 11.8 | 11.9 | 11.8 |

***Table 6-9*** *Summary of isotopic data per sex and age groups of human individuals from Rua Francisco Augusto Flamengo (FAF), Setubal. Undetermined individuals are adult individuals of unknown sex. Standard deviation is calculated where the sample number is at least 3.*

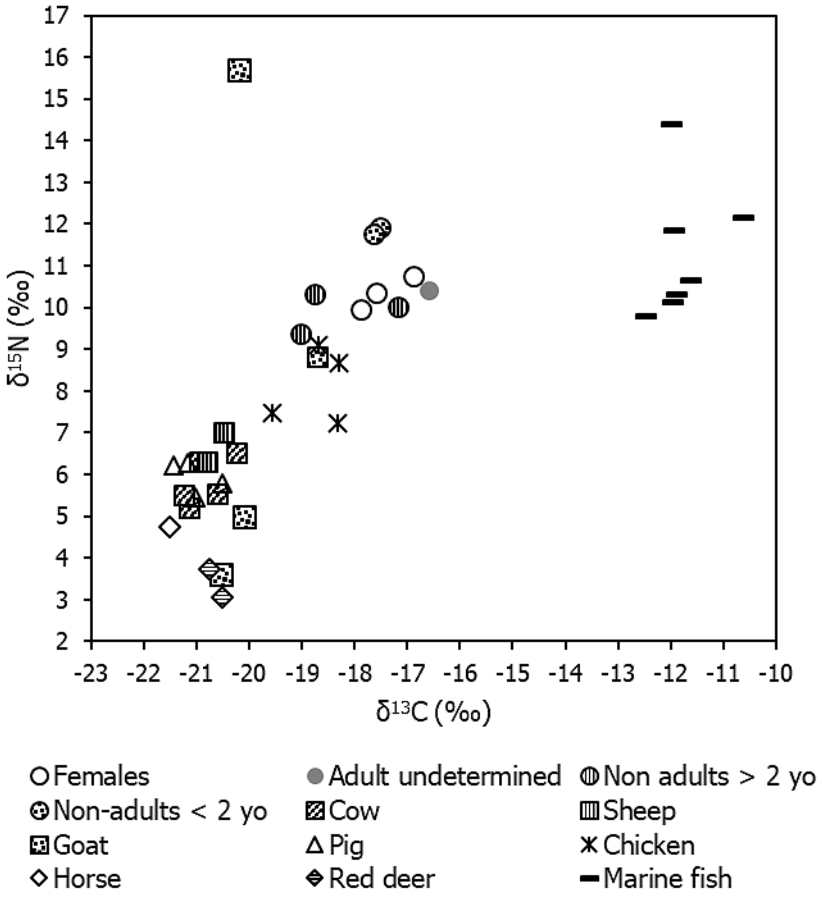

*Fig. 6-10 Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) per age and sex groups of the population from Rua Francisco Augusto Flamengo, Setubal. Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

## 6.6 Summary of trends in Central Portugal

Despite the coastal location of both sites, the early medieval population of Lisbon has a terrestrial diet with no marine resources showing in its diet. High status women have a similar diet to the urban population, while males seem to have different eating habits. While this may reflect the social organization of the Islamic household, it seems to affect the high status population only, as no sex-related difference can be seen in the urban population's diet. The Muslim population in Setubal, however; shows a mixed diet with carbon isotope values that would suggest either low trophic level fish or $C_4$ resources as a complement to their diet. The coastal location of this site and the shell middens excavated there, support the idea of a marine diet.

A different economy seems to appear after the Christian conquest and both Muslims and Christians in Lisbon rely more significantly on marine resources during the Late Medieval period. This evidence is supported by historical sources that attest an over-exploitation of the Portuguese coast and the need to find new areas to supply the demand of fish.

Similarly to what has been observed for the Northern populations, different dynamics and economic strategies were in place in rural and urban sites. To a first analysis it seems that rural sites are less likely to follow what historical sources recall for the period, and are significantly affected by the local environment and the availability of resources. The urban sites on the contrary, show patterns that would be expected for the time period and the faith group, i.e. millet and $C_4$ crops/low trophic level fish in the Christian population in Coimbra and terrestrial based diet focussing on meat and animal resources in the Muslim population of Lisbon. This dichotomy is not surprising, as the urban centres would have access to a wider range of resources and could supply the most desirable foodstuff from the region. In contrast, a small rural settlement would be less likely to rely on imported resources and would be based on a subsistence economy which is significantly affected by local procurement.

# 7. SOUTHERN PORTUGAL

This chapter presents the results obtained from the southern sites: Beja, Silves and Loulé. Since Beja is an inland site, it is presented separately from the other two sites that are in close proximity to or on the coast.

## 7.1 Southern Portugal: Beja

Muslims and Christian individuals from Beja were excavated from the same cemetery. Due to the lack of animal remains from the site, the animal baseline for this burial population derives from recently published animal data from a nearby site (Monte da Cegonha) of Late Antique chronology (Saragoça et al. 2016). The human data is plotted by faith in Figure 7-1 and summary statistics are provided in Table 7-1. A breakdown of the Christian and Muslim population by sex is plotted in Figures 7-2. Five individuals were radiocarbon dated from this cemetery to aid the interpretation of the site and the results are presented in Table 7-2.

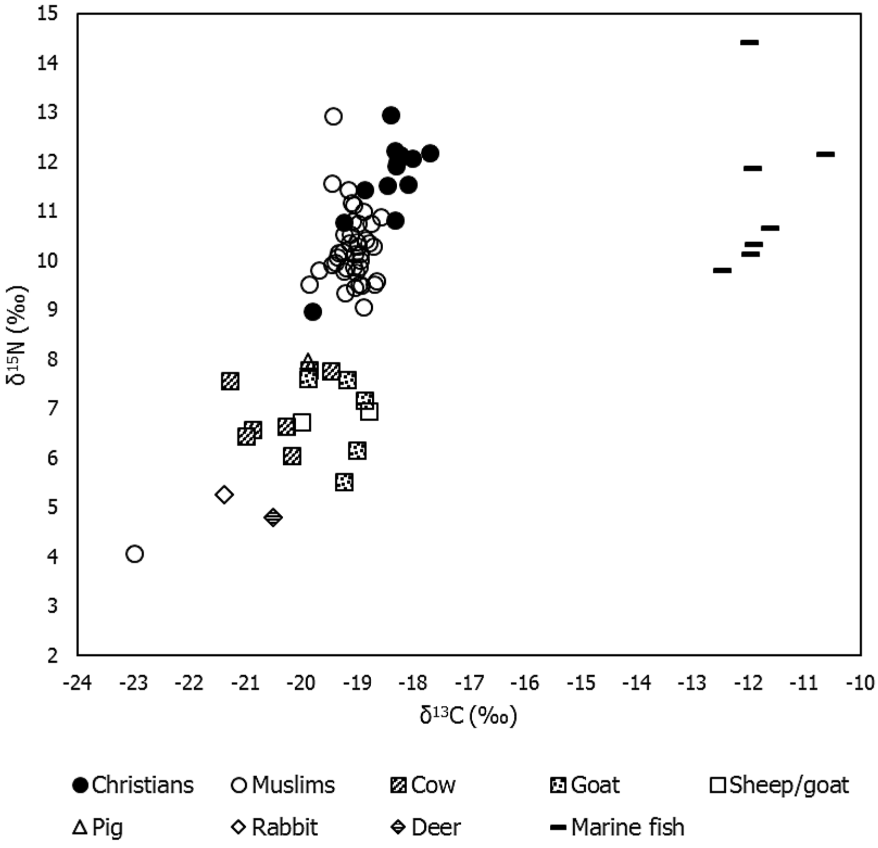

***Figure 7-1*** *Scatter plot of $\delta^{13}$C and $\delta^{15}$N ratios (‰) of humans (n=54) from Escola Secundária Diogo Gouveia, Beja (BEJ) including Muslims (n=41) 8th-12th C and Christians (n=13) 13th-15th C., and animals (n=17) from Monte das Cegonhas (Saragoça et al. 2016). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

The animals included in the graph from Monte da Cegonha (7th-9th C) follow a similar pattern to the animals analysed in this thesis, showing a $C_3$ plant-based diet (Table 7-1). The range in both $\delta^{13}C$ and $\delta^{15}N$ values for all species is ~2‰ which is more contained than other sites, particularly for $\delta^{15}N$.

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Samples | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Christians | 13 | -19.8 | -17.7 | 2.1 | -18.5±0.5 | 9.0 | 13.0 | 4 | 11.6±1.0 |
| Muslims | 43 | -23.0 | -18.6 | 4.4 | -19.2±0.7 | 4.1 | 12.9 | 8.8 | 10.1±1.2 |
| Christians (F) | 6 | -19.2 | -18.0 | 1.2 | -18.5±0.4 | 10.8 | 13.0 | 2.2 | 11.8±0.7 |
| Christians (M) | 5 | -18.3 | -17.7 | 0.6 | -18.1±0.3 | 10.8 | 12.2 | 1.4 | 11.6±0.6 |
| Muslims (F) | 21 | -19.7 | -18.6 | 1.1 | -19.1±0.3 | 9.4 | 12.9 | 3.5 | 10.3±0.8 |
| Muslims (M) | 19 | -23.0 | -18.7 | 4.3 | -19.3±0.9 | 4.1 | 11.6 | 7.5 | 9.9±1.5 |

***Table 7-1*** *Summary of isotopic data for humans from Escola Secundária Diogo Gouveia, Beja (BEJ) by faith and sex (F=females, M=males). Standard deviation is calculated where the sample number is at least 3.*

The human population plots in two clusters by faith. Although some Christian individuals have similar values to the Muslims, the difference in diet based on faith group is evident and statistically significant for both $\delta^{13}C$ and $\delta^{15}N$ (two samples Mann-Whitney U test, p=0.00 and p=0.00 respectively). The Muslim diet is similar to the one at other sites in this Portuguese dataset, with widely ranging $\delta^{15}N$ values (~9‰) indicating a variety of protein sources contributing to the diet but not much variation in $\delta^{13}C$ values, which indicate $C_3$-based terrestrial diets and suggest an almost exclusive reliance on $C_3$ plants. The range of $\delta^{15}N$ values are also affected by one outlier individual (BEJ3200) that shows significantly depleted values of both $\delta^{13}C$ and $\delta^{15}N$. Such carbon isotope values would be in accordance with colder climate (chapter 2) and the nitrogen isotope values are even lower than the herbivorous animals suggesting a complete lack of animal proteins. These values are rather unexpected and although the skeleton did not show signs of obvious pathology, medical conditions or illnesses may have affected this individual. Unfortunately the effect of pathologies on bulk collagen stable isotopes is not well understood (Webb et al. 2015, Katzenberg and Lovell 1999).

The offset between the Muslim population and the faunal remains mean values is ~3‰ although the variation in nitrogen isotope is quite wide and some individuals have $\delta^{15}N$ values that are 4-5‰ higher than the faunal remains. Despite the nitrogen isotope variability, the offset is still within the anticipated range of trophic level enrichment. $C_4$ plants make no significant contribution to the diet of the Muslim community in Beja.

Christian individuals demonstrate higher values for both $\delta^{13}C$ and $\delta^{15}N$, indicating a reliance on marine resources. Cultural preferences will certainly play an important role in differentiating the diet of the two faith groups as historical sources provide wide support to the idea that fish was not a highly regarded food (discussed above). In addition, fish is strongly identified with Christianity and the practice of fasting during Lent and the rest of the year.

What may be the most important factor, however is the differing chronology for these two faith groups, as although they share the same burial ground, radiocarbon dating carried out as part of this project has revealed that they are not contemporaneous. Radiocarbon dating was undertaken on two Muslim and three Christian intercutting graves (Table 7-2). This revealed that the Christians date to the post-conquest period, i.e. post 1238 CE. Two other Muslim individuals were radiocarbon dated by the archaeological unit who first excavated this cemetery and provided similar chronology to the other Muslims (1 sigma 903-914 cal CE; 969-1019 cal CE) (Serra 2012:242). Interestingly, the oldest individual (BEJ 7278), who dates to the early medieval period right after the Islamic expansion of the 8th C, also has the highest nitrogen isotope values (over 6‰ higher than the animal mean), which might suggest an origin from an arid climate. As it has been mentioned above, the difference in diet between these two populations could be not only related to faith but also to chronology since these two groups used the same cemetery 100 years apart. The Christian conquest might have brought about changes in the newly unified Portuguese kingdom's economy which could affect the foodways of the local population. Further discussion about chronological changes in diet in the Portuguese dataset is provided in the Discussion, Chapter 8.

| Skeleton ID | Lab code | Faith | $^{14}C$ (yrs BP) | Correction ΔR | Cal CE 1σ (68.2%) | Cal CE 2σ (95.4%) |
|---|---|---|---|---|---|---|
| BEJ7278 | 28461 | Muslim | 1191±23 | 95±15 | 777-876 | 770-936 |
| BEJ3207 | 28464 | Muslim | 973±24 | 95±15 | 1021-1146 | 1016-1153 |
| BEJ3259 | 28462 | Christian | 695±24 | 95±15 | 1276-1295 | 1268-1383 |
| BEJ3083 | 28463 | Christian | 651±23 | 95±15 | 1290-1385 | 1283-1391 |
| BEJ3102 | 28465 | Christian | 601±21 | 95±15 | 1310-1397 | 1300-1405 |

***Table 7-2*** *Radiocarbon results for two Muslims and three Christians from Beja. The correction factor (ΔR) has been applied following Soares et al. (2016) and calibration of the conventional age was performed using the dataset INTCAL13 (Reimer et al.2013) with the software OxCal 4.3.*

A correction was carried out for the marine reservoir effect, calculating the amount of marine protein in the diet. This value is included in the calibration curve in OxCal 4.3 and a new set of dates are produced and presented in Table 7-3 (full explanation of the methodology applied for radiocarbon dating calibration can be found in Appendix A). As can be appreciated from the table, the Muslim individuals do not have a lot of marine protein in their diet and therefore the dates are not significantly impacted. On the other hand, the Christians who have a higher marine protein intake, have also higher potential to appear older than they are if the marine reservoir effect is not taken into account.

| Skeleton ID | % of marine protein | Cal CE 1σ (68.2%) | Cal CE 2σ (95.4%) |
|---|---|---|---|
| BEJ7278 | 17.4 | 887-990 | 778-1019 |
| BEJ3207 | 20.0 | 1051-1218 | 1035-1249 |
| BEJ3259 | 30.8 | 1324-1436 | 1300-1450 |
| BEJ3083 | 28.9 | 1330-1452 | 1304-1490 |
| BEJ3102 | 30.2 | 1415-1490 | 1330-1620 |

***Table 7-3*** *Radiocarbon results corrected for the marine reservoir effect. The calculations were performed following the equation Marine 2 (Arneborg et al. 1999, Richards and Hedges 1999, Schulting and Richards 2001)*

A sex-related difference in diet has not been found in either the Muslim or Christian populations at Beja. The urban population therefore appears to have had access to similar foodstuffs regardless of sex categories in both periods.

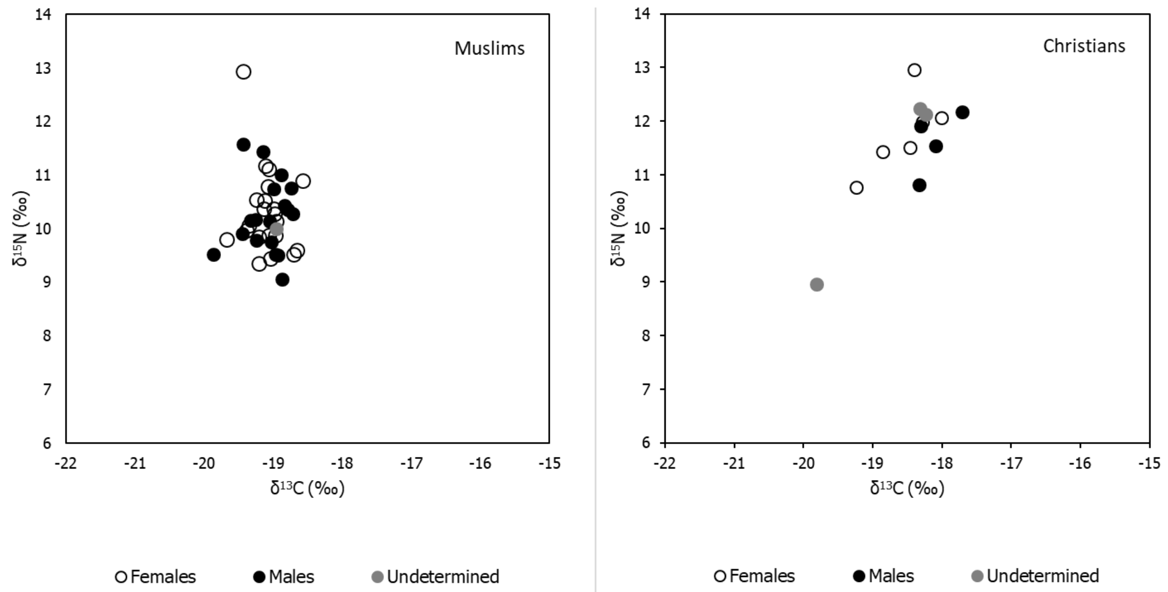

***Figure 7-2*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of Muslims and Christians per sex. One outlier Muslim individual (BEJ3200) is not included in the Muslim plot in order to increase the scale of the figure.*

## 7.2 Southern Portugal: Silves

In this section the results from Silves are presented. Both Muslim and Christian individuals have been excavated in Silves but from different sites. Muslims were analysed from Rua 25 de Abril and Rua A and pertain to the period of Islamic rule (11th-13th C). Christians were analysed from the sites of Rua Miguel Bombarda and Largo da Sé, both dating to later Christian rule (13th-15th). These assemblages are contemporaneous to the Muslims and Christians in Beja. The animal baseline included a number of faunal remains from waste pits excavated in Silves and of medieval chronology (11th-15th C). Isotopic results for human and animal samples are plotted in Figure 7-3 and summary statistics are provided in Table 7-4. A breakdown of the Christian and Muslim population by sex is shown in Figure 7-4.

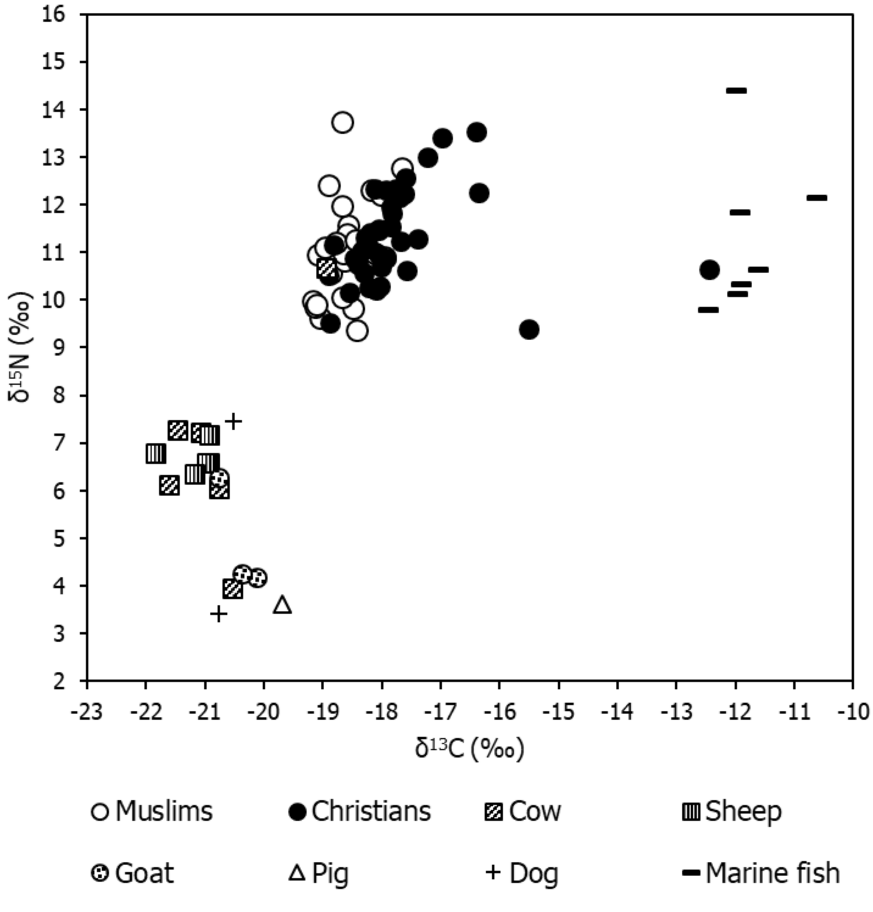

***Figure 7-3*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of humans (n=65) from Silves (Muslims 11th-13th C and Christians 13th-15th C), and animals (n=16) from Silves (11th-15th C). Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

| | | $\delta^{13}$C/‰ | | | | $\delta^{15}$N/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species/Faith | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Muslims | 25 | -19.2 | -17.7 | 1.5 | -18.6±0.4 | 9.4 | 13.7 | 4.3 | 11.1±1.1 |
| Christians | 40 | -18.9 | -12.5 | 6.4 | -17.8±1.1 | 9.4 | 13.5 | 4.1 | 11.3±1.0 |
| Cow | 7 | -21.6 | -19.0 | 2.6 | -20.8±0.9 | 4.0 | 10.7 | 6.7 | 6.8±2.0 |
| Sheep | 4 | -21.8 | -20.9 | 0.9 | -21.2±0.4 | 6.4 | 7.2 | 0.8 | 6.7±0.3 |
| Goat | 3 | -20.8 | -20.1 | 0.7 | -20.4±0.3 | 4.2 | 6.3 | 2.1 | 4.9±1.2 |
| Pig | 1 | - | - | - | -19.7 | - | - | | 3.6 |
| Dog | 1 | - | - | - | -20.6 | - | - | - | 7.5 |
| Marine fish | 2 | -12.5 | -10.6 | 1.9 | -11.6 | 9.8 | 12.2 | 2.4 | 11.0 |

***Table 7-4*** *Summary of isotopic data for humans and animals from Silves. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

The animal diet appears to have a similar distribution to what has been observed for all the other sites: great variability in nitrogen isotope values while less variability in carbon isotope values, suggesting reliance on $C_3$ plants and lack of $C_4$ plants as fodder. At this site, there is no species related patterning in diet and herbivores, omnivores and dogs show very similar terrestrial values based on $C_3$ resources. Cattle appear to be the most variable species, similar to other sites, with $\delta^{15}$N values ranging from 4.0‰ to 10.7‰. The only pig of the assemblage presents lower values than most of the herbivores.

The trophic level offset between the mean animal values and the human values is about 5‰ and at the high end of the accepted range for trophic level enrichment. The human individuals plot in two different groups in relation to faith, similarly to what was observed at Beja. The Muslim population has widely spread $\delta^{15}$N values ranging from 9.4‰ to 13.7‰ which is very similar to the Christian population, however, the Christians exhibit a wider range in $\delta^{13}$C (-18.9‰ to -12.5‰) and enrichment in $\delta^{13}$C compared to Muslims. This pattern again suggests a higher intake of proteins from marine resources for the Christian population. Two Christian individuals (LSE10 and RMB11B) show significant enrichment in $\delta^{13}$C (~2‰ and ~5‰ respectively) coupled with lower $\delta^{15}$N values which could be due to either low trophic level fish or more likely $C_4$ plant consumption in this case. The difference between Muslims and Christians in Silves is statistically significant for $\delta^{13}$C (Mann Whitney test U=149, p value=0.00) but not for $\delta^{15}$N. Similarly, to Beja, these two populations are of different chronology;

therefore, a change in economy resulting from the political shift is an important factor to consider, although the pattern is more ambiguous compared to Beja.

When the population is divided by sex, no difference can be observed in the diet of males and females, although it is notable that in the Christian population, the individuals with higher nitrogen isotope values are all females and in the Muslim population they are all males.

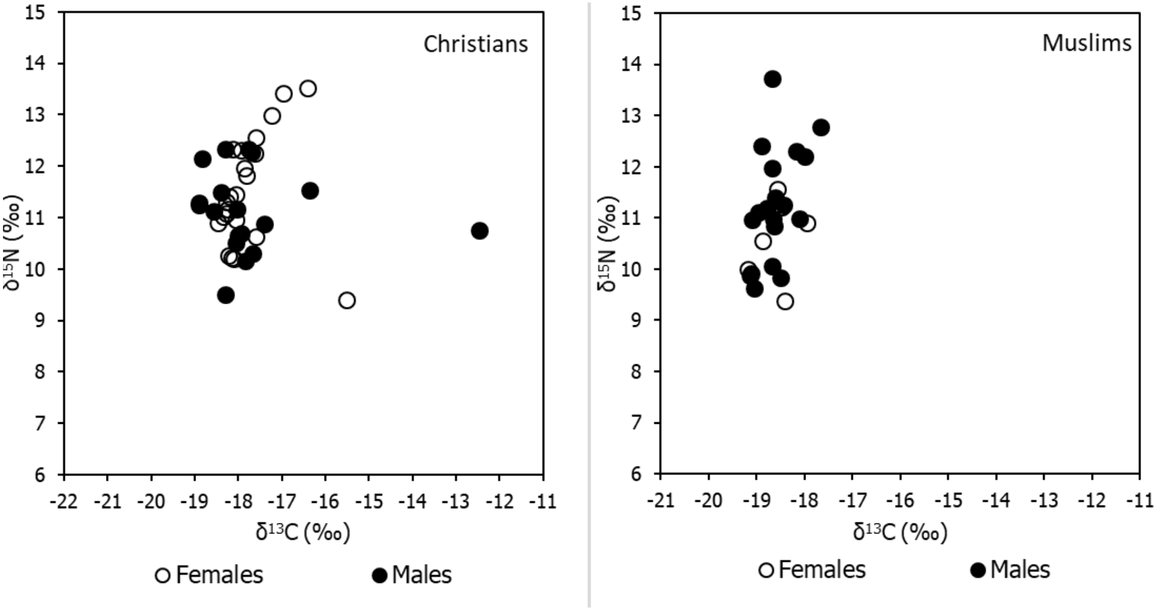

***Figure 7-4*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of Muslims and Christians by sex.*

## 7.3 Southern Portugal: Loulé

In this last section, the results from Loulé are presented. This cemetery was serving a small settlement on the beach and belonged to a small rural Muslim community (11th-13th C). Faunal remains come from the same site and are results of waste activities mostly related to cooking and eating. This settlement is similar to Setubal in terms of its location on the seashore and rural nature. Isotopic results for humans and animals are plotted in Figure 7-5 and summary statistics are provided in Table 7-5. The animal diet appears to have a similar variation in terms of $\delta^{15}N$ (~8‰) compared to all the other sites; however if only herbivores are considered, the $\delta^{15}N$ range decreases to ~4‰. The bigger variation for the animal data from Loulé is shown in their $\delta^{13}C$ values, suggesting that both $C_3$ and $C_4$ resources were used to manage both herbivores and omnivores. Goats have lower $\delta^{15}N$ values than cattle and sheep and this difference is statistically significant (two samples Mann Whitney U test, U=0 and p=0.00), although it is not significant for $\delta^{13}C$. This trend is further discussed in Chapter 8 since it is observed across all sites in this thesis when grouped together. The only horse of the assemblage shows a diet based on $C_4$ resources which is rather unique in this thesis data set.

One horse specimen was analysed for Lisbon and its value suggests a mixed diet of $C_3$ and $C_4$ resources, while the specimen from Coimbra shows depleted $\delta^{13}C$ values compared to all other animals. Three individuals are not a large enough sample to discuss trends in horse rearing; however it seems that $C_4$ resources were more likely to be given to horses at Islamic sites.

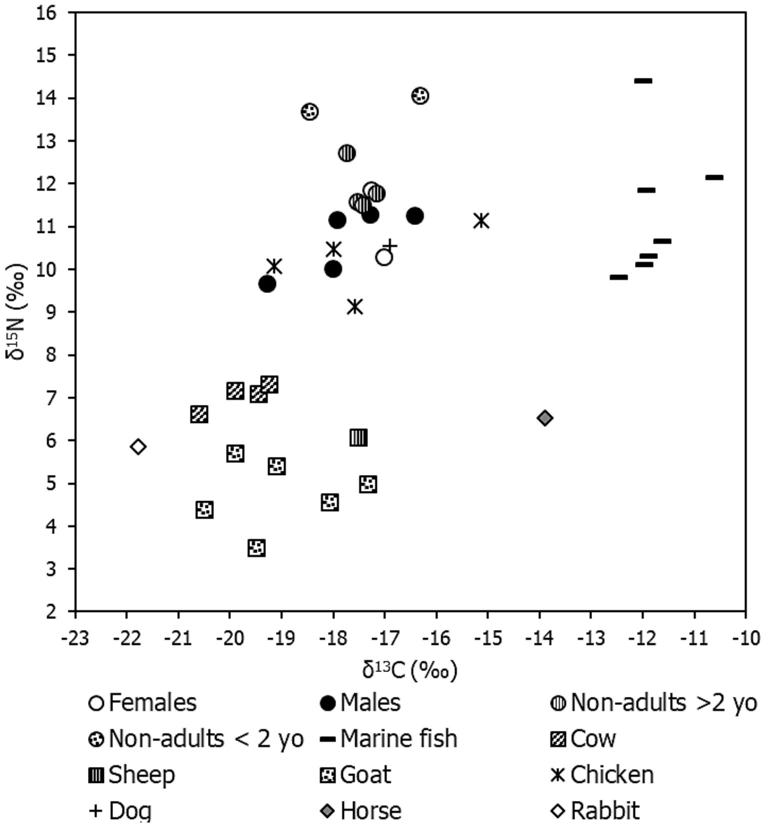

***Figure 7-5*** *Scatter plot of $\delta^{13}C$ and $\delta^{15}N$ ratios (‰) of humans from Quinta do Lago, Loulé (LU) (n=13) (11th-13th C), and animals (n=18) from the same site. Marine fish (n=7) from Lisbon, Silves and Loulé (10th-14th C).*

Omnivores' diet, including one dog and four chickens, is consistent with the one that has been observed at most of the sites and significantly similar to the human diet. Although the difference is not statistically significant, chickens have enriched $\delta^{13}C$ values compared to cattle, while the difference is less clear compared to goats. . Also in this case, chickens are plotting with the human population (Fig. 7-5) and are likely to have been kept as backyard animals, feeding on domestic waste. A similar scenario to late medieval Lisbon and Setubal can be observed for Loulé, since it is not possible to ascertain if the higher $\delta^{13}C$ values of the chickens and the humans are due to low trophic level fish or $C_4$ plant consumption. Human diet is based on low trophic level proteins, as indicated by the relatively low nitrogen isotope values with input of $C_4$ plants and/or of low trophic level fish.

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species/Faith | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Adults | 7 | -19.3 | -16.4 | 2.9 | -17.6±0.9 | 9.7 | 11.9 | 2.2 | 10.8±0.8 |
| Non-adults >2yo | 4 | -17.7 | -17.2 | 0.6 | -17.5±0.2 | 11.5 | 12.7 | 1.2 | 11.9±0.6 |
| Non-adults < 2yo | 2 | -18.5 | -16.3 | 2.2 | -17.4 | 13.7 | 14.1 | 0.4 | 13.9 |
| Cow | 4 | -20.6 | -19.2 | 1.4 | -19.8±0.6 | 6.6 | 7.3 | 0.7 | 7.1±0.3 |
| Sheep | 1 | - | - | - | -17.5 | - | - | - | 6.1 |
| Goat | 6 | -20.5 | -17.3 | 3.2 | -19.1±1.2 | 3.5 | 5.7 | 2.2 | 4.8±0.8 |
| Chicken | 4 | -19.1 | -15.1 | 4.0 | -17.5±1.7 | 9.1 | 11.2 | 2.1 | 10.2±0.8 |
| Dog | 1 | - | - | - | -16.9 | - | - | - | 11.0 |
| Marine fish | 2 | -12.0 | -11.9 | 0.1 | 11.9 | 10.1 | 10.3 | 0.2 | 10.2 |

***Table 7-5*** *Summary of isotopic data for humans and animals from Loulé. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.*

The reliance on $C_4$ plants rather than low trophic level fish is challenging to detect from stable isotope values because of their similar $\delta^{15}N$ values. The $\delta^{15}N$ values are relatively low (the highest value for the adult population is 11.5‰) and the offset is within the accepted range of trophic level enrichment (~4‰ for $\delta^{15}N$ and ~1‰ for $\delta^{13}C$). If on one hand, the carbon-enriched values of the horse and of the goats suggest that $C_4$ resources were available and used on site as animal fodder, the location of this settlement on the seashore would suggest that low trophic level fish was also easily available and shell middens dating to the Islamic period have been excavated on site. Similarly to what has been observed for Setubal, rural coastal populations seem to be affected more heavily by the environment in their food choices than urban areas and it is likely that at Loulé a mixed-resources diet was obtained from low trophic level fish or molluscs, $C_4$ plants and terrestrial proteins.

Because of the small sample size, it is not possible to indulge in further speculation about age and sex related diet; however as it is shown in Figure 7-5, all adults have a similar diet. The two non-adult individuals with the highest $\delta^{15}N$ values are less than 2 years old, while the others range between 4 and 7 years of age and have a similar diet to the adult population. Nitrogen isotope values of the youngest individuals show an offset of ~3‰ in comparison to the adult mean, suggesting they are still retaining the breastfeeding signal, similar to what has been shown in the populations of São Jorge Castle in Lisbon and Setubal.

## 7.4 Summary of trends in Sothern Portugal

Southern Portugal included two major multi-faith urban sites that showed a similar trend and a faith-related difference in diet and one small rural coastal site. In the urban sites Muslims have a terrestrial diet but exhibit a wide range of $\delta^{15}N$ values at both Beja and Silves indicating the inclusion of different trophic level resources into their diet. The high variation in $\delta^{15}N$ is also seen for the faunal remains across many of the Portuguese sites in this thesis and therefore is believed to have an impact on the human values as well. Little variation is seen in the Muslim terrestrial $\delta^{13}C$ values at the urban sites, while at the rural coastal site, higher $\delta^{13}C$ values suggest the inclusion of low trophic level fish or $C_4$ resources in the diet.

The Christian population at both urban sites show an increasing reliance on marine resources compared to the Muslim population and the local fauna, as shown by the higher $\delta^{13}C$ and $\delta^{15}N$ values. These two populations are in addition of later medieval chronology and like the later medieval population from Lisbon, show a significant change in diet compared to the earlier chronology sites.

# 8. INTEGRATED DISCUSSION

This chapter provides a wider discussion of dietary patterning between sites, starting with an overview of the animal and human dataset across all sites. The chapter continues with a consideration of the intersection of human dietary practices with a number of factors such as sex but also faith, and chronology in an effort to explore the multi-faceted nature of foodways in Medieval Portugal. A discussion of status related diet in Islamic Portugal has been undertaken in an accepted publication for the only high status site of this data set, São Jorge Castle, Lisbon. A copy of the publication is provided in Appendix C.

## 8.1 Animal data across all sites

The following discussion focuses on the diet of those animals that contributed the most to the human diet and for which we have the most data: herbivores, chickens, pigs and fish. The assessment of herbivore and omnivore data across sites is instrumental and necessary to explore the human dietary practices.

### 8.1.1 Domestic herbivores across all sites

The comparison of herbivores across all regions is undertaken to explore possible patterning of diet and husbandry practice in relation to species. As explained in Chapter 4, when sheep and goat bones were not distinguishable, ZooMS (Buckley et al. 2010) was used to assign the samples to species in order to explore possible difference in husbandry practices between these two groups of herbivores. Differences between grazers (sheep) and browsers (goat) are easily documented in tropical climates thanks to higher presence of $C_4$ plants that account for the majority of the grasses (Cerling et al. 2003, Balasse and Ambrose 2005). A study on modern caprines from Mongolia showed a difference in $\delta^{13}C$ and $\delta^{15}N$ values between provisioned individuals and wild ones (Makarewicz and Tuross 2006). This difference within the same species has been used as evidence of human manipulation of the animal diet. Wild species showed lower values of $\delta^{13}C$ and $\delta^{15}N$ while heavily managed animals showed consistently higher values. Similarly to the dataset in this thesis, the $\delta^{15}N$ values of domestic sheep are significantly higher than goats but this difference has been interpreted as a reflection of a premature weaning of kid compared to lambs, because of the high reliance of Mongolian herders on goat milk. Ibn al-Awwam in his 12th century Treatise of Agriculture (Ibn al-Awwam 1802) mention the use of species of millet and barley to raise and fatten cattle, and bitter vetch is mentioned in order to produce good and abundant milk in all species. This legume can fix nitrogen and may contribute to lower $\delta^{15}N$ values in animals that were kept for milk, providing that these guidelines were widely followed; however all herbivores were potentially kept for milk and the quantity of this legume in their diet might have been marginal. Only one study from medieval southern Europe has reported differences between the two species, with goats showing more variable nitrogen isotope values and a possible input of $C_4$ resources in 11th century Crete (Bourbou and Richards 2007). This lack of data is also due to the previously mentioned difficulty in assigning all fragments to species and therefore it is standard practice to include both sheep and goat in the same 'ovicaprid' group and compare it to other herbivores (i.e. cattle),concealing the differences that might exist among these three species. Hence, the application of ZooMS and stable isotopes analysis to animal remains undertaken in this dataset offers the opportunity to systematically explore feeding and husbandry practices of sheep and goat and cattle between sites. Summary data of the three species are presented in Table 8-1 below and scatter plot of $\delta^{15}N$ and $\delta^{13}C$ ratios is found in Figure 8-1.

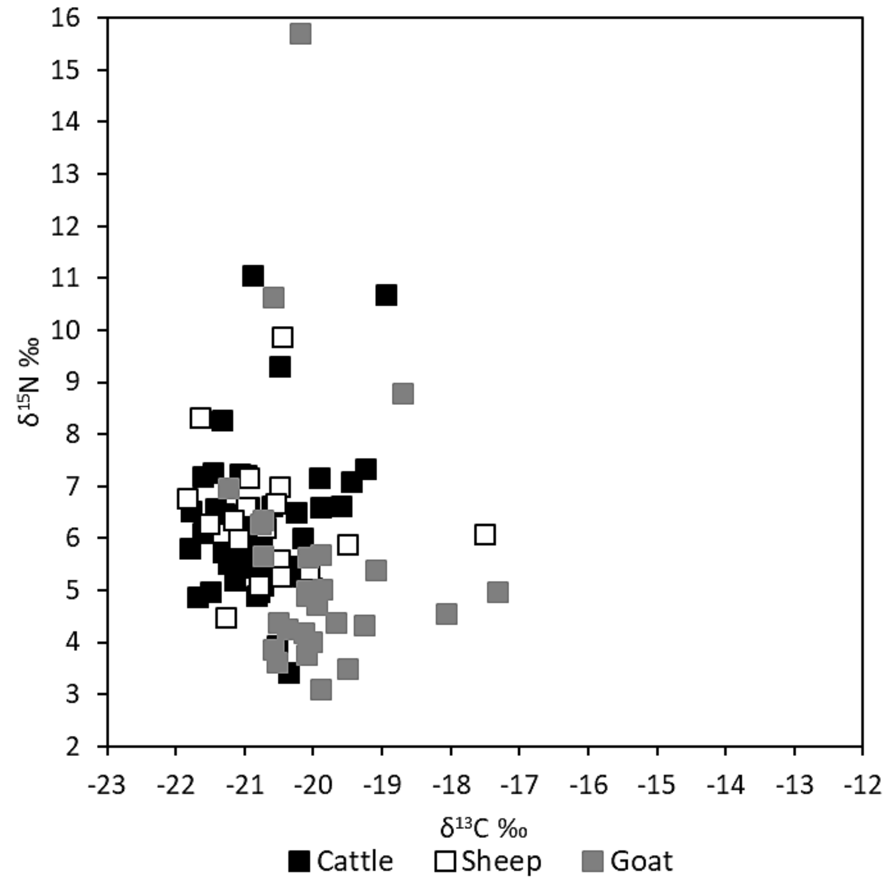

***Figure 8-1*** *Bivariate plot of $\delta^{13}C$ and $\delta^{15}N$ (‰) ratios of cattle, sheep and goat from all sites.*

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **No.** | **Min** | **Max** | **Range** | **Mean±1σ** | **Min** | **Max** | **Range** | **Mean±1σ** |
| Sheep | 18 | -22.0 | -17.5 | 4.3 | -20.6±1.0 | 4.5 | 8.3 | 3.9 | 6.2±09 |
| Goat | 26 | -21.2 | -17.3 | 3.9 | -20.0±0.7 | 3.1 | 15.7 | 12.6 | 5.6±2.6 |
| Cattle | 46 | -21.8 | -18.9 | 2.8 | -20.7±0.6 | 3.4 | 11.1 | 7.6 | 6.2±1.4 |
| ALL | 90 | -21.8 | -17.3 | 4.5 | -20.5±0.8 | 3.1 | 15.7 | 12.6 | 6.0±1.8 |

*Table 8-1: Summary isotopic data for all cattle, sheep and goats.*

Statistical comparison indicates there is a significant difference between goat and the other two species for $\delta^{13}C$ and $\delta^{15}N$. Specifically there is a significant difference between goat and sheep $\delta^{13}C$ (Mann Whitney U=108, p=0.00) and $\delta^{15}N$ values (Mann Whitney U=355, p=0.00); and a significant difference between goat and cattle $\delta^{13}C$ (Mann Whitney U=959, p=0.00) and $\delta^{15}N$ values (Mann Whitney U=327, p=0.00). There is no statistically significant difference in the cattle $\delta^{13}C$ and $\delta^{15}N$ values compared to sheep (Mann Whitney U=422, p=0.90 and Mann Whitney U=436, p=0.73 respectively).

Mean values differ by >1‰ in all three species, due to the high variability of both carbon and nitrogen isotope values; however the plot illustrates the statistical difference showing the lower $\delta^{15}N$ and higher $\delta^{13}C$ values of goats. Interestingly this pattern did not appear in the assessment of individual sites (although a faint difference between cattle and goat could be seen at Loulé), suggesting that sample size is an issue even when a fairly good number of specimens is analysed per site. Goats appear to have a different diet compared to cattle and sheep and were therefore managed differently, feeding at a lower trophic level and with a possible inclusion of $C_4$ resources in their diet. One outlier goat is not considered here as it is uncertain if this animal was local to Palmela or Portugal at all (Chapter 7).

From these results it appears that sheep and cattle had a different diet to goat, however it has to be considered that this difference could reflect the different feeding approaches of grazers versus browsers. In East African open habitats grazers generally have lower mean $\delta^{15}N$ values than browsers and mixed feeders from open grassland habitats (Ambrose 1991) however the results of this thesis point to the opposite trend. Similar results have been obtained on a small group of sheep and goats in Greenland Norse and while no significant difference could be seen between the two species, goats had the higher $\delta^{15}N$ values (Nelson et al. 2012).

Another option for this difference in $\delta^{15}N$ values is that grazers were possibly closer to human settlements and managed more heavily. These two species might have been subjected to different husbandry regimes for different reasons. Cattle gave milk and were kept for their labour in the fields, while mutton and lamb meat were highly valued, and Arab physicians regarded the meat of young lamb as close to perfection (Rosenberger 1999). Further confirmation of the preferred slaughter age for cattle and caprines is given by a number of zooarchaeological studies that confirm younger age-at-death of sheep and goat compared to cattle in the Iberian Islamic dataset (Davis et al. 2008; García-García 2012, Moreno-García et al. 2008, Pereira 2014). Few specifics are known about stock raising in Al-Andalus. Berbers originally from the Atlas mountains, who represented the majority of the population settled in southern Portugal, practised a mainly pastoral economy and introduced the merino sheep from Morocco sometime before the 14th century (Gerli 2013: 40). Sheep raising was a convenient response to the often contrasting ecological patterns of the Iberian countryside, including extensive portions of non-arable fields and elevated and mountainous areas, which fostered a predominantly pastoral economy based on transhumance, especially in the interior of the Peninsula. In addition, in Castile, it is often presented as a convenient response to a fluctuating political situation (Gerli 2013:752). Important routes of sheep movement are known from the north of Portugal, in the Bragança district, toward Serra da Estrela as early as the Neolithic period, and they still continue today (Fernández-Mier and Tente 2018; Silva 2013; Van Den Brink and Janssen 1985). Cattle are never mentioned in historical sources in relation to transhumance and were kept closer to the urban settlements in available pastures. Examples of extensive pastures located in close proximity to an urban centre exist for Lisbon, where the use of land was contested by shepherds, farmers and hunters (Catarino 1998:119-120).

On the one hand, much is still to be learned regarding goat herds and their management in the Iberian Middle Ages, especially because of the reliance on cattle and sheep in the late medieval economy. The isotopic results presented here, on the other hand, provide direct evidence of different strategies in the management of goat compared to the other domestic herbivores although a dietary difference based on different feeding approaches (grazing vs browsing) cannot be ruled out. This global pattern evidenced throughout Portugal demonstrates the utility of isotopic analysis on animal remains, but also suggest that an effort should be made in future to discriminate between sheep and goat to further explore animal husbandry and livestock management in medieval Iberia.

### 8.1.2 Omnivores data across all sites

The diet of omnivores across all regions is explored to identify feeding patterning in relation to species and in comparison to the herbivore data. Animals such as pigs and chickens can display a variety of diet and have been managed in a number of different ways thanks to their flexible omnivorous and foraging habits. During the Middle Ages, chickens were kept in backyards, free-ranging or fed domestic food waste. Similarly, husbandry practices for pigs could vary significantly including pannage, free-ranging and grazing upon food leftovers and household rubbish (Hamilton and Thomas 2012). Summary statistics of the two species are presented in Table 8-2 below and scatter plot of $\delta^{15}$N and $\delta^{13}$C ratios is found in Figure 8-2.

| | | $\delta^{13}$C/‰ | | | | $\delta^{15}$N/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | No. | Min | Max | Range | Mean±1σ | Min | Max | Range | Mean±1σ |
| Pig | 23 | -22.1 | -18.9 | 3.22 | -20.6±0.8 | 3.6 | 8.9 | 5.3 | 6.3±1.3 |
| Chicken | 20 | -20.3 | -12.6 | 7.7 | -18.2±1.9 | 6.4 | 11.2 | 4.7 | 8.8±1.4 |

***Table 8-2**: Summary isotopic data for all medieval pigs and chicken.*

Statistical comparison indicates that there is a significant difference between pigs and chickens $\delta^{13}$C and $\delta^{15}$N values (Mann Whitney U=24, p=0.00; Mann Whitney U=35, p=0.00 respectively). Specifically, pigs show very similar values to cattle and sheep with terrestrial carbon isotope values and a wide range of nitrogen isotope values (~5‰). However, chickens show higher $\delta^{13}$C and $\delta^{15}$N values, suggesting that their diet was complemented or based on $C_4$ resources and higher trophic level proteins compared to pigs. Pigs show a similar diet to herbivores, and is possible to infer that were managed in a similar way suggesting that backyard rearing was not so common. The widely ranging $\delta^{15}$N values may reflect in this case the different husbandry practices that could be used to manage pigs including free-ranging, pannage, the use of domestic scrap food or a mix of the three. The adaptability of pigs is displayed in the results with some individuals consuming low trophic level proteins while others, similarly to chickens, show $\delta^{15}$N values compatible with human diet. These results are not particularly surprising since the varied diet at which pigs can be kept; however, the almost exact same values are displayed by cattle and sheep. This suggests that regional environmental variation and vicinity to the urban environment might be the most likely causes of the nitrogen isotope range in all these species.

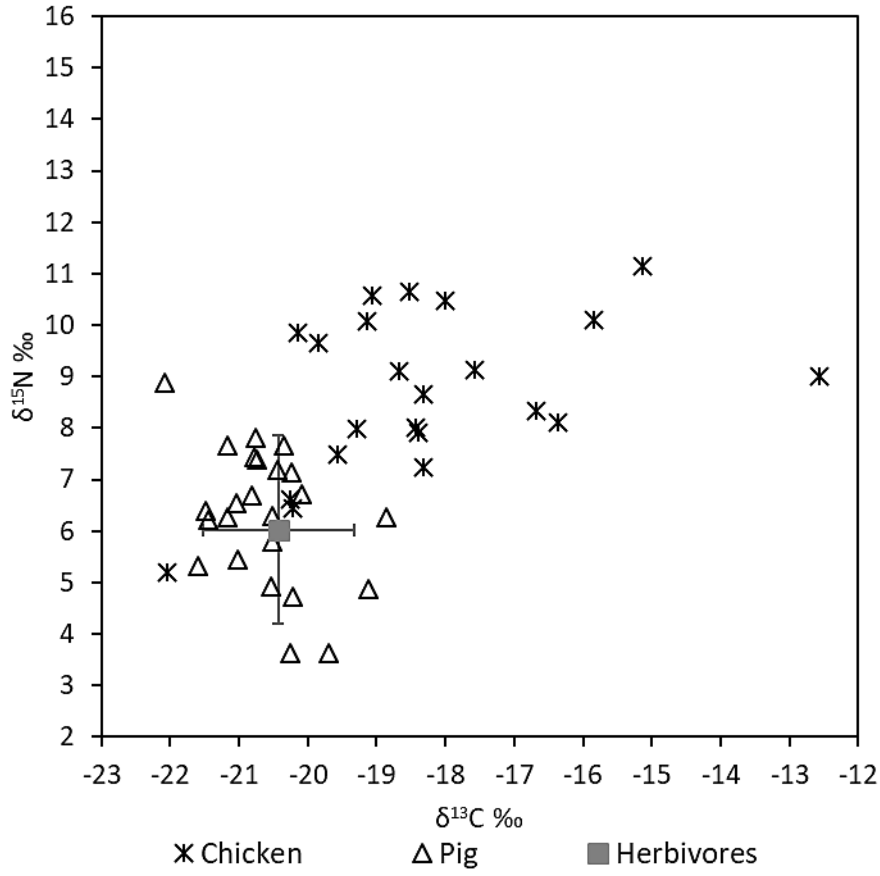

*Figure 8-2 Bivariate plot of $\delta^{13}$C and $\delta^{15}$N (‰) ratios of pig and chicken from all sites.*

The variability of pig diet has been attested before in a number of European Medieval sites in England (Hamilton and Thomas 2012, Hammon and O'Connor 2013, Millard et al. 2013), Belgium (Ervynck et al. 2007) and Norway (Halley and Rosvold 2014). Isotopic data for medieval Iberian faunal remains are rather scarce, however, a late Roman site in Galicia also showed a highly variable diet in pigs (Lopez-Costas and Müldner 2016), as well as in Tomar, a medieval Christian site in Portugal (Curto et al. 2018), and in the Basque Country, where pigs were free-range in the early medieval period and kept at domestic waste in the late Middle Ages (Lubritto et al. 2017). Unfortunately the wide chronology of the faunal remains in this thesis does not allow for a chronological comparison between early and late medieval pigs.

Chickens show higher $\delta^{13}$C and $\delta^{15}$N values compared to pigs. Higher $\delta^{15}$N values are common among chickens: during the Middle Ages they were often kept in backyards and likely foraged in domestic waste (Blench and MacDonald 2000). In addition, consuming insects could also produce higher nitrogen isotope values as shown by isotopic studies (Daugherty and Briggs 2007, Ponsard and Arditi 2000). Strong evidence of backyard rearing also comes from the comparison between chicken and human diet, which is very similar at every site (Chapter 6 and 7), and highlights the easy access that chickens had to the same food consumed by humans.

Little is known of chicken rearing for the Iberian Middle Ages; however, medical treatises and cookery books indicate that chickens had to be fattened, especially capons, before being consumed (García-Sánchez 1990:61). A French agronomic study on farming customs of the Middle Ages, and the Ibn al-Awwam 12th century *Treatise on Agriculture* both suggest the use of millet especially for this purpose, indicating that it may have been a common practice in Medieval Europe (de Serres 1805:9, Ibn al-Awwam 1802). Ethnographic evidence from north-west Spain demonstrates that millet is still traditionally used as animal fodder, particularly for cattle and chickens (Moreno-Larrazabal et al., 2015). Isotopic data from late medieval Spain also indicated a similar trend, with chickens being purposely fed $C_4$ plants and/or scavenging in food scraps that included $C_4$ resources (Alexander et al. 2015). In this data set, chickens have higher $\delta^{13}C$ values compared to pigs and herbivores, but only few of them show values that suggest an almost complete reliance on $C_4$ resources. It is likely that chickens had a mixed diet based on domestic waste and $C_4$ plants that were in some cases a complement to their diet, or the main resource in at least five specimens: three from Coimbra ( CPC 1CH, CPC 3CH, CPC 4CH), one from Lisbon (LS96B) and one from Loulé (LU 23CH).

### 8.2 Inter-site comparison

Summary data for domestic herbivores and omnivores from each site is provided in Appendix A.4. In order to explore inter-site variations, the main domestic species are plotted in separate box plots for $\delta^{13}C$ and $\delta^{15}N$ in order of geographical location from north to south and inland to coast in Figure 8-3 and 8-4. Both the tables and the plots show that there is considerable overlap among herbivores and omnivores across sites and widely ranging $\delta^{15}N$ values at all locations.

Despite the small sample size at some locations, the comparison of the interquartile range of herbivore samples across all sites show that there is no geographic trend in $\delta^{13}C$ values. However, a few patterns can be appreciated from the box plots. Firstly, the presence of outliers indicates that cattle is the most variable species in terms of $\delta^{13}C$ values. The distribution of $\delta^{13}C$ among cow is not the same across all locations, although the mean is very similar, and there is a statistically significant difference between Laranjal and Loulé and the rest of the assemblages (Independent Samples Kruskal-Wallis Test $p=0.01$). The distribution of $\delta^{13}C$ is quite variable among sheep from different sites as well; however, the majority of the samples show reliance on $C_3$ plants. The only individual with high carbon isotope values is the one from Loulé, where the presence of $C_4$ resources as fodder is suggested by the values of one horse, two chickens and two goats (Chapter 7). A similar pattern can be seen in the $\delta^{13}C$ values of goat across sites which are similar to cow (discussed above), and also for this species, Loulé shows higher $\delta^{13}C$

values compared to the other sites. Loulé shows consistently higher $\delta^{13}C$ values in all herbivorous species compared to all other sites. Hot and dry climate can cause an increment of ~2‰ in $\delta^{13}C$ (Chapter 2), which would be an appealing explanation for the consistent higher values of Loulé. However, other southern sites like Silves do not follow this pattern and the northernmost site, Laranjal, actually has slightly higher $\delta^{13}C$ values as well. Hence, the variability portrayed in the $\delta^{13}C$ data seems to be more likely affected by the local environment and husbandry practices rather than following a general geographical trend linked to climate variations. In regard to Loulé the higher values of $\delta^{13}C$ in all species are a sign of a mixed diet that included both $C_4$ and $C_3$ resources as animal fodder (Chapter 7). Nitrogen isotope values do not show a geographical trend either and exhibit a broader range of values compared to carbon. Statistical comparison indicate no difference between herbivores at all sites (Independent Kruskal-Wallis Test cow $p=0.2$; sheep $p=0.1$; goat $p=0.7$). Wide ranges (~5‰) of herbivore nitrogen isotope values have been observed before (Jay and Richards 2007); however, the ranges exhibited at Iberian sites (including the one in this thesis) are particularly broad and larger than 5‰ (Alexander et al. 2015; Curto et al. 2018). This wide range is due to the presence of herbivores with very low $\delta^{15}N$ values (~3‰) alongside others with 9-10‰ and up to 15‰ $\delta^{15}N$. Enrichment in $^{15}N$ values for herbivores can occur for a number of reasons (Chapter 2). Environmental factors include temperature, aridity, coastal proximity and isotopic composition of plants (Amundson et al. 2003; Hartman 2011). High values (up to 9.6 ‰) of $\delta^{15}N$ have been found for cattle in a medieval Belgian site and related to the consumption of plants with higehr $\delta^{15}N$ values (Ervynck et al. 2007). High $\delta^{15}N$ values in plants can be a result of specific human land use practices such as manuring, that can shift the baseline values (Fraser et al. 2011) or high stocking rates of fields (Bogaard et al. 2007). Animals that are reared near urban centres are more likely to show enriched $^{15}N$ values (Hedges et al. 2005; Reitz et al. 2016), and increased pressure for the use of pastures around Lisbon is known from medieval historical sources (Gomes Barbosa 1995). The variation in herbivore values can also indicate a wider provisioning area. From historical sources, it is known that animals consumed in urban areas were not always reared near the settlements (Catarino 1998:39). Toponyms in the surroundings of Lisbon, with particular mention of the areas upstream of the river Tagus for the Islamic and Christian period, suggest the existence of pastures (Gomes Barbosa 1995:20; Catarino 1998:34). Thus, these differences in herbivore diet might suggest distinct management strategies and/or provenance for these individuals. Metabolic and physiological pathways between different species could also affect $\delta^{15}N$ values; however, this is not the case in the analysed sites, since a wide range of values is exhibited among individuals of the same species (Itahashi et al. 2014).

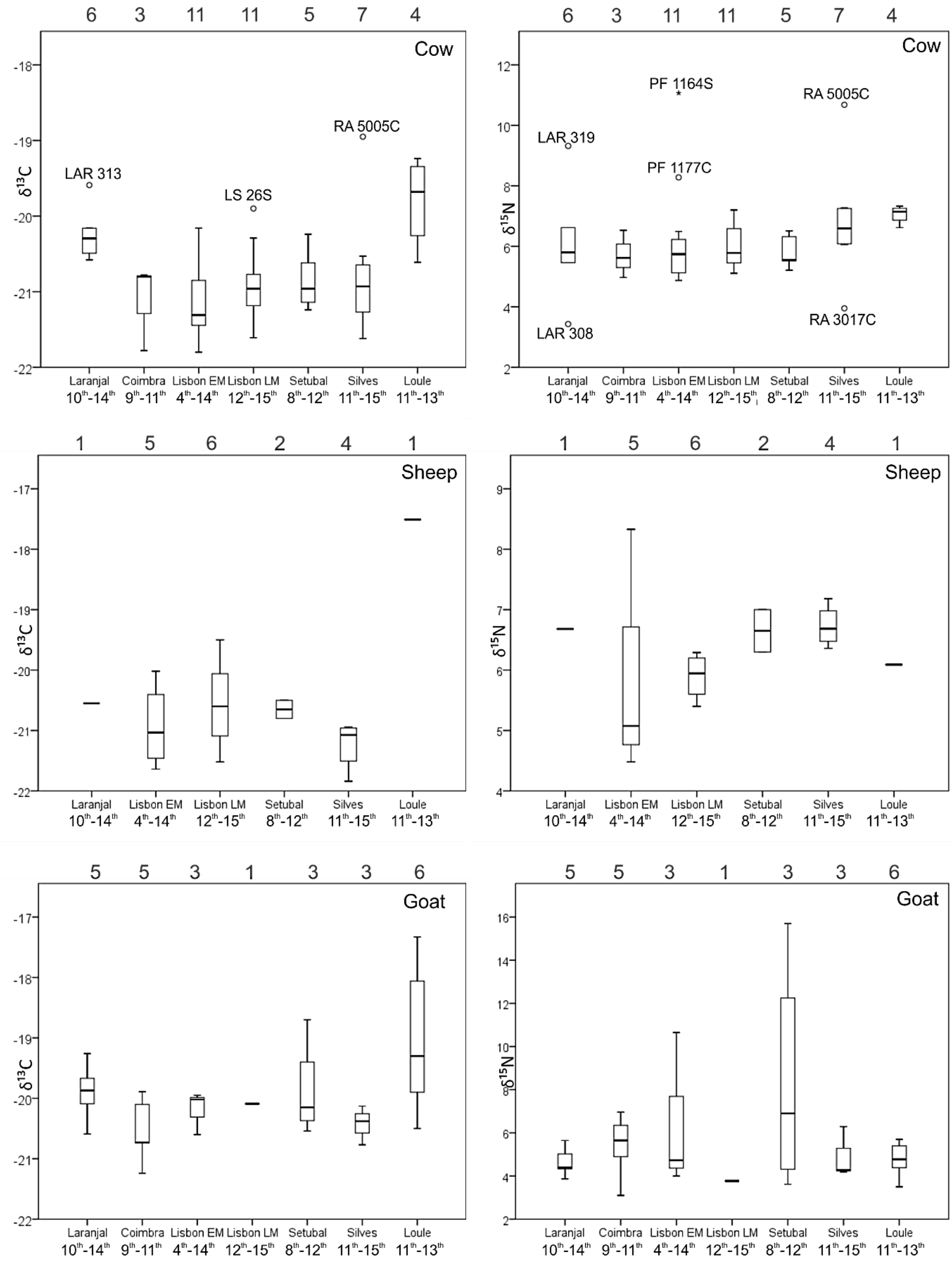

***Figure 8-3*** *Box plots for cow, sheep and goat δ$^{13}$C and δ$^{15}$N (‰) ratios. The whiskers indicate the range of values, the boxes represent the interquartile range (50%) of the values and the horizontal lines show median values. Labelled individuals are statistical outliers at each site. Samples numbers are displayed above the plots per each site. Site dates are in centuries.*

Grazing at coastal areas has also been previously suggested as another explanation for $^{15}$N values enrichment. Two aspects of these phenomena have to be considered: firstly the sea spray effect which can cause an enrichment in plant $^{15}$N values and hence in the consumers' values (Richards et al. 2006; Choy and Richards 2009). Secondly, coastal saltmarsh grazing has been reported as a possible cause of higher $\delta^{15}$N values (Britton et al. 2008). Both these phenomena were believed to be responsible for the high $\delta^{15}$N values recorded in domestic herbivores at Whithorn in UK and Orkney (Müldner et al. 2009; Schulting et al. 2017). Although this is a possibility, the sites that display the highest $\delta^{15}$N values are not coastal locations and tend to be urban or defensive centres, suggesting that heavy management and the anthropic activities could be more significant factors in this case.

Distribution of omnivores' $\delta^{13}$C and $\delta^{15}$N values across sites show similar patterns of variability (Fig. 8-4). Also for omnivores, no geographical trend can be seen for $\delta^{13}$C and $\delta^{15}$N, and pig and chicken seem to have had a very variable and flexible diet at each site.

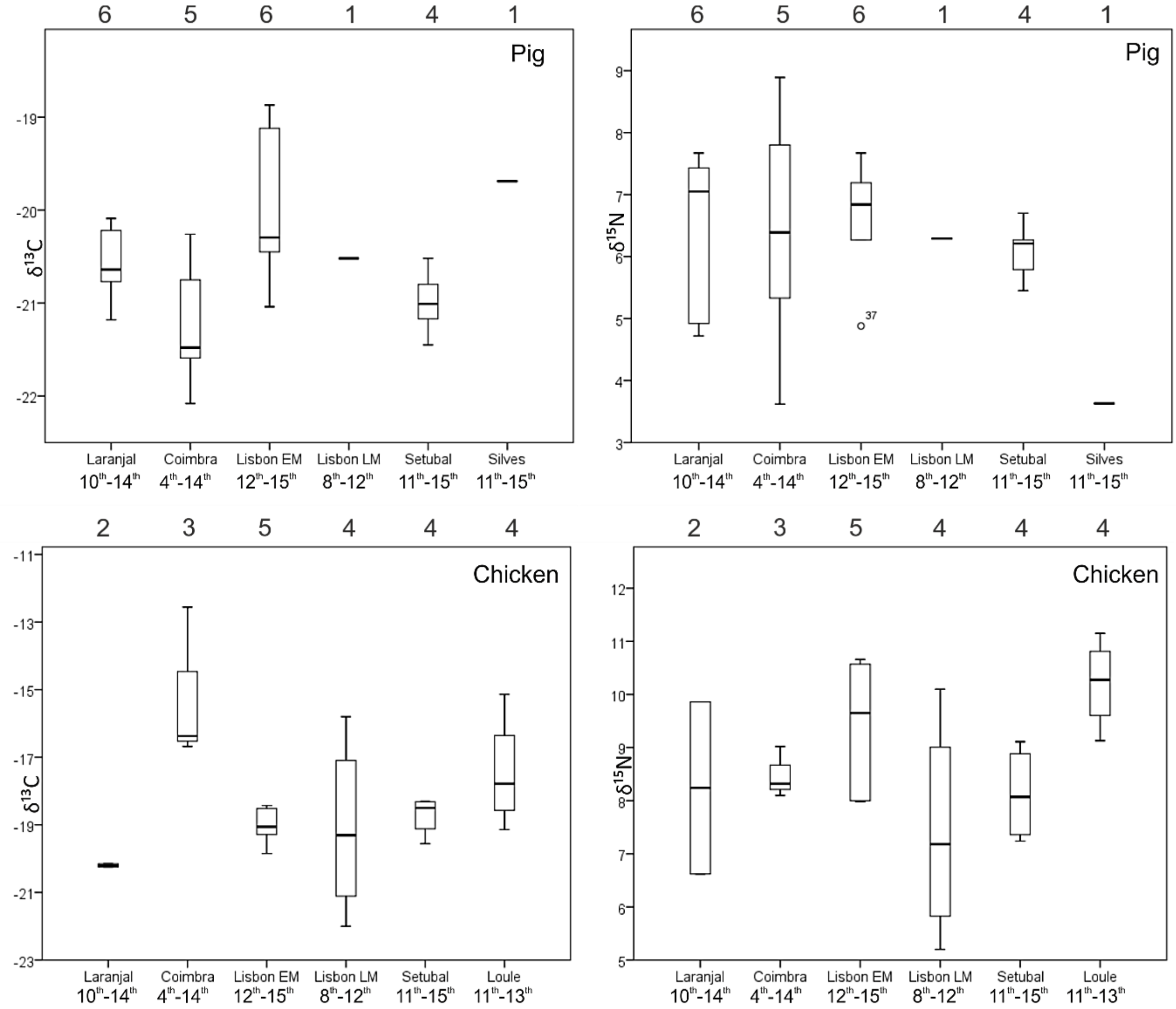

*Figure 8-4 Box plots for pig and chicken $\delta^{13}$C and $\delta^{15}$N (‰) ratios. The whiskers indicate the range of values, the boxes represent the interquartile range (50%) of the values and the horizontal lines show median values. Site dates are in centuries.*

Pig show generally lower δ$^{13}$C values in Coimbra and Setubal, while a mixed diet based on $C_3$ and $C_4$ resources can be observed for this species in Early Medieval Lisbon and Silves, although only one sample is given for the latter. Interestingly the pig δ$^{15}$N values are also very similar to the herbivores ones, suggesting that pig was often kept at a similar diet (discussed above). Chickens have similar δ$^{13}$C values across sites with the exception of Coimbra, where $C_4$ resources were predominantly used as fodder for this species. The δ$^{15}$N values are similar across sites although there is some difference in the distribution. The flexibility of these two species in terms of their dietary requirement is reflected in the values and is congruent with the historical and archaeological evidence reviewed in Chapter 3 and further discussed in Chapter 6 and 7.

### 8.2.1 Fish

Fish vertebrae were available from five sites including Early Medieval Lisbon (2 samples), Late Medieval Lisbon (1 sample), Silves (2 samples) and Loulé (2 samples). Table 8-3 provides the raw values for each sample with information on their feeding practices. These marine species are common in both the Mediterranean and along the Atlantic coast.

| Site | Common name | Scientific name | Diet | δ$^{13}$C (‰) | δ$^{15}$N (‰) |
|---|---|---|---|---|---|
| EM Lisbon | Tope shark | *Galeorhinus galeus* | Fish, crustaceans and worms | -11.9 | 11.9 |
| EM Lisbon | Hake | *Merluccius merluccius* | Fish and crustaceans | -12.0 | 14.4 |
| LM Lisbon | Seabream | *Pagrus pagrus* | Fish, crustaceans and molluscs | -11.6 | 10.6 |
| Silves | Tope shark | *Galeorhinus galeus* | Fish, crustaceans and worms | -12.5 | 9.8 |
| Silves | Seabass | *Dicentrarchus Sp.* | Fish | -10.6 | 12.2 |
| Loulé | Seabream | *Pagrus pagrus* | Fish, crustaceans and molluscs | -11.9 | 10.3 |
| Loulé | Seabream | *Pagrus pagrus* | Fish, crustaceans and molluscs | -12.0 | 10.1 |
| **Mean ±1σ** | | | | **-11.8±0.5** | **11.3±1.5** |

***Table 8-3*** *Raw values of medieval fish species sampled in this thesis. Dietary information derived from FishBase (Froese and Pauly 2018).*

When all species are considered, values of $\delta^{13}C$ and $\delta^{15}N$ are -11.8±0.5 and 11.3±1.5 respectively. A recent study on cod in the North Atlantic and North Sea revealed average $\delta^{13}C$ and $\delta^{15}N$ values of -13.0±0.7 and 15.0±1.0 respectively for Scottish and English medieval and post-medieval samples (Barrett et al. 2011). These values are higher $\delta^{15}N$ and lower in $\delta^{13}C$ compared to the samples in this study. While the nitrogen isotope values are a reflection of the trophic level, and therefore size, biology and origin of the fish can play an important role in determining its values, carbon sources in marine ecosystems are extremely variable. Fish remains from Roman and Late Antique Galician sites (López-Costas and Müldner 2016) showed values of -12.0±0.5 and 12.5±1.9 for $\delta^{13}C$ and $\delta^{15}N$ respectively and are closer to the ranges given by the samples in this thesis. In addition, Mediterranean species from medieval Spain (Alexander et al. 2015) report values of -10.6±0.7 for $\delta^{13}C$ and 10.6±1.7 for $\delta^{15}N$. Although the complexity of marine ecosystems and its influence on isotopic values have been previously discussed (Chapter 2) and is challenging to untangle, data from medieval fish show that while moving from Northern seas to Southern latitude and eastward into the Mediterranean, the values of $\delta^{13}C$ are higher, while $\delta^{15}N$ values decrease. This is especially true for the Mediterranean Sea whose fish tent to exhibit lower $\delta^{15}N$ values than those from the Atlantic coast (Jennings et al. 1997; Garcia-Guixé et al. 2010).

The small sample size of fish remains included in this thesis is unlikely to provide a good characterisation of the highly variable nature of $\delta^{13}C$ values for marine fish along the Portuguese coast and therefore this has been borne in mind when interpreting human dietary data. Because of the established trades between the Al-Gharb and the Mediterranean under Islamic rule, and between Portugal and the Northern Atlantic in the late Christian medieval period, marine species from both locations could be part of the data set sampled for this study.

## 8.3 Human data across all sites

The discussion will move on to consider the pattern of human data across all sites to explore geographical trends, and will include a section to compare data from Portugal with other medieval sites along the Atlantic coast. The chapter will then consider the isotopic evidence for diet in relation to the topics highlighted in the research questions such as faith, sex and chronology.

### 8.3.1 Inter-site comparison

A comparison of human data across sites is undertaken in order to explore any geographical trend related to dietary practices and resource exploitation. A summary of all human data per site is provided in Table 8-4 and plotted in Figure 8-5. The plot illustrates some overlap in isotopic data, especially for Muslim individuals; however, some trends may be identified. Christian sites show greater variability in terms of both $\delta^{13}$C and $\delta^{15}$N values, showing that it is impossible to determine a typical Christian diet in medieval Portugal. This suggests that rather than a faith-related diet, other factors such as food access, resource management and environment were determining the dietary practices at the Christian sites. Islamic sites also show widely ranging values, although there is less variability compared to the Christian sites. Similarly, to what has been previously discussed for the animals, isotopic values of human populations are affected by a number of factors including the animal baseline, environment and climate, economic resources, food availability as well as social status, sex and age.

| | | $\delta^{13}$C/‰ | | | | $\delta^{15}$N/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal (C) | 9 | -22.8 | -17.1 | 5.7 | -20.1±1.8 | 8.1 | 12.0 | 3.9 | 9.6±1.2 |
| Coimbra (C) | 16 | -19.2 | -14.3 | 4.9 | -16.8±1.3 | 8.3 | 11.0 | 2.7 | 10.1±0.7 |
| Lisbon EM (M) | 32 | -19.4 | -16.5 | 2.9 | -18.4±0.6 | 8.7 | 13.1 | 4.5 | 10.3±1.1 |
| Lisbon LM (C) | 15 | -19.9 | -15.3 | 4.6 | -18.2±1 | 6.1 | 12.7 | 6.6 | 10.4±1.5 |
| Lisbon LM (M) | 23 | -19.3 | -8.2 | 11.1 | -17.8±2.3 | 8.4 | 13.1 | 4.7 | 10.7±1.1 |
| Setubal (M) | 9 | -19.0 | -16.6 | 2.4 | -17.7±0.8 | 9.4 | 11.9 | 2.5 | 10.5±0.8 |
| Beja (C) | 13 | -19.8 | -17.7 | 2.1 | -18.5±0.5 | 9.0 | 13.0 | 4 | 11.6±1.0 |
| Beja (M) | 43 | -23.0 | -18.6 | 4.4 | -19.2±0.7 | 4.1 | 12.9 | 8.8 | 10.1±1.2 |
| Silves (C) | 40 | -18.9 | -12.5 | 6.4 | -17.8±1.1 | 9.4 | 13.5 | 4.1 | 11.3±1.0 |
| Silves (M) | 25 | -19.2 | -17.7 | 1.5 | -18.6±0.4 | 9.4 | 13.7 | 4.3 | 11.1±1.1 |
| Loulé (M) | 7 | -19.3 | -16.4 | 2.9 | -17.6±0.9 | 9.7 | 11.9 | 2.2 | 10.8±0.8 |

***Table 8-4*** *Summary of $\delta^{13}$C and $\delta^{15}$N data for humans from each site. Muslim populations are indicated with an (M) while Christian populations with a (C) and Lisbon sites are also divided by chronology for clarity (EM = early medieval, LM= late medieval).*

Particularly interesting are the differences in diet between Muslims and Christians of the same location, which can be appreciated from the plot and will be discussed further in the chapter.

The northern sites of Laranjal and Coimbra exhibit the lowest δ$^{15}$N values although their δ$^{13}$C values are very different. While low trophic level proteins were consumed at both sites, in Laranjal the majority of the population is consuming terrestrial resources and almost exclusively $C_3$ plants. On the other hand, Coimbra shows higher δ$^{13}$C values suggesting the inclusion of $C_4$ resources into the diet. This is the only site where strong evidence for $C_4$ plant consumption can be seen isotopically. Low trophic level fish could be an option in order to justify these values, however, the inland location of Coimbra and the historically attested importance of millet in this areas (Chapter 3) favour the first hypothesis. It is noteworthy that these two Christian Northern sites show very different values especially for δ$^{13}$C, although are of similar chronology and geographical location, indicating that a great degree of variability exists even in the same geographical area, chronology and within the same faith group. A second interesting trend is the faith-related difference in diet shown in Beja, Silves and late medieval Lisbon (although there is a significant overlap in this last case).

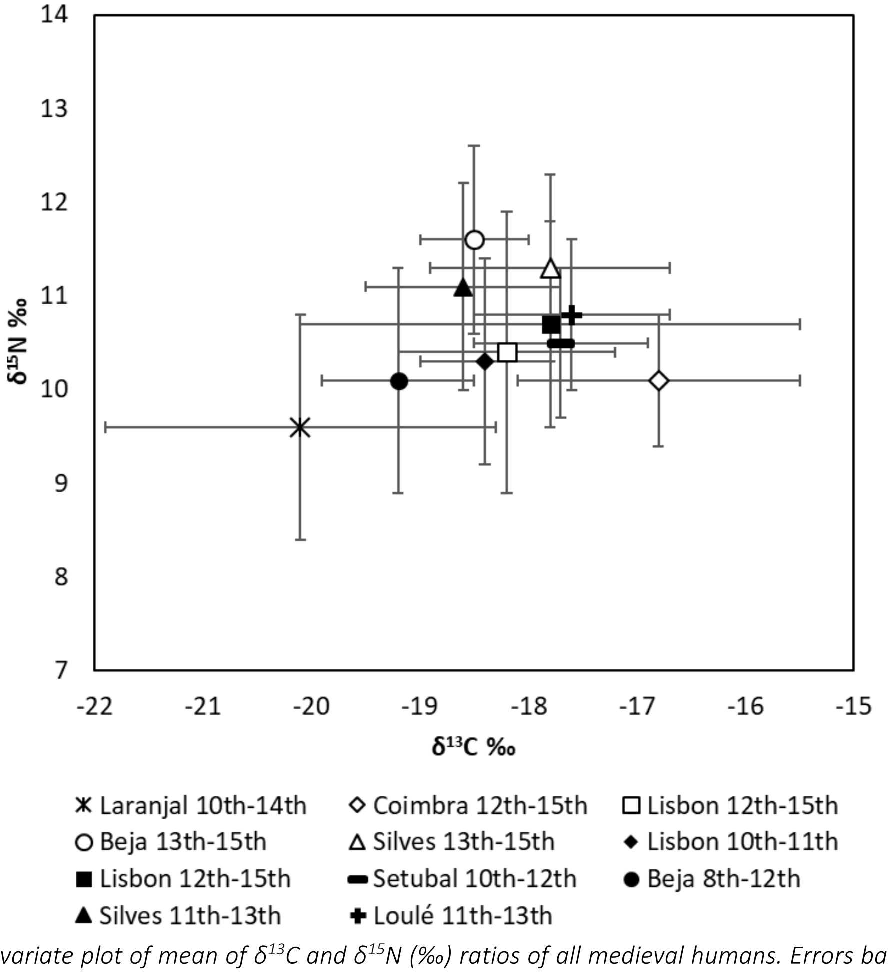

***Figure 8-5*** *Bivariate plot of mean of δ$^{13}$C and δ$^{15}$N (‰) ratios of all medieval humans. Errors bars signify ±1σ. Christian populations are represented with white symbols, while Muslim populations with black ones. For samples sizes see table 8-6.*

In Beja and Silves, Christians (of later chronology) show an enrichment in both $^{13}$C and $^{15}$N, suggesting the progressively increasing reliance on marine resources compared to the early medieval Muslim period. Late medieval Lisbon shows the opposite trend with Muslims having slightly higher values of $\delta^{13}C$ and $\delta^{15}N$; however, although this trend is more visible in the Figure 8-5, the difference was not statistically significant (Chapter 6).

Early medieval Islamic diet is terrestrial and based on $C_3$ resources, although some $C_4$ plants or low trophic level fish can cause higher values in a few individuals. Small coastal Islamic settlements; however, such as Setubal and Loulé, have very similar $\delta^{15}N$ values to the other early medieval Muslim population, but higher $\delta^{13}C$ values. As has been previously discussed (Chapters 6 and 7), this could be due to the inclusion of low trophic level marine resources in the diet of these littoral communities. Although the preference of Islamic cuisine for meat over fish is well-known (Chapter 3), it is likely that small communities living on the beach such these two, would have had easy access to small fishes and molluscs and these resources would complement their diet in a more significant way than in an urban environment. In addition, the focus on meat over fish that appears in cookbooks describe a high-status diet while historical data for late medieval Muslim Egypt (Lewicka 2011) suggest that the populace accessed fish on a regular basis. In this case, stable isotope analysis are perfectly placed to explore and address gaps in the historical narrative so far produced from written sources. In order to explore further geographical patterns within the human populations, the results are plotted in separate box plots for $\delta^{13}C$ and $\delta^{15}N$ (Figure 8-6). Statistical comparison between human populations show a statistical significant difference in $\delta^{13}C$ values across sites (Mann Whitney U test p=0.00; Independent Samples Kruskal-Wallis Test p=0.00). This indicate that many of the sites in the dataset differ significantly in terms of their carbon values, as it easily appreciated from the boxplot as well as the high number of outliers. Despite the high variability of the carbon isotope values, no geographical pattern is revealed. The two northern sites show contrasting values with Laranjal having the most depleted $\delta^{13}C$ values and Coimbra showing the highest $\delta^{13}C$ values as a whole. This somehow contradicting evidence shed light onto the diversity of human dietary practice within the same region. Although a general assumption is made about similar faith groups having a similar diet, especially when living in the same geographical area, these two sites disprove it and suggest that the variety of resources available and the factors influencing its consumption are multiple and complex to define as discussed in the diet and faith section below. As has been discussed in previous chapters (3 and 6), $C_4$ plants were grown and consumed in the north of Portugal and their inclusion in the human diet is believed to be the main reason for the high $\delta^{13}C$ values in Coimbra. Although $C_4$ resources are traditionally and preferentially used as animal fodder, a connection between these secondary crops and the social status of the individuals consuming can be made (Alexander et al. 2015). However, faunal remains at both sites show $\delta^{13}C$ values related to $C_3$ plants, with the exception of chickens in Coimbra.

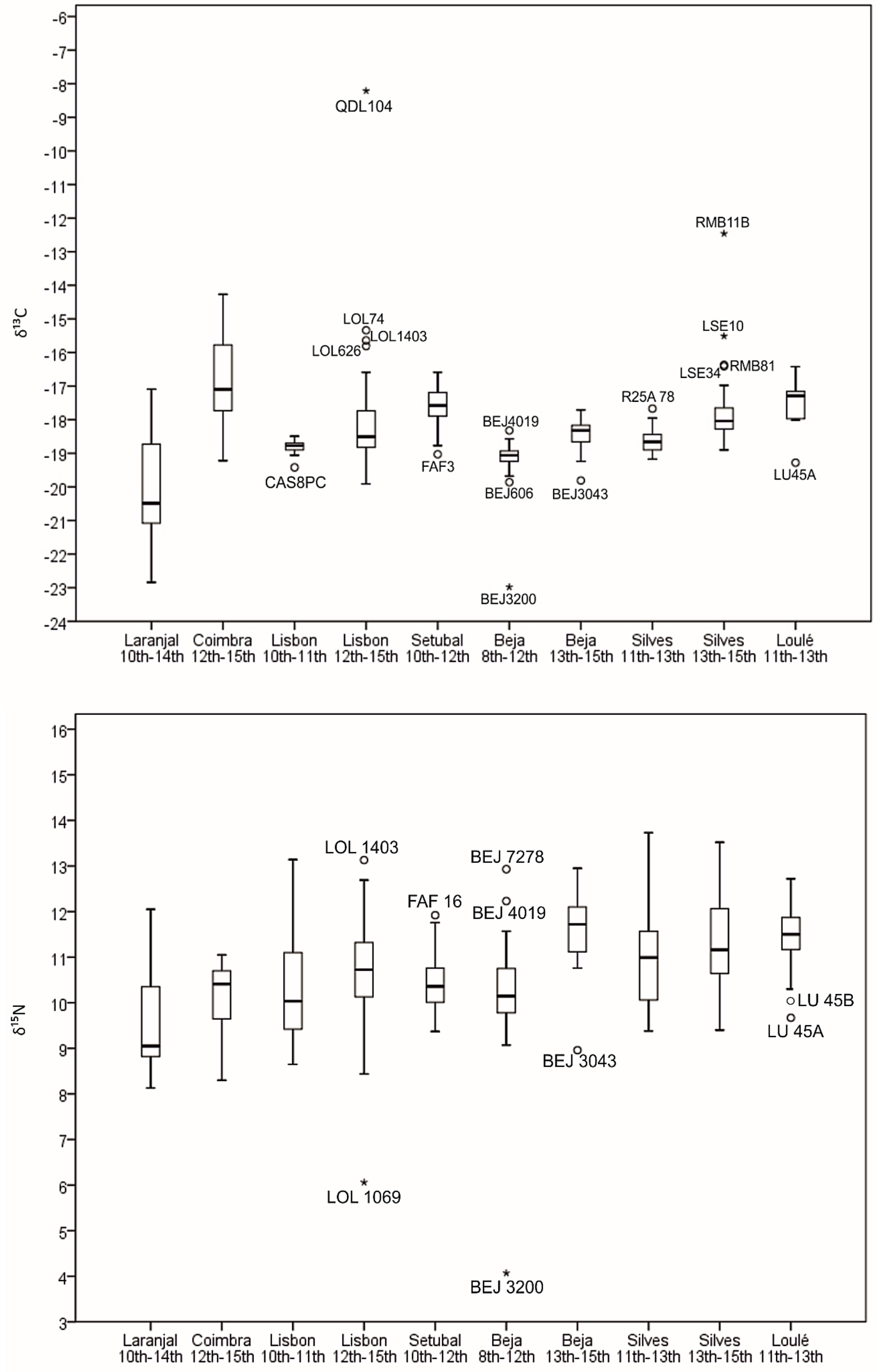

***Figure 8-6** Box plots for human $\delta^{13}C$ and $\delta^{15}N$ (‰) ratios across all sites sampled. Labelled individuals are statistical outliers at each site. Site dates are in centuries. Samples number from left to right 9, 16, 32, 38, 9, 42, 12, 25, 40, 13. statistical outliers at each site. Site dates are in centuries. Samples number from left to right 9, 16, 32, 38, 9, 42, 12, 25, 40, 13.*

This evidence might corroborate the hypothesis that, at least in Coimbra, $C_4$ resources were preferentially used for human consumption and are potentially not linked to social status. However, as it has been highlighted, a sex-related difference exists at this site, showing higher $\delta^{13}C$ values in females. The most interesting variation in $\delta^{13}C$ values happening at a local level, rather than at a regional level. For example, early medieval Lisbon shows a very contained range of $\delta^{13}C$ values compared to all sites, while a much wider range of $\delta^{13}C$ values is represented in the later medieval population (whose values are also higher). A similar change can be seen in Beja and Silves where the early medieval Muslim populations show lower $\delta^{13}C$ values and a more contained range of variability compared to late medieval Christian populations. Setubal and Loulé have similar values and distribution, although show slightly higher $\delta^{13}C$ values compared to other contemporaneous Muslim populations (see Chapters 6 and 7). However, while the animals from Setubal have depleted $\delta^{13}C$ values, herbivores from Loulé show a mixed diet based on $C_3$ and $C_4$ resources. The relatively low nitrogen isotope values of these two populations does not allow us to discriminate between low trophic level marine proteins and $C_4$ plants, and because of their coastal location, it is likely that both resources would have been part of the diet at these sites. Similarly to the $\delta^{13}C$ values, there is no geographical trend in $\delta^{15}N$ values across sites. The two Northern Christian sites have similar values, although Coimbra does not have values above 11‰. An analogous pattern of local variation rather than regional one can be seen in $\delta^{15}N$. Early medieval Lisbon has a widely ranging $\delta^{15}N$ value, similar to the values of late medieval Lisbon period, although the median of the earlier population is lower. A more significant difference in $\delta^{15}N$ values is shown at Beja between the Muslim and Christian population, while Silves has a similar distribution to Lisbon with both populations showing widely ranging $\delta^{15}N$ values, but the earlier Muslim one has a lower median value. The two rural coastal sites, Setubal and Loulé, have rather different $\delta^{15}N$ values and might suggest that the exploitation of marine resources rather than $C_4$ plants could be the reason behind the higher carbon isotope values at Loulé. Even tough animal remains at Loulé had a mixed or mainly $C_4$ resources-based diet, proving the presence and exploitation of $C_4$ plants on site; the enrichment in the human $^{15}N$ values suggests that the human $\delta^{13}C$ values might come from marine resources.

## 8.4 Comparison with European Atlantic and Mediterranean data

Isotopic results from this thesis are compared to medieval sites located along the Atlantic coast as well as the Mediterranean in the following section and plotted in Figure 8-7. A number of studies have been published in recent years about diet in Medieval Iberia (Chapter 2) and therefore only a selection of them is used in this comparison in order to explore the dietary relationship between the two sides of the Iberian Peninsula. Sites along the Atlantic coast such as the Basque countries, Galician sites and including Brittany have been chosen to provide a direct comparison with populations of similar chronology facing the Ocean. Mediterranean sites such as the Balearic Islands have been widely studied and are included because they provide information on dietary practices along the Mediterranean coast for the same time period. Several isotopic studies exists for Muslim populations from Spain, however the populations from the Balearic Islands have been widely explored with hundreds of isotope measurements, providing a reliable term of comparison for early medieval diet at a coastal location but on the Mediterranean coast. Finally, two recent studies have been published on the diet of a Late Antique and a Late Medieval Portuguese population providing a local comparison of close chronology to the samples analysed in this thesis.

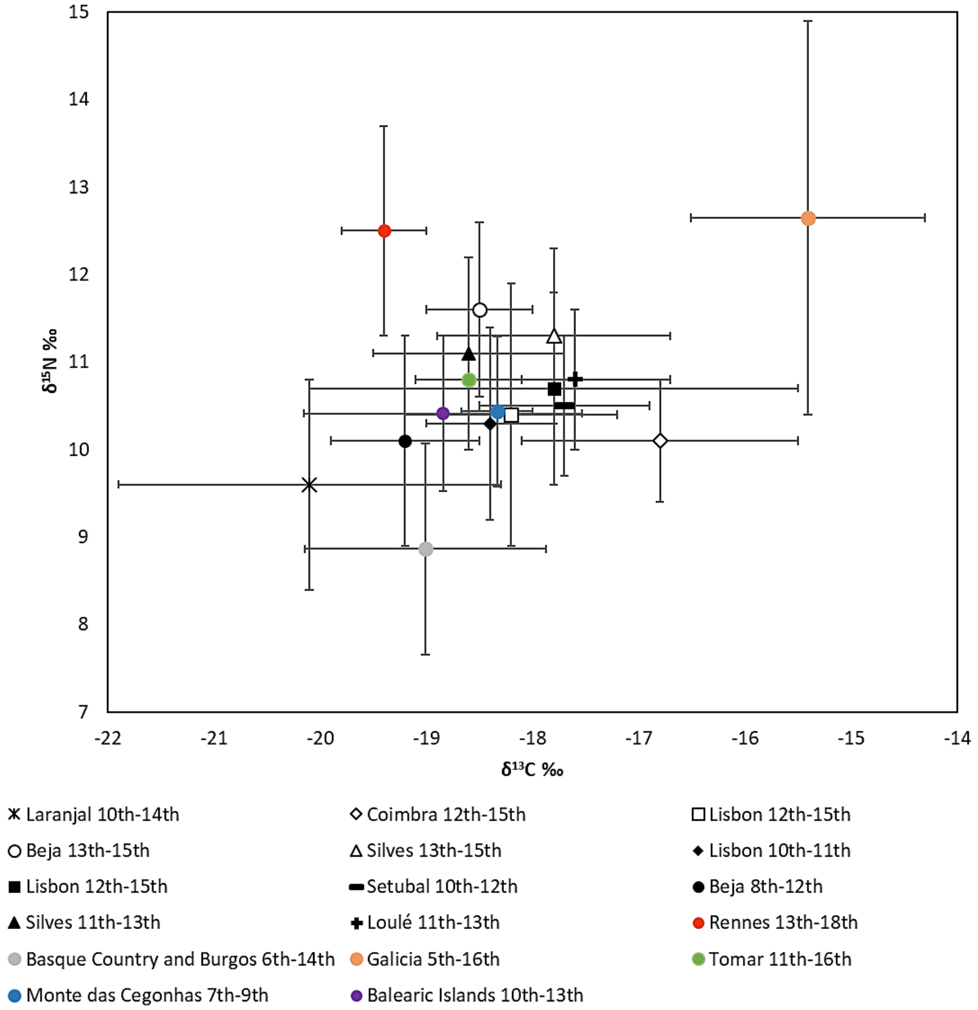

*Figure 8-7 Bivariate plot of mean $\delta^{13}C$ and $\delta^{15}N$ (‰) ratios of all medieval humans from Portugal in comparison to published values for human populations from medieval Europe, Mediterranean and Atlantic coast. Error bars signify ±1σ. Dates are in centuries CE. References for comparative data: Rennes (Colleter et al. 2017), Galicia (López-Costas and Müldner 2016), Basque Country and Burgos (Lubritto et al. 2017; Guede et al. 2017), Tomar (Curto et al. 2018), Monte da Cegonha (Saragoça et al. 2016), Balearic Island (Fuller et al. 2010; Pickard et al. 2017).*

Coimbra is the only site in the Portuguese dataset with a clear presence of $C_4$ resources in the human diet, which poses further questions on the unique practices at this site. The importance of millet and other $C_4$ grains to the diet of medieval European populations is not well documented. Two studies from Medieval Poland (Reitsema et al. 2010; Reitsema et al. 2017) and one from the Czech Republic (Kaupová et al. 2018) and one from Hungary (Gugora et al. 2018) revealed $C_4$ consumption in early medieval populations with social and sex-based differences. While these studies are particularly intriguing to inform on sex and status-related $C_4$ plants exploitation in central Europe, and although ethnographical evidence for the use of millet as animal fodder exists for north-west Spain (see section 8.1.2 of this chapter), isotopic data from closer geographical locations would be more relevant to the Coimbra population. Since little is known on the actual input of $C_4$ resources to the diet of both humans and animals in South-Western Europe, this dataset provide a significant contribution to the use and importance of $C_4$ grains in medieval Europe.

The two Portuguese populations from Monte da Cegonha (7th-9th) and Tomar (11th-16th) show little difference compared to the early medieval populations in this thesis. Since all the late medieval populations in this thesis exhibited an increasing reliance on marine resources, it is interesting to note that the population from Tomar did not follow this pattern, although the long chronology of the burials (6 centuries) coupled with the small sample size (n=33) could provide a distorted representation of food practices at the site. Overall, the data from other published historical Portuguese populations show great similarity to the Muslim sites possibly exhibiting a distinct local signal. Interestingly, Mediterranean diet represented by the populations from the Balearic Islands show very similar values to the Portuguese sites. This indicates that also in the Mediterranean, despite the easy access to marine resources, the majority of the Muslim population had a terrestrial diet, suggesting that faith but also cultural practices were guiding food choices and supply. No late medieval Christian population has been analysed so far from the Iberian Peninsula a part from this thesis, which could provide useful comparative data on late medieval dietary practices. Further analysis of contemporaneous populations, both Christian and Muslim, would be key to explore the importance of terrestrial versus marine resources in medieval Portugal and the reasons behind the transition from agricultural and farming to the Early Modern Portuguese seafaring economy.

### 8.5 Diet and sex

Historical sources discussed in Chapter 3 suggest that men and women had a different role in Christian and Islamic medieval societies that extended to both the public and private sphere of life. The theme of a gender-based access to food in both faith groups was therefore explored in this data set. Isotopic results have indicated that statistically significant differences in diet between males and females exists only at the high status Muslim burial ground in Lisbon (São Jorge Castle) and the Christian site of Coimbra. All the other populations show no sex-related difference in diet suggesting that if there was a difference between the two sex groups in terms of their dietary practices, it is not detectable by bulk collagen stable isotopes technique. When considering the diet of São Jorge Castle population in relation to sex, women and men display a different diet, with males generally possessing higher $\delta^{15}N$ than females (Chapter 6). This could indicate that males consumed higher trophic level protein from chickens or potentially freshwater fish, which would also serve to enrich $^{15}N$ values (Hedges and Reynard 2007). This sex difference in food consumption can be an expression of family organization and use of domestic space. Historical sources from as early as the 11th century describe specific spaces for women within a household or palace in Al-Andalus (Díez Jorge 2002:159). This separation between men and women is recurrent in public spaces from the mosque to the caravanserai, affecting all strata of society. In the household, the man was required to provide a separate room for his wife and a separate house if he married a second wife (Pérez Ordoñez 2009:5). A series of norms and regulations about the use of domestic space are reported, such as the imposition of receiving a guest at the door to allow enough time for the women to relocate to another room or behind a curtain to protect themselves from any unwanted gaze (Marín 2000:237). However, respect of these norms would prove challenging in smaller households or nuclear houses such as those excavated in Praça da Figueira and common across Islamic settlements, usually composed of one room (Díez Jorge 2002:161). Smaller spaces of multifunctional purpose were achieved with a few pieces of furniture that could be moved around and used in different occasions, reminiscent of the nomadic life (Palazón and Castillo 2007:237). The social class of women played a significant role in the degree of freedom they could benefit from. Medium and lower class women were free to wander in public spaces and use the public baths, while the high status individuals were precluded from this privilege (Lachiri 1993).

Historical sources provide scarce information on the women in Al-Andalus and even less on their diet; however, medical recommendations are provided on the consumption of specific foods for women, especially during pregnancy and breastfeeding (García-Sánchez 2006). Apart from this specific period in a woman's life, it is impossible to identify foods that were uniquely associated with gender. Women were encouraged to consume high calorific food such as fats, sugars and carbohydrates in order to put on weight for aesthetic and fertility purposes (García-Sánchez 2006:217). The *Kitāb al-Tabīj*, an Andalusian cookbook compiled by an anonymous author in the 13th century, includes a few recipes referred to as 'food for women' that had exactly this purpose (Martinelli 2012). In this case, the diet shown by the São Jorge Castle women could fit this scenario with lower trophic level protein consumed and a potentially higher consumption of carbohydrates and vegetables (although the latter will not show up in bone collagen if sufficient animal protein was consumed, as is likely the case here).

When this high-status population is compared with a contemporaneous Muslim urban population from Calçadinha do Tijolo, female individuals have a very similar diet to these lower status individuals that include both females and males. This sex related difference does not seem to affect the urban population in Lisbon. It appears that high-status males have more distinctive eating habits compared to the rest of the urban population of the time. This difference for the high-status male individuals could be linked to their activities taking place outside the home and them potentially having access to a wider range of foodstuffs. A sex difference in diet is not a common trend among isotopic datasets for Muslim populations from Spain (Fuller et al. 2010; Salazar-García et al. 2014, 2016; Alexander et al. 2015), although it is found elsewhere in Muslim Spain with males consuming higher trophic level proteins (possibly riverine fish) in Tauste, for example (Guede et al. 2017).

Significant differences between sexes have been reported for a number of Christian medieval sites in the UK such as Newark Bay, Orkney (Richards et al. 2006), York (Müldner and Richards 2007), Trino Vercellese, Italy (Reitsema and Vercellotti 2012), Giecz, Poland (Reitsema et al. 2010), Solt-Tételhegy, Hungary (Gugora et al. 2018) and the Czech Republic (Kaupová et al. 2018). While the British sites show higher $\delta^{13}C$ and $\delta^{15}N$ values in males suggesting a higher consumption of marine proteins compared to females, such difference in marine consumption are not reflected in this dataset. The medieval site of Giecz presents a similar scenario to the one in Lisbon with males having higher $\delta^{15}N$ values, which was interpreted as females eating less and lower trophic level meat than males. Difference between sexes are not always expressed in the $\delta^{15}N$ values. In fact, the above-mentioned case studies from Hungary, Poland and Czech Republic are particularly interesting in relation to the Coimbra population. At the Polish sites men have higher $\delta^{15}N$ but also higher $\delta^{13}C$. Higher $\delta^{13}C$ values suggesting higher consumption of $C_4$ plants for males were also found at Trino Vercellese (Reitsema and Vercellotti 2012) while at Coimbra females have higher δ$^{13}$C values compared to males but equal δ$^{15}$N values, suggesting that $C_4$ plants and particularly millet were consumed in bigger quantities (Chapter 6). Unfortunately, historical sources do not give any hint on the reason why women might have consumed more $C_4$ resources in Medieval Portugal. $C_4$ crops are traditionally identified as a secondary crop and often used as fodder in Portugal (Catarino 1998:78), although, the herbivore isotopic data in this thesis do not show values compatible with this practice for any of the analysed sites, with the exceptions of one horse in Loulé (Chapter 6 and 7). If $C_4$ plants have in fact a strong correlation to social status, the easier access to these crops by females has implications regarding their position in society. However, the δ$^{15}$N values are equal to males indicating that the difference between the two groups was purely based on the type of crops consumed and not on meat or fish consumption. A recent study on a medieval Christian population from Portugal (Curto et al. 2018) did not show any input of $C_4$ resources suggesting that this phenomenon might be something strictly linked to the Coimbra medieval society.

Altogether sex-related difference in diet are not commonly found in isotopic studies of medieval populations, even when $C_4$ crops are present at the site (Iacumin et al. 2014, Reitsema et al. 2017), and this dataset is also a good example as out of 12 sites, only two showed a difference between males and females. Although historical sources may allude to the different role of males and females in the medieval society and their different participation in food processing and consumption, it may be that the difference is too subtle to be detected using bulk collagen isotopic analysis (Müldner and Richards 2006). Despite the obvious limitations of the technique, further research in microhistory might prove particularly useful to explore themes of identities, gender and family organization in past societies.

### 8.6 Fish consumption: disentangling faith and chronology

Thanks to the wide data set provided in this thesis, it has been possible to explore the diet of Muslims and Christians from the same locations, specifically in Lisbon, Beja and Silves. The difference among different faith groups at these locations is evident and significant (Chapter 6-7). The difference still exists and is significant when all Christian and Muslim individuals from all sites are compared (δ$^{13}$C values Independent-Samples Kruskal-Wallis Test p=0.00 and Independent-Samples Mann-Whitney U Test U=4, p=0.00; δ$^{15}$N values Independent-Samples Kruskal-Wallis Test p=0.04 and Independent-Samples Mann-Whitney U Test U=5, p=0.04). The box plots (Figure 8-8) show the great range of values that both populations have for δ$^{13}$C and δ$^{15}$N, as well as the numerous outliers.

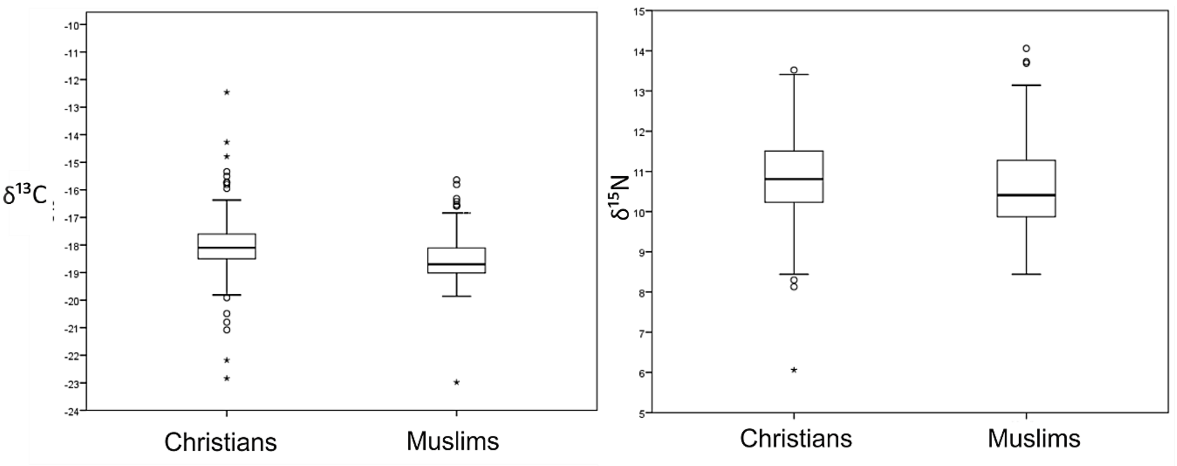

***Figure 8-8*** *Box plots for human δ$^{13}$C and δ$^{15}$N (‰) ratios of all Christians and Muslims grouped together. Samples included 93 Christians and 143 Muslims.*

The numerous outliers and the fact that they are mainly found in urban centres offer the intriguing possibility of non-local individuals being buried at the same sites. However, further exploration would be necessary with the aid of mobility isotopes such as strontium ($^{87}$Sr/$^{86}$Sr) and oxygen (δ$^{18}$O) recently applied to a Late Antique Portuguese population (Saragoça et al. 2016).

Overall, the median for the Christian diet shows an increment of ~1‰ for δ$^{13}$C and δ$^{15}$N. Geographical, environmental and internal variability within populations of differing faith, which were previously discussed (Chapter 6 and 7), are in some cases shrouding the difference between faith groups' diet. In fact, when Christians and Muslims are divided by location, a significant variation exists between faith groups' diet from the same site (Figure 8-9). The δ$^{13}$C values of Muslim individuals are more depleted at all sites, while Christians' diet shows higher δ$^{13}$C ratios. A similar pattern can also be observed in the δ$^{15}$N values, although it is less obvious and there is virtually no difference between the two faith groups' δ$^{15}$N values in Silves. However, the increment of both stable isotopes ratios for Christians at these three sites provides strong evidence in support of an increasing reliance on marine resources for this faith group, but also through time, since Christians are of later chronology. The increased fish consumption is likely due to Christian abstinence from animal products, whose prohibition of eating meat and dairy during a third up to half of the year would have affected the food choice of the population in a significant way. During a total of 182 days each year, including Wednesdays, Fridays and Lent, meat, dairy and eggs were proscribed by the medieval Church (Woolgar 2003).

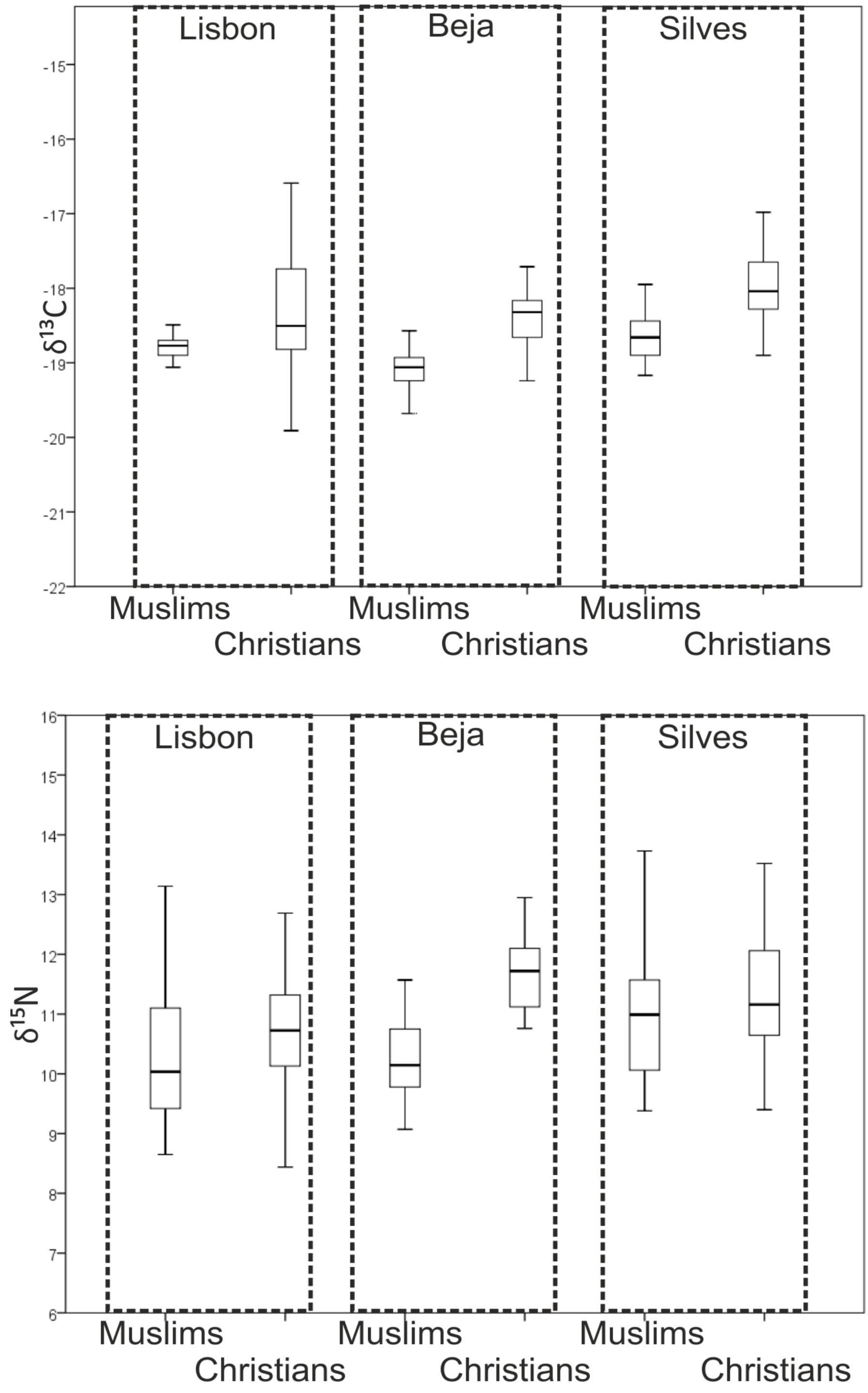

***Figure 8-9*** *Box plots for human $\delta^{13}C$ and $\delta^{15}N$ (‰) ratios of Christians and Muslims grouped together. Samples from left to right 32, 38, 42, 12, 25, 40.*

Fish was allowed during fasts and would have been the only available source of animal protein during much of the year. Such a drastic dietary restriction may leave an isotopic signature in human bone, however it is challenging to disentangle religion and economic reasons. Did medieval people develop the technology to go out into the Atlantic seeking huge quantities of fish because they felt obliged to eat them for religious reasons? Or did fish become a major feature of abstinence rules because it had become cheap enough to act as a marker of voluntary poverty once marine technology opened up a new resource?

Studies on medieval England, Belgium and Renaissance Italy have highlighted similar trends of an increasing presence of fish in the human diet linked to Christianity, and monastic and high status sites have been found to have higher percentages of marine resources than lay sites (Fornaciari 2008; Mays 1997; Müldner and Richards 2005, 2007;Polet and Katzenberg 2003, Salamon et al. 2008). However, a recent study suggested that at least for one of the English monasteries, St. Giles, this change in isotopic values was due to a shifting animal baseline and not to stricter fasting rules (Bownes et al. 2018), suggesting that caution has to be used when comparing populations from different sites. In addition by the end of the Middle Ages in England, meat seems to be much cheaper than before and become more suitable as a monastic food, especially older animals and beef (McCleery 2016, Thomason 2015). In this dataset, populations of Muslims and Christians come from the same locations and in some cases from the same burial ground, providing strong isotopic evidence for a change in diet among Christian late medieval populations. Furthermore, Muslim populations at all three sites exhibit a terrestrial diet, despite their proximity to the coast in Lisbon and Silves. Similarly to what has been observed at the Balearic Islands (Fuller et al. 2010, Pickard et al. 2017), despite the easy access to marine resources, the diet of the Muslim population tended to be mainly terrestrial, and marine fish, although consumed, was not the main source of proteins for this faith group. As previously discussed in Chapter 3, cultural preference has played a key role in food choices and cookery books pay little attention to fish and its preparations. However, this data set provides an additional layer to the often over-simplified view of archaeological populations' diet as the two small rural settlements in this thesis, Setubal and Loulé, show the inclusion of low trophic level fish in the Muslim diet (see section 8.3 in this chapter and Chapter 6-7). Along the course of the Middle Ages (7th-15th C) a number of impactful political, social, economic and religious changes struck the entire Iberian Peninsula creating a very unique mosaic of political systems, people, languages, beliefs and food. One of the main historical question about this period is whether it is possible to assess the effect of the Christian conquest onto foodways and more generally how the society and its dietary practices evolved with time and political transitions.

When all Early Medieval sites (n=122) (8th-13th) are pulled together and compared to Late Medieval sites (n=99) (14th-15th C) both $\delta^{13}C$ and $\delta^{15}N$ values are statistically different (Independent-Samples Mann Whitney U test/Kruskal-Wallis Test p=0.00 and p=0.00 respectively). The difference can also be appreciated in the boxplots below with early medieval sites showing lower $\delta^{13}C$ and $\delta^{15}N$ values compared to the late medieval sites (Figure 8-10). These suggests that along the medieval period and especially after the Christian conquest, finalised in Portugal in the 13th century, marine resources become much more prevalent in the diet of the Portuguese people.

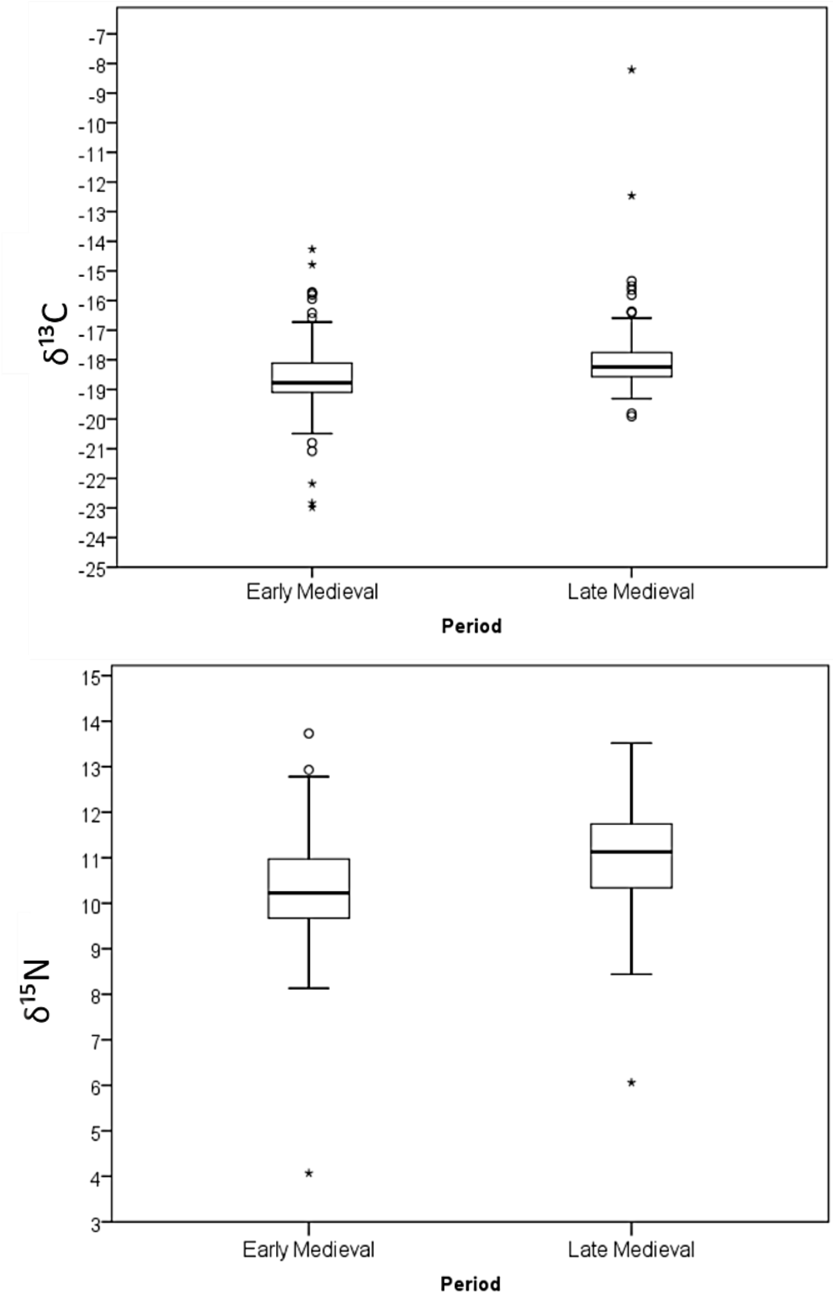

***Figure 8-10*** *Box plots for human $\delta^{13}C$ and $\delta^{15}N$ (‰) ratios of Early (8th-13thC) and Late (14th-15thC) medieval sites. Early medieval sites (n=122) include Laranjal, Coimbra, Lisbon 10th-11thC, Setubal, Beja 8th-12thC, Silves 11th-13thC and Loulé. Late medieval sites (n=99) include Lisbon 12th-15tCh, Beja 13th-15thC and Silves 13th-15thC.*

It is not the first time that Christianity has been linked to an increasing amount of marine protein added to the diet of the populace as has been discussed above. However, a turning point in this thesis and the interpretation of this data set was provided by the late medieval site of Lisbon. As previously presented (Chapter 6), the excavation of the Islamic quarter where Muslims lived under strict control after the Christian conquest, provided numerous burials of both Muslims and Christians as well as deviant burials and possibly Jewish individuals. While the interpretation of this burial site is still ongoing, this site is considered to be low status and possibly used for groups of outsiders. In this regard, it is particularly noteworthy that both Muslims and Christians buried at this location have increased values of $\delta^{13}C$ and $\delta^{15}N$, suggesting an increasing reliance on marine resources. The diet that was displayed by early medieval Muslim individuals in Lisbon was terrestrial and a significant change can be observed between the early and late medieval period. Fish has been always considered a relatively high-status commodity in Christian medieval society and was never consumed in the same quantities by Muslim people under Islamic rule. The causes of this sudden change are difficult to determine but if it is understood that Muslim minorities living under Christian rule - in a highly controlled environment - are showing marine protein in their diet (up to 63%), fish might have become widely available on the market by the late medieval period, and more accessible to all classes, including religious minorities. The evidence from the Muslim community under Christian rule is particularly noteworthy because it sparks doubt about a faith-related only difference in diet, reconsidering the role of the economic changes brought about by the Portuguese Kingdom after the Christian conquest. Three main urban sites that provide both early and late medieval populations from the same location have been carefully scrutinised, that is Lisbon, Beja and Silves, to explore marine resources consumption through time (Figure 8-9). When these populations are modelled against the equation Marine 2 (Appendix A) (Arneborg et al. 199, Richards and Hedges 1999, Schulting and Richards 2001) to calculate the percentage of marine protein in their diet, a steady increase of 11% on average is shown between the early and late medieval sites (Figure 8-11). Before the inclusion of the Lisbon late medieval site in the dataset, the differences in diet between early medieval sites and late medieval sites also happened to be faith-related. This is especially true for the urban environment, which seems to be more sensitive to the changes in political climate than the rural sites throughout this thesis. In addition to marine resources, $C_4$ plants cannot be ruled out as complementary resource to the diet of some of the late medieval individuals from Lisbon. This is applicable to the individuals with higher $\delta^{13}C$ and lower $\delta^{15}N$, which could be consuming $C_4$ resources or low trophic level fish. As it has been discussed (Chapter 2), stable isotopes cannot always discriminate between these two protein sources and therefore is not possible to ascertain which food group is responsible for such values in Lisbon. Notably, one Muslim woman (QDL 104) exhibits $\delta^{13}C$ and $\delta^{15}N$ values that suggest a diet based almost exclusively on $C_4$ plants.

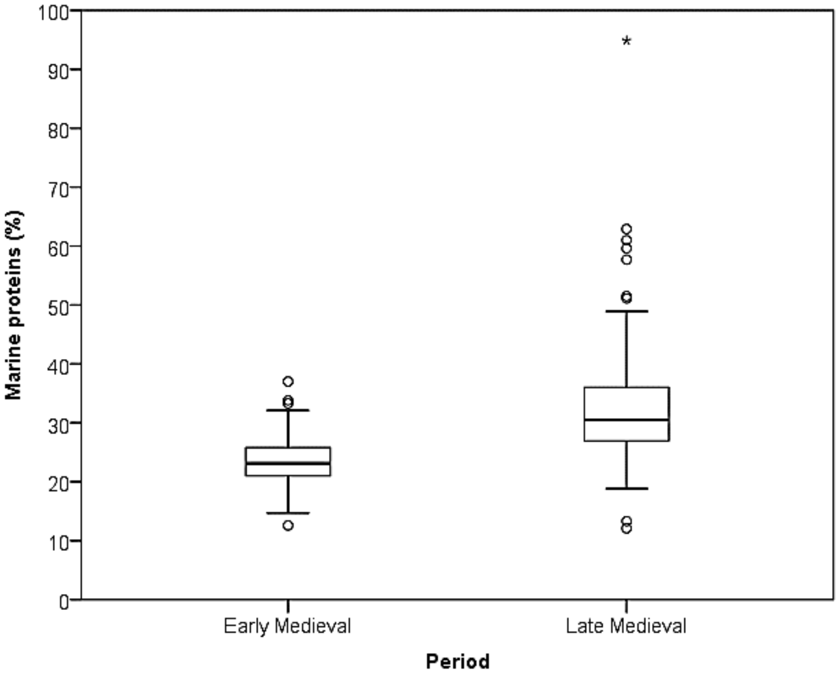

*Figure 8-11 Box plot of the fraction of marine proteins in the diet at early and late medieval sites of Lisbon, Beja and Silves. Early medieval sites include Lisbon 10th-11thC, Beja 8th-12thC and Silves 11th-13thC (n=81). Late medieval sites include Lisbon 12th-15thC, Beja 13th-15thC and Silves 13th-15thC (n=92).*

These lines of evidence are not necessarily in contrast and the diet of this late medieval population seem to be more varied than the population from the early medieval period with a number of resources complementing their diet including marine fish, $C_4$ plants and terrestrial resources. What is striking is the higher reliance on high trophic level fish for some of the Muslim individuals at this site in accordance with other Christian late medieval sites and in contrast to the early medieval Muslim populations in this thesis.

### 8.6.1 Fishing and seafaring Muslim activities

Muslim seafaring activities are known for the early medieval period and the military importance of the marine fleet in Al-Andalus grew from the 10th century onwards with Almeria being one of the most important ports (Delgado 1991:176). The Mediterranean was controlled by the Umayyad fleet in the West and by the Fatimid Egyptian one in the East which operated for defensive and commercial reasons; however the Atlantic coasts played a strategic role in establishing important commercial routes with the North of Africa (Constable 1996). Cereals, gold and black slaves followed a long route across the Saharan desert to reach the Maghrebi ports and were shipped to the Iberian Peninsula (Lévi-Provençal 1982 (5):136). The following centuries provide historical evidence for a continuation of Islamic naval power along the Atlantic coast. An example of Almohad naval initiative and the efficiency of the caliph's sailors is the first attempt of the Portuguese Kingdom to conquer Lisbon. The naval siege, undertaken by a Christian fleet in 1140, failed. The Portuguese King was then forced to call in crusaders' ships to reinforce its own squadrons and successfully took the city in 1147 (Lay 2002). In 1189, an English squadron provided support to the Portuguese during the assault on Silves, although the city was taken back two years later. After this victory, the Islamic navy kept control of the Gulf of Cadiz from its bases in the numerous ports, forming a string of anchorages from Cape Saint Vincent to Gibraltar (Picard 2018:279).

Several types of ships are known to be travelling across the Mediterranean for different purposes during the Middle Ages. Merchant ships were powered by sails and were round and large in order to provide enough space for people and goods. Oar-powered galleys, used by naval squadrons, were narrower, fast and easy to manoeuvre. Triangular or Latin-rigged sails were also common among Muslims and Christians in the Mediterranean because of their versatility (Constable 1996). Knowledge of medieval vessels, shipyards and arsenals, is mainly obtained from written sources, since recoveries from underwater archaeology have been limited (Amato and Bombico 2013). Pictorial representation of the vessels have therefore provided a useful record, although they are in some cases harder to date. Three 10th-13th century bowls made in Mallorca show two three-masted ships with Latin-rigged sails and a simple Latin-rigged sail with a rear steering oar. Two of the bowls show a very similar representation that may suggest this iconography was repeating a common and well-known model in the merchant marines of the Muslim world (Pryor and Bellabarba 1990) (Figure 8-12). An additional iconographic example comes from an engraved stone slab from Silves. The red sandstone block was found in the Christian medieval cemetery near the Cathedral and was lined with an irregular series of stone blocks along the perimeter of the grave. The re-use of structural element of nearby domestic Islamic building was a common practice in this cemetery (Casimiro et al. 2008). The image represents a long, sub-trapezoidal hulled boat with the bow to the right. One mast stands in the middle with two oblique lines possibly representing the main sail tied to the yard, while ten vertical lines represent the paddles (Gomes et al. 2014).

*Figure 8-12 Bowls from the National Museum of Pisa, dating to 10th-13th century. (Adapted from Amato and Bombico 2013 fig. 19-20).*

The sail seem to correspond to the Latin type and other similar representations have been found on stone slabs in Mertola (Gómez Martínez and Lopes 2011), Granada (Barrera Maturana 2002) and Denia's castle (Bazzana et al. 1984) (Figure 8-13). Historical sources that mention fishing practices are scarce for this period in Al-Andalus, although it does not mean that fishing was not practiced. Historians suggest that fishing was a marginal activity mainly undertaken by lower classes and therefore did not find space in the chronicles or geographical texts when more noble activities could be enumerated instead (Delgado 1991:398-399). Fish is mentioned as an accessible protein source, especially for low-status people in littoral settlements, who could not afford meat (García-Sánchez 1983). Notably the consumption of low trophic level fish has been found in this thesis at the small rural settlements on the beach of Setubal and Loulé (Chapter 6-7). Sardines and tuna are the most common species according to the sources, although a big variety of freshwater and marine species are also mentioned (Chapter 3). Two types of fishing techniques are known: a specific one for tuna (*almadraba*) which was introduced by Phoenicians and consisted in trapping and catching tunas when crossing the Gibraltar Strait; and trawling (Pezzi 1985). Unfortunately, types of fishing boats are not described in historical sources, highlighting again the marginality of this activity in the eyes of the chroniclers compared to other seafaring activities (Delgado 1991:405).

It seems that naval technology was mainly applied to military and trading activities, which were centrally controlled, while fishing remained during these centuries, a marginal littoral activity affecting the dietary practices of low status coastal populations. The isotopic data presented here, in addition to the published studies of other contemporaneous Muslim populations, and the extreme scarcity of fish remains across contemporaneous Iberian sites seems to support this hypothesis (see Chapter 3). Although the technology was theoretically available, the main economic activities were still based on terrestrial resources such as pastoralism and agriculture.

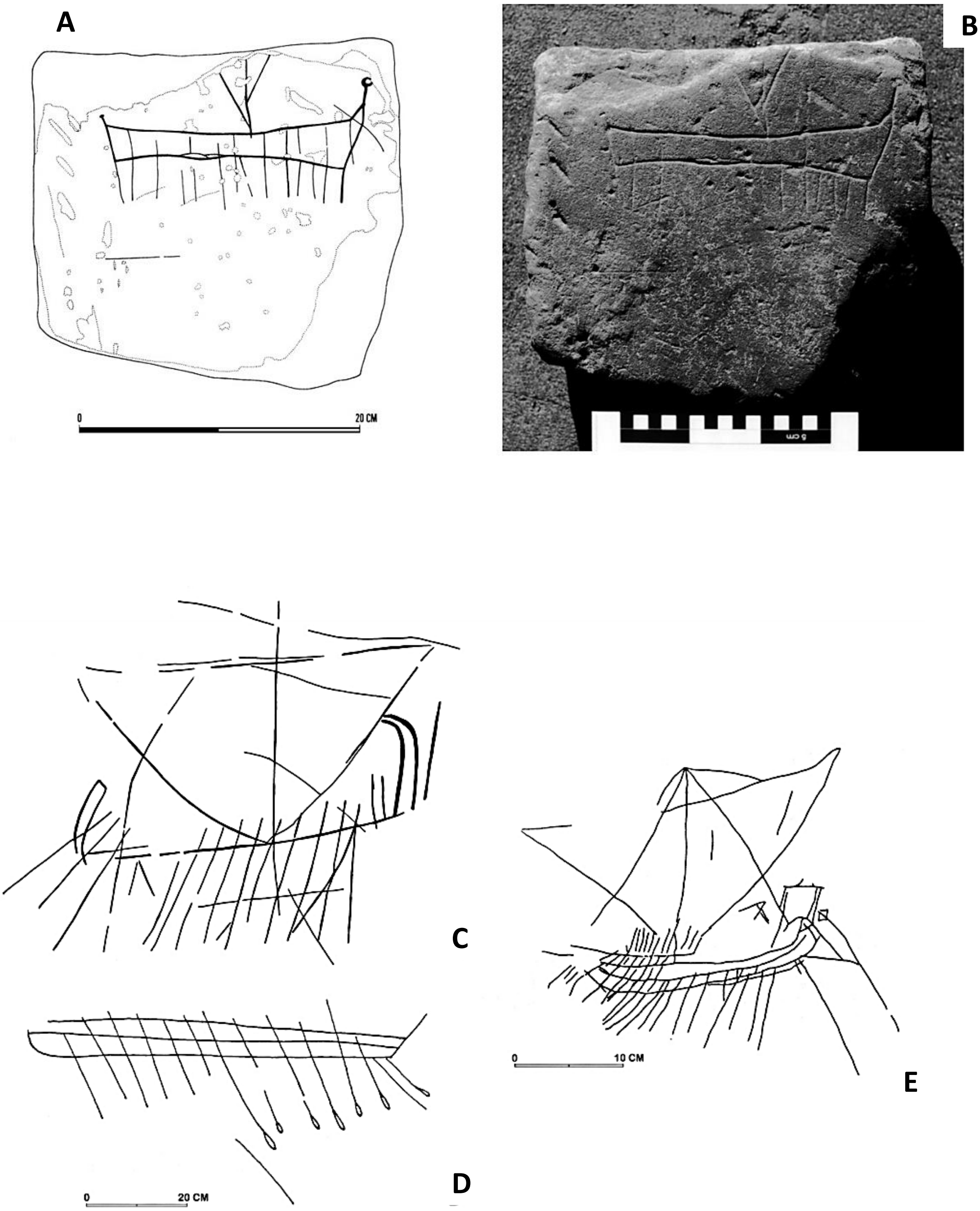

***Figure 8-13*** *a)Engraving of a boat from Silves; b) Sandstone block from Silves with ship engraving (Gomes et al. 2014); Engraved boats from c) Mertola, d)Granada and e) Denia's castle (Gomes et al. 2014 Fig. 4).*

Historical sources are similarly scarce for the early medieval period in the Northern Kingdom of Portugal and especially regarding fishing practices. The populations of the northern coast often appears with Galician population in the sources and both groups are said to have had practiced coastal fishing despite the lack of governmental support and dangerous pirates (Sampaio 1923:383). Normans boats first and Muslims ones later are threatening and sacking the coastal settlements between the 10th and the 11th century, discouraging any audacious off-shore navigation and preventing the exploration of the sea in a systematic way (Dória 1979:30). The 12th century and the crusades brought a closer alliance between the port cities of Northern Portugal and the crusaders' fleets that would stop there during the journey to the Holy Land. Historians have pointed at this newly established commercial relationship as a fructuous environment in which not only goods were exchanged but also naval knowledge and expertise, that would be further developed in the 13th century (Sampaio 1923:304; Peres 1943:24).

### 8.6.2 Expansion in the late medieval period

The economy of northern Portugal therefore seems to be on the brink of a big expansion at the beginning of the 13th century; while, in the south, the completion of the Christian conquest, allowed them to take resources away from the southern territories. The focus of maritime activities shifted from the south to the northern Christian ports, and the northern Atlantic coast becomes a central area in this new route (Delgado 1991). In the 13th century merchants from Portugal together with northern Castilian merchants from Cantabrian, Asturian, and Galician coasts, began to take advantage of economic opportunities in the Bay of Biscay and northern Europe. Gradually, these traders came to control much of the traffic from the Iberian Peninsula to England and Flanders (Contasble 1996:243). English rulers were amongst the first to grant safe-conducts to the Portuguese in the 13th century. In 1226, Henry III (1216–72) allowed 106 merchants from Portugal to engage freely in trade in England for one year (Miranda 2013). In 1353, King Edward III (1312-1377) signed a commercial treaty with Portuguese ambassadors to allow Portuguese fishermen to carry on their industry off the coasts of England and Brittany (Prestage 1934:72). The reasons behind this rapid expansion of the Portuguese fishing industry are multiple; however, it is worth considering that an over-exploitation of the Portuguese coast might have forced the fishing boats further north to ensure that the demand for fish was met. However, at the same time, English boats are also starting a similar process, venturing further offshore. Barrett et al. (2011) suggests that also in this case the exhaustion of marine resources was the propelling force to enlarge the fish catchment area. However, the reasons behind the demand-driven intensification of local fishing are difficult to underpin and abstinence from meat in Christian practice is difficult to attest before the 11th century. Population growth has also been indicated as a likely cause as fish is an affordable source of protein and concentration of people in urban centre might have increased the pressure on food resources.

Fish became a much less expensive and more common foodstuff than in the Early Medieval period. Some of the species remained expensive, both marine (croacker, red porgy, red bream, and hake) and freshwater ones (including allis shad, lamprey and eel), and were accessible to a selected group of people. However, less expensive fishes (sardines, sole and allis shad) were also present and would be easily accessible by the lower classes (Martins 2016). The isotopic data from the late medieval populations in this thesis confirm the idea of a generalised and increased access to marine resources after the Christian conquest. A further consideration has to be made on the peculiar change of diet for the Muslim minority in Lisbon. If fish indeed became an inexpensive item, it seems a rather logical choice to use it to complement a poor diet based on grains and vegetables. Historical sources describing the Muslim quarter in Lisbon report a number of restrictions for this community. For examples, only few selected butchers were allowed to provide halal meat and only one of these shops is known for the Lisbon Islamic quarter, which might not have been sufficient to satisfy the needs of a growing population (Oliveira and Viana 1993). The isotopic data for the faunal remains from the same Islamic quarter indicated a very homogenous diet for all species, which is in contrast with the widely ranging values of all the other faunal assemblages in this thesis. This might suggest that the channels of meat supply were also restricted and highly controlled. Historical sources indicate the existence of a corral in the Lisbon Islamic quarter where the animals were kept all together before being killed (Oliveira and Viana 1993:199). In this scenario of scarcity, fish was a safe choice for halal meat-eaters, which could supplement the lack of meat with marine proteins while resting assured of complying with the religious food restrictions.

Although the influence of different elements such as sex, faith, technology, economic and political power have been considered in an effort to identify their direct correlation to food practices, it is apparent how they are all strictly related and interconnected. Although faith affects dietary practices with well-known food restrictions in both Islam and Christian traditions, the new economy and political scene of the late Middle Ages is also responsible for the change in resource availability and therefore food consumption. Even though it is appealing to see this economic change as being directly related to the Christian conquest, the data in this thesis cannot sustain such claim and future research on the importance of fish in the Portuguese culture, both because of its religious symbolism and economic importance, is necessary to address this debate. The discussion of the isotopic results undertaken in this chapter emphasises the closely-knit nature of the relationship between food and social, political and economic factors; implying that all these aspects have to be holistically considered to reconstruct foodways in Medieval Portugal.

# 9. CONCLUSIONS

Analyses of $\delta^{13}C$ and $\delta^{15}N$ isotopes were used in this thesis to explore dietary practices and resources availability and exploitation in the multi-faith society of medieval Portugal. This is the first application of this technique to the archaeological remains of human and animals from Muslim sites in Portugal and the most comprehensive isotopic study to date of late medieval Christian populations. The isotopic data was combined and contextualised with the evidence provided by historical and archaeological sources for diet. The results indicate that on the whole humans consumed a diet based on $C_3$ terrestrial resources, although at certain sites, a mixed diet complemented by variable amounts of $C_4$ plants was found. Relatively high $\delta^{15}N$ values are found across all human populations, suggesting that animal protein significantly contributed to the diet, however the high variability of the faunal values hinder further speculation about the type of animal protein primarily consumed. Humans of differing faith tend to have an isotopically different diet, however the chronology and a changing economy over time also seems to be affecting food provision and dietary practices with marine resources being consumed primarily in the late medieval period. The research questions outlined in the introduction of this thesis provide the framework followed for the conclusion and final discussion of this work below.

## 9.1 Diet, geographical location and urban vs rural settlement

An animal baseline was constructed with samples from each location (apart from Beja for which published faunal values of close chronology were used), and used to interpret the human diet at each site. A clear geographical trend in diet of both animals and humans was not found. The animals displayed a high degree of variability, especially in $\delta^{15}N$ values, which did not follow a geographical pattern, but are more likely a reflection of a number of factors such as wide catchment area, feeding strategies, proximity to human settlement and specific husbandry practices at each site (Chapters 6). It is not possible to define a major contributing factor for this distribution within this dataset; however, pastoral and farming strategies seem to be varied across medieval Portugal.

When animal data were assessed by species, herbivores including cow and sheep consumed mainly $C_3$ plants although some individuals showed a mixed diet including $C_4$ plants. Interestingly goats showed lower values of $\delta^{15}N$ and higher values of $\delta^{13}C$ compared to cow and sheep. Although these patterns might be due to the difference between grazing and browsing feeding strategies, the values suggest that lower trophic level protein and higher proportions of $C_4$ plants were consumed by this species. This trend was only appreciated when all data were pulled together, suggesting that sample size can be an issue even in assemblages with adequate numbers. This finding cannot be assessed in comparison to other medieval Iberian dataset because of the difficulty in differentiating between sheep and goat during zooarchaeological analysis. In this case, ZooMS has proved to be useful to this study since this trend would have not been otherwise identified. Omnivore diet did not follow a geographical distribution either; however, pigs showed a diet in accordance to herbivores values in this thesis suggesting that they were managed in a similar way. Chickens showed higher $\delta^{13}C$ and $\delta^{15}N$ values compared to pigs and other herbivores, suggesting that a variety of higher trophic level proteins were consumed as well as a significant amount of $C_4$ plants which is in accordance with historical sources, isotopic studies and ethnographical evidence for medieval Iberia.

Similarly to the animal baseline, the human data set did not reveal a geographic trend. Both isotope values exhibit a wide range of variability; however, this has no correlation with the location, for example the two northern populations (Laranjal and Coimbra) show the lower and higher median $\delta^{13}C$ values of the entire dataset respectively. This indicated that social factors and individual practices affected the values of all populations more than the regional environment and climate. The urban population of Coimbra showed the greatest reliance on $C_4$ plants (e.g. millet), with females consuming higher proportions than males.

The assessment of diet in relation to settlement type revealed that for the Islamic period, urban sites had a terrestrial diet based on $C_3$ plants with little or no discernible contribution of marine resources. However the subsistence strategy at rural sites (Setubal and Loulé) showed higher values of both $\delta^{13}C$ and $\delta^{15}N$, suggesting that either low trophic level fish or $C_4$ plants were consumed. The idea of coastal fishing is supported by historical sources, which define this activity as common practice during the Islamic period among the lower classes. This evidence is further supported by shell mounds being excavated at Loulé. Overall, rural sites of both faith (Laranjal, Setubal and Loulé) showed different dietary practices when compared to the nearest urban centre (Coimbra, Lisbon and Silves), implying that easily accessible local resources would dictate food availability and consumption, rather than social factor such as status, sex or faith. However, to fully explore this trend across the medieval period for both faith groups, further analysis of rural sites is required.

## 9.2 Diet, sex and status

The results of this thesis indicated that at some sites there was a difference between the diet of males and females (i.e. Coimbra and São Jorge Castle, Lisbon). These two populations had a diametrically opposed sex-related trend. Lisbon sex-related food inequalities manifested through higher trophic level animal protein being consumed by males; while in Coimbra, females had similar trophic level to males but relied on bigger proportions of $C_4$ plants. Interestingly these trends (lower trophic level meat/smaller quantities of animal protein and $C_4$ resources) are associated with lower social status which can inform on the position of women within medieval societies. Overall, widespread sex-related difference is absent from all other sites suggesting that men and women did not have a very different diet or that the difference between foodstuffs preferentially consumed by men and women cannot be detected isotopically. This is a common trend in Medieval Iberia although few case studies presenting sex-related difference in diet are found (Chapter 3).

The relationship between diet and status was not explored in this work since only one population (São Jorge Castle, Lisbon) was of higher social status. However a discussion of status related diet in Islamic Portugal has been undertaken in Toso et al. (2018), provided in Appendix C.

## 9.3 Diet, faith and chronology

The data set in this thesis demonstrated that dietary differences existed between Christian and Muslim groups in Medieval Portugal. Muslims had a terrestrial diet based on $C_3$ resources, in both interior and coastal sites, with the exception of two rural sites (Setubal and Loulé) where low trophic level fish might have complemented the protein intake of these populations. Christians showed greater reliance on marine resources as confirmed by higher $\delta^{13}C$ and $\delta^{15}N$ values compared to the Muslim populations. However, all the main Christian populations from cities that had previously been under Islamic rule (Lisbon, Beja and Silves) are also of later chronology, questioning the idea that this difference in subsistence strategy is solely faith-related. Furthermore, the only religious minority group in this data set, a Muslim population living in Lisbon under Christian rule at the end of the medieval period, showed a marine diet in accordance with the other late medieval (Christian) populations. This indicated that a change occurred after the Christian conquest and both faith groups exploited marine resources more heavily in the late Middle Ages. A religious minority would not benefit from a prestigious role within the society, like the case of Muslims living in Lisbon Muslim quarter, therefore suggesting that fish must have become an ordinary commodity for these groups. This trend is remarkable especially in the light of an almost complete absence of marine protein in the early medieval Muslim diet under Islamic rule and suggests that restrictions and control over the supply of halal meat within the Muslim quarter of Lisbon might have helped to develop this interest in fish as a viable and safe substitute. Unfortunately, this data set alone cannot provide a definite answer to this question, nor it can prove that the increasing fish consumption in the late medieval period is a direct consequence of the Christian conquest. These themes should be addressed through the isotopic analysis of Christian minorities living under earlier Islamic rule as well as other late medieval Christian and Muslim groups, in order to explore the transition and economic change from an agricultural Islamic society to a Christian maritime one. In addition, further research on fish remains from Portuguese sites should be undertaken in order to characterise the type of fishing practices during this time (inshore vs. offshore) to ascertain if and to what extent the technological advancement in the late Middle Ages had an impact on seafaring activities and resource exploitation and availability.

## 9.4 Future research

The results of this thesis have indicated areas of future development to explore some of the trends resulting from this research. These include:

- The analysis of additional animal remains from the medieval sites included in this thesis to assess whether the difference in diet between browsers and grazers is a common phenomenon and whether the consumption of $C_4$ plants by chickens is a widespread practice. Analysis of further fish remains both marine and freshwater environments are needed to characterise the species availability and isotopic values through the Middle Ages along the Atlantic coast. The analysis of securely dated context of faunal remains would be also beneficial in assessing any change in husbandry and fishing practices between the early and late medieval period.
- The diversity of dietary signals in urban Muslim populations and the presence of several outliers appear to indicate the presence of immigrants. However, $\delta^{13}C$ and $\delta^{15}N$ values do not support any assumption on mobility within this data set. Therefore, future research could focus on assessing the presence of local and non-local individuals in these populations using other isotopes such as strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O$) and sulphur ($\delta^{34}S$). These isotopes have been used in skeletal material to identify geographic origin of human populations (Dury et al. 2018; Nehlich et al. 2012; Müldner et al. 2009). Dental enamel is usually sampled for this analysis which is less prone to diagenesis and retains the isotopic signal of the environment during tooth formation, providing information on the individual childhood location. Sulphur isotopes specifically are also useful to identify differences between marine and freshwater resources in diet, which could be particularly useful in this study due to the lack of sampling of freshwater fish.
- The absolute dating of a greater number of human individuals in this thesis would be beneficial. The radiocarbon dating of the burials from Beja has been a significant

stepping stone in this work since, from the archaeological excavation, Muslims and Christians at this site look contemporaneous, while, in fact, they used the same burial ground at least 100 years apart. This important result provided the first evidence for a difference in diet that was not only based on faith but also chronology. A similar approach would be particularly useful for the multi-faith burial site in the Lisbon Muslim quarter.

- The analysis conducted in this thesis could be extended to other religious minority groups such as Christian living under Muslim rule and Muslims living under Christian rule (represented in this thesis in one collection from Lisbon Muslim quarter) to further explore themes of co-existence and food availability and supply within religious minorities in the Middle Ages. This would also further confirm is diet had a stronger chronology-related rather than faith-related correlation among these populations.
- This study could be expanded geographically to explore further the interior part of the country and the northern Christian kingdom. Much archaeological research is undergoing on settlement strategy in these areas and could be coupled with more specific demographic, dietary and economic information.

### 9.5 Summary and final remarks

The results from this work have identified the following major findings:

- **Species**: the animal data indicated that a species-related diet for goat that showed lower nitrogen isotope values and higher carbon ones, suggesting the inclusion of $C_4$ plants into their diet. No difference can be seen for sheep and cow, suggesting that these animals had differing roles in agriculture and food provision. Different feeding strategies between browsers and grazers could also contribute to this isotopic trend. Chickens were consistently mirroring the human diet at all sites suggesting that backyard rearing was commonly practised throughout Portugal and $C_4$ plants were a common addition to the chickens' diet at least in certain locations;
- **Geographical location:** No geographical trend in $\delta^{13}C$ and $\delta^{15}N$ values for animal or human populations was found. This indicate that the local environment and the individual practices affected the values of all populations more than the climate and environment. Comparison to other published isotopic studies of medieval populations revealed that there is no similarity between this dataset and other Atlantic settlements in Galicia and Brittany, but similarities in $\delta^{13}C$ and $\delta^{15}N$ values are found between Portuguese sites and the Balearic Islands;

- **Urban/rural**: Wide ranges in isotopic values for all urban populations are observed. This indicates the potential of $\delta^{13}C$ and $\delta^{15}N$ data to identify outliers or the potential for migrants in the human populations and indicate the level of choice and diversity in urban diets;
- **Faith:** a faith-related difference in diet between Muslims and Christians from all sites. In addition, this difference is particularly notable at three major urban multi-faith sites: Lisbon, Beja and Silves;
- **Sex**: a correlation between diet and sex at the high-status Muslim burial site of São Jorge Castle in Lisbon with males displaying higher $\delta^{15}N$ values. Differences in diet correlating to sex have also being found in the Christian population from Coimbra where females consume larger quantities of $C_4$ plants than males;
- **Chronology**: a widespread difference in diet between early and late medieval sites with a clear change in economy possibly brought about by the Christian conquest. All three major urban sites (Lisbon, Beja and Silves) show an increment of at least 11% in the quantity of marine protein included in the human diet. The role of fish become central to the human diet by the late medieval period as indicated by isotopic and historical sources.

In conclusion, this study provided the first large body of isotopic data on Muslim and Christian populations from Medieval Portugal identifying a number of trends in human and animal diets that have been interpreted in the light of historical and archaeological data. It has highlighted how diverse diet and foodways were in the Middle Ages and what factors might have interplayed in defining food access and distribution among different groups over the medieval period. Finally, it has contributed to the wider debate on the impact of the Christian conquest on these populations and on the economy of medieval Portugal in its transition from an Islamic agricultural society to a Christian maritime one. The results of this thesis have clearly shown the usefulness and potential of isotopic analysis to meaningfully explore the diet of populations living along the Atlantic coast of the Iberian Peninsula in the Middle Ages, opening new avenues of research within this discipline.

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# APPENDIX A

## A.1 Radiocarbon dating calibration and reservoir correction

### A.1.1 Terminology and conventions

Radiocarbon determinations and calibrated dates are reported following recently revised conventions (Millard 2014). The following methodology has been used to calibrate the radiocarbon date and calculate the reservoir correction:

- Provide laboratory code
- Provide information of the type of sampled material
- Clearly state whether $\delta^{13}C$ value were obtained by accelerator mass spectrometry (AMS) or by isotope-ratio mass spectrometry (IRMS). AMS values should not be used for dietary reconstructions or reservoir corrections (Millard 2014:557).
- The laboratory measurement is reported as a conventional radiocarbon age in radiocarbon years BP
- Include the calibration curves
- Include the reservoir offset ($\Delta R$) used
- Include the software used for calibration
- Provide the calibrated date as a range
- Provide both probability values (68% or 95%) for each range
- Clearly state the calendar timescale used (e.g. cal AD, cal CE).

In this thesis, calibrated and calendar ages were reported as BCE (Before Common Era). All radiocarbon measurements presented in this study are calibrated with OxCal 4.3 (Bronk Ramsey 2009) using atmospheric curve IntCal13 (Reimer et al. 2013). In addition, because the collagen of the radiocarbon dated individuals showed potential marine protein contribution, the aquatic curve Marine13 was also used (Reimer et al. 2013) with the regional reservoir offset (Monge Soares et al. 2016). The percentage of non-atmospheric carbon derived from aquatic reservoir is estimated using the equation marine 2 (Arneborg et al. 1999, Richards and Hedges 1999, Schulting and Richards 2001). The results of the radiocarbon measurements and atmospheric calibration with IntCal13 are presented below.

| Skeleton ID | Lab code | Element | $^{14}$C (yrs BP) | Cal CE 68% | Cal CE 95% |
|---|---|---|---|---|---|
| BEJ7278 | 28461 | Rib | 1191±23 | 777-876 | 770-936 |
| BEJ3207 | 28464 | Rib | 973±24 | 1021-1146 | 1016-1153 |
| BEJ3259 | 28462 | Rib | 695±24 | 1276-1295 | 1268-1383 |
| BEJ3083 | 28463 | Rib | 651±23 | 1290-1385 | 1283-1391 |
| BEJ3102 | 28465 | Rib | 601±21 | 1310-1397 | 1300-1405 |

### A.1.2 Regional reservoir offset

A marine calibration curve must be applied in the case of individuals that incorporate carbon fixed in non-terrestrial reservoirs through food chain, i.e. individuals with a marine diet. Such samples are depleted in $^{14}$C and will present an offset in $^{14}$C age in relation to contemporaneous samples containing atmospheric carbon exclusively. The Western Atlantic coast of the Iberian Peninsula is influenced by a dynamic upwelling which strongly affects the fluctuations in the ocean reservoir offset on the western coast of Portugal (Monge Soares and Dias 2006). This marine phenomenon occurs in the open ocean and along coastlines, when deep water rises and replaces the surface water. The upwelling activity varies through time and research has shown that coastal values of ΔR in these regions may exhibit significant variability (Monge Soares and Dias 2006; Monge Soares and Martins 2009). In the case of dynamic upwelling situations like the one of the Portuguese coast, the use and determination of a mean ΔR is considered to be meaningless and it is strongly suggested to use the determined ΔR value that is closer to the $^{14}$C age to be calibrated (Monge Soares and Martins 2009). In the case of this study corresponds to 800 to 1500 BCE. The recommended ΔR values for this period is 95±15 (Monge Soares 1993).

Because the individuals here included presented a mixed diet with the inclusion of marine protein in their collagen, a correction of the radiocarbon dates was carried to account for the marine reservoir effect, applying the calibration curve Marine 13. The new set of dates, calibrated with calibration curve Marine13 (Stuiver et al. 1986) and including the regional reservoir offset (ΔR) are presented below.

| Skeleton ID | $^{14}$C (yrs BP) | Correction ΔR | Cal CE 68% | Cal CE 95% |
|---|---|---|---|---|
| BEJ7278 | 1191±23 | 95±15 | 887-990 | 778-1019 |
| BEJ3207 | 973±24 | 95±15 | 1051-1218 | 1035-1249 |
| BEJ3259 | 695±24 | 95±15 | 1324-1436 | 1300-1450 |
| BEJ3083 | 651±23 | 95±15 | 1330-1452 | 1304-1490 |
| BEJ3102 | 601±21 | 95±15 | 1415-1490 | 1330-1620 |

In addition, the contribution of marine protein to the diet was calculated following the equation marine 2 (Arneborg et al. 1999, Richards and Hedges 1999, Schulting and Richards 2001). In this method the contribution (%) of marine versus terrestrial resources is estimated from the measured $\delta^{13}$C values of bone collagen following a linear equation developed between previously established endpoint values (Arneborg et al. 1999, Richards and Hedges 1999). This method is less accurate than the equation marine 1; however is more conservative and is preferable when no specific values can be provided for terrestrial dietary resources such as plants (C3 and/or C4). In addition, faunal remains from Beja were not available either, hence, the equation marine 2 was considered to be a better option for this specific case studies. The estimation of marine protein (%) per each individual has been a fundamental step in assessing dietary changed between faith groups but also an economic shift that seems to happen during the late medieval period. For this purpose, the estimated values of marine protein (%) at the sites of Lisbon, Beja and Silves are provided below, including early medieval (EM) and late medieval (LM) assemblages.

| Location | Sample No | Chronology | Faith | % of marine protein |
|---|---|---|---|---|
| Lisbon | CAS7PC | EM | Muslim | 21.5 |
| Lisbon | CAS2PN | EM | Muslim | 25.6 |
| Lisbon | CAS12PC | EM | Muslim | 23.4 |
| Lisbon | CAS19PC | EM | Muslim | 23.2 |
| Lisbon | CAS16PC | EM | Muslim | 23.1 |
| Lisbon | CAS14PC | EM | Muslim | 27.9 |
| Lisbon | CAS8PC | EM | Muslim | 17.5 |
| Lisbon | CAS1PN | EM | Muslim | 24.8 |
| Lisbon | CAS1PC | EM | Muslim | 25.6 |
| Lisbon | CAS2PC | EM | Muslim | 24.2 |
| Lisbon | CDT409 | EM | Muslim | 26.4 |
| Lisbon | CDT410 | EM | Muslim | 23.4 |
| Lisbon | CDT418 | EM | Muslim | 26.9 |
| Lisbon | CDT421 | EM | Muslim | 26.0 |
| Lisbon | CDT425 | EM | Muslim | 25.8 |
| Lisbon | LOL 74 | LM | Christian | 62.9 |

| Location | Sample No | Chronology | Faith | % of marine protein |
|---|---|---|---|---:|
| Lisbon | LOL 65 | LM | Christian | 40.4 |
| Lisbon | LOL21 | LM | Christian | 37.9 |
| Lisbon | LOL 1443 | LM | Christian | 36.2 |
| Lisbon | LOL 71 | LM | Christian | 34.8 |
| Lisbon | LOL 29 | LM | Christian | 33.8 |
| Lisbon | LOL 1250 | LM | Christian | 32.5 |
| Lisbon | LOL1247 | LM | Christian | 27.8 |
| Lisbon | LOL 1224 | LM | Christian | 27.4 |
| Lisbon | LOL 1236 | LM | Christian | 25.9 |
| Lisbon | LOL1219 | LM | Christian | 24.5 |
| Lisbon | LOL 24 | LM | Christian | 24.2 |
| Lisbon | LOL1244 | LM | Christian | 23.2 |
| Lisbon | LOL1091 | LM | Christian | 21.6 |
| Lisbon | LOL1069 | LM | Christian | 12.1 |
| Lisbon | LOL626 | LM | Muslim | 59.6 |
| Lisbon | LOL 1403 | LM | Muslim | 57.7 |
| Lisbon | QDL 134 | LM | Muslim | 48.9 |
| Lisbon | LOL1477 | LM | Muslim | 46.3 |
| Lisbon | QDL131 | LM | Muslim | 42.3 |
| Lisbon | LOL423 | LM | Muslim | 30.0 |
| Lisbon | LOL1585 | LM | Muslim | 28.8 |
| Lisbon | LOL18 | LM | Muslim | 28.5 |
| Lisbon | LOL 442 | LM | Muslim | 28.4 |
| Lisbon | BOL 818 | LM | Muslim | 28.1 |
| Lisbon | LOL1066 | LM | Muslim | 27.7 |
| Lisbon | LOL422 | LM | Muslim | 26.7 |
| Lisbon | BOL 824 | LM | Muslim | 26.6 |
| Lisbon | LOL1187 | LM | Muslim | 25.9 |
| Lisbon | LOL437 | LM | Muslim | 24.8 |
| Lisbon | BOL 933 | LM | Muslim | 24.7 |
| Lisbon | BOL815 | LM | Muslim | 23.8 |
| Lisbon | LOL629 | LM | Muslim | 22.3 |
| Lisbon | QDL102 | LM | Muslim | 22.2 |
| Lisbon | BOL 942 | LM | Muslim | 21.7 |
| Lisbon | BOL 943 | LM | Muslim | 21.1 |
| Lisbon | QDL124 | LM | Muslim | 18.8 |
| Beja | BEJ7143 | EM | Muslim | 27.0 |
| Beja | BEJ1150 | EM | Muslim | 26.0 |
| Beja | BEJ6087 | EM | Muslim | 25.5 |
| Beja | BEJ7173 | EM | Muslim | 25.4 |
| Beja | BEJ1056 | EM | Muslim | 25.1 |
| Beja | BEJ1053 | EM | Muslim | 24.6 |
| Beja | BEJ3144 | EM | Muslim | 24.0 |
| Beja | BEJ7006 | EM | Muslim | 23.6 |
| Beja | BEJ1084 | EM | Muslim | 23.5 |
| Beja | BEJ6150 | EM | Muslim | 23.0 |
| Beja | BEJ1065 | EM | Muslim | 22.8 |

| Location | Sample No | Chronology | Faith | % of marine protein |
|---|---|---|---|---|
| Beja | BEJ6248 | EM | Muslim | 22.7 |
| Beja | BEJ7010 | EM | Muslim | 22.6 |
| Beja | BEJ7031 | EM | Muslim | 22.5 |
| Beja | BEJ3282 | EM | Muslim | 22.4 |
| Beja | BEJ7298 | EM | Muslim | 22.3 |
| Beja | BEJ1059 | EM | Muslim | 22.2 |
| Beja | BEJ6292 | EM | Muslim | 21.9 |
| Beja | BEJ701 | EM | Muslim | 21.8 |
| Beja | BEJ6279 | EM | Muslim | 21.7 |
| Beja | BEJ1092 | EM | Muslim | 21.5 |
| Beja | BEJ7243 | EM | Muslim | 21.5 |
| Beja | BEJ1096 | EM | Muslim | 21.4 |
| Beja | BEJ6177 | EM | Muslim | 21.0 |
| Beja | BEJ3176 | EM | Muslim | 20.9 |
| Beja | BEJ7125 | EM | Muslim | 20.7 |
| Beja | BEJ3024 | EM | Muslim | 20.6 |
| Beja | BEJ7061 | EM | Muslim | 19.9 |
| Beja | BEJ7094 | EM | Muslim | 19.9 |
| Beja | BEJ3207 | EM | Muslim | 19.6 |
| Beja | BEJ7047 | EM | Muslim | 19.5 |
| Beja | BEJ1026 | EM | Muslim | 19.4 |
| Beja | BEJ7311 | EM | Muslim | 18.6 |
| Beja | BEJ1081 | EM | Muslim | 18.4 |
| Beja | BEJ3180 | EM | Muslim | 17.9 |
| Beja | BEJ7278 | EM | Muslim | 17.4 |
| Beja | BEJ7288 | EM | Muslim | 17.3 |
| Beja | BEJ1147 | EM | Muslim | 17.3 |
| Beja | BEJ3157 | EM | Muslim | 14.7 |
| Beja | BEJ606 | EM | Muslim | 12.6 |
| Beja | BEJ3200 | EM | Muslim | 0.0 |
| Beja | BEJ3164 | LM | Christian | 36.5 |
| Beja | BEJ3190 | LM | Christian | 33.2 |
| Beja | BEJ1125 | LM | Christian | 32.3 |
| Beja | BEJ3259 | LM | Christian | 30.8 |
| Beja | BEJ3102 | LM | Christian | 30.3 |
| Beja | BEJ3113 | LM | Christian | 29.9 |
| Beja | BEJ4019 | LM | Christian | 29.8 |
| Beja | BEJ3263 | LM | Christian | 29.7 |
| Beja | BEJ3083 | LM | Christian | 28.9 |
| Beja | BEJ4016 | LM | Christian | 28.2 |
| Beja | BEJ3040 | LM | Christian | 23.8 |
| Beja | BEJ6115 | LM | Christian | 19.6 |
| Beja | BEJ3043 | LM | Christian | 13.3 |
| Silves | R25A 78 | EM | Muslim | 37.0 |
| Silves | R25A 56 | EM | Muslim | 33.8 |
| Silves | R25A 87 | EM | Muslim | 33.3 |
| Silves | R25A 76 | EM | Muslim | 32.1 |

| Location | Sample No | Chronology | Faith | % of marine protein |
|---|---|---|---|---|
| Silves | R25A 73 | EM | Muslim | 31.4 |
| Silves | R25A 80 | EM | Muslim | 28.6 |
| Silves | R25A 33 | EM | Muslim | 28.5 |
| Silves | R25A 62 | EM | Muslim | 27.9 |
| Silves | R25A 74 | EM | Muslim | 27.8 |
| Silves | RA13 | EM | Muslim | 27.0 |
| Silves | R25A 25 | EM | Muslim | 26.7 |
| Silves | R25A 5 | EM | Muslim | 26.4 |
| Silves | R25A 17 | EM | Muslim | 26.0 |
| Silves | RA9 | EM | Muslim | 25.8 |
| Silves | R25A 22 | EM | Muslim | 25.8 |
| Silves | R25A 86 | EM | Muslim | 25.7 |
| Silves | R25A 29 | EM | Muslim | 24.7 |
| Silves | R25A 10 | EM | Muslim | 23.7 |
| Silves | R25A 37 | EM | Muslim | 23.4 |
| Silves | R25A 18 | EM | Muslim | 22.6 |
| Silves | R25A 26 | EM | Muslim | 21.6 |
| Silves | R25A 30 | EM | Muslim | 21.1 |
| Silves | RA15 | EM | Muslim | 21.0 |
| Silves | R25A 9 | EM | Muslim | 20.7 |
| Silves | R25A 47 | EM | Muslim | 20.3 |
| Silves | RMB11B | LM | Christian | 94.9 |
| Silves | LSE10 | LM | Christian | 61.0 |
| Silves | RMB81 | LM | Christian | 51.5 |
| Silves | LSE34 | LM | Christian | 51.1 |
| Silves | LSE70 | LM | Christian | 44.7 |
| Silves | LSE2 | LM | Christian | 41.8 |
| Silves | RMB5B | LM | Christian | 40.1 |
| Silves | LSE33 | LM | Christian | 38.0 |
| Silves | LSE40 | LM | Christian | 37.8 |
| Silves | LSE18 | LM | Christian | 37.5 |
| Silves | RMB10B | LM | Christian | 36.9 |
| Silves | RMB21 | LM | Christian | 36.6 |
| Silves | RMB46 | LM | Christian | 35.9 |
| Silves | LSE9 | LM | Christian | 35.3 |
| Silves | RMB65 | LM | Christian | 35.1 |
| Silves | LSE4 | LM | Christian | 35.0 |
| Silves | LSE31 | LM | Christian | 34.0 |
| Silves | RMB4B | LM | Christian | 34.0 |
| Silves | RMB12B | LM | Christian | 33.2 |
| Silves | RMB69 | LM | Christian | 33.0 |
| Silves | LSE3 | LM | Christian | 32.8 |
| Silves | RMB66 | LM | Christian | 32.8 |
| Silves | LSE1 | LM | Christian | 32.7 |
| Silves | LSE11 | LM | Christian | 32.1 |
| Silves | LSE5 | LM | Christian | 32.1 |
| Silves | RMB8 | LM | Christian | 31.7 |

| Location | Sample No | Chronology | Faith | % of marine protein |
|---|---|---|---|---:|
| Silves | LSE26 | LM | Christian | 31.1 |
| Silves | LSE32 | LM | Christian | 30.8 |
| Silves | LSE17 | LM | Christian | 30.7 |
| Silves | LSE44 | LM | Christian | 30.2 |
| Silves | LSE59 | LM | Christian | 30.2 |
| Silves | RMB43 | LM | Christian | 30.2 |
| Silves | RMB6B | LM | Christian | 30.0 |
| Silves | LSE45 | LM | Christian | 29.5 |
| Silves | RMB68 | LM | Christian | 28.9 |
| Silves | LSE28 | LM | Christian | 28.2 |
| Silves | RMB61 | LM | Christian | 27.2 |
| Silves | RMB39 | LM | Christian | 24.2 |
| Silves | RMB8B | LM | Christian | 23.5 |
| Silves | RMB26 | LM | Christian | 23.3 |

# Appendix B

## B.1 Human samples catalogue

Catalogue codes:

**Age**

Adult=over 18 yrs

Juvenile = <18 yrs

**Estimated age**= age-at-death estimated following anthropological analysis. These data are not available for all individuals and therefore were not taken into account (Chapter 4)

**m**= months, used to indicate age in months for non-adult individuals

**Sex**

M= male

F= female

U= Undetermined

**Yield (%)**= Percentage yield of collagen

**C/N**: atomic carbon/nitrogen ratio

*=radiocarbon dated

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bragança | Laranjal | 10th-14th | LAR8 | Christian | Rib | F | Adult | | 1.3 | 8.1 | 2.2 | 3.4 | -21.1 | 10.4 |
| Bragança | Laranjal | 10th-14th | LAR54 | Christian | Rib | F | Adult | | 0.6 | 4.9 | 1.1 | 3.5 | -20.5 | 8.4 |
| Bragança | Laranjal | 10th-14th | LAR52 | Christian | Rib | F | Adult | | 2.7 | 14.6 | 5.1 | 3.3 | -17.1 | 9.0 |
| Bragança | Laranjal | 10th-14th | LAR50 | Christian | Rib | M | Adult | | 1.3 | 11.2 | 3.3 | 4.0 | -18.5 | 10.9 |
| Bragança | Laranjal | 10th-14th | LAR26 | Christian | Left ulna | M | Adult | | 0.9 | 6.0 | 1.8 | 3.8 | -20.8 | 8.8 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bragança | Laranjal | 10th-14th | LAR150 | Christian | Rib | M | Adult |  | 1.3 | 30.4 | 10.4 | 3.4 | -18.7 | 12.1 |
| Bragança | Laranjal | 10th-14th | LAR145 | Christian | Left tibia | M | Adult |  | 0.8 | 3.1 | 0.4 | 3.4 | -22.8 | 9.9 |
| Bragança | Laranjal | 10th-14th | LAR136 | Christian | Rib | M | Adult |  | 1.2 | 11.5 | 4.1 | 3.3 | -19.3 | 9.0 |
| Bragança | Laranjal | 10th-14th | LAR106 | Christian | Right humerus | M | Adult |  | 0.2 | 3.4 | 0.6 | 3.7 | -22.2 | 8.1 |
| Coimbra | São João de Almedina | 12th-15th | SJA1 | Christian | Rib | F | Adult | 60-65 | 7.7 | 41.5 | 15.3 | 3.2 | -16.7 | 10.8 |
| Coimbra | São João de Almedina | 12th-15th | SJA11 | Christian | Rib | F | Adult | 55-65 | 5.1 | 32.6 | 11.9 | 3.2 | -15.7 | 10.5 |
| Coimbra | São João de Almedina | 12th-15th | SJA12 | Christian | Rib | F | Adult | 45-50 | 1.7 | 21.7 | 8.0 | 3.2 | -14.8 | 9.8 |
| Coimbra | São João de Almedina | 12th-15th | SJA15 | Christian | Rib | F | Adult | 40-50 | 5.2 | 42.5 | 15.5 | 3.2 | -19.2 | 10.5 |
| Coimbra | São João de Almedina | 12th-15th | SJA20 | Christian | Rib | F | Adult | 60-70 | 3.5 | 29.8 | 10.4 | 3.3 | -15.7 | 9.3 |
| Coimbra | São João de Almedina | 12th-15th | SJA26B | Christian | Rib | F | Adult | 40-50 | 5.4 | 27.7 | 10.2 | 3.2 | -15.8 | 9.8 |
| Coimbra | São João de Almedina | 12th-15th | SJA5A | Christian | Rib | F | Adult | 60-70 | 1.2 | 36.1 | 12.7 | 3.2 | -14.3 | 10.6 |
| Coimbra | São João de Almedina | 12th-15th | SJA6 | Christian | Rib | F | Adult | 55-65 | 2.1 | 39.4 | 14.0 | 3.3 | -16.0 | 10.7 |
| Coimbra | São João de Almedina | 12th-15th | SJA14 | Christian | Rib | M | Adult | 40-50 | 4.5 | 34.1 | 12.6 | 3.2 | -17.7 | 9.1 |
| Coimbra | São João de Almedina | 12th-15th | SJA19 | Christian | Rib | M | Adult | 35-49 | 3.2 | 37.1 | 13.4 | 3.2 | -17.3 | 8.3 |
| Coimbra | São João de Almedina | 12th-15th | SJA2 | Christian | Rib | M | Adult | 55-65 | 4.4 | 26.7 | 9.7 | 3.2 | -18.5 | 9.8 |
| Coimbra | São João de Almedina | 12th-15th | SJA21 | Christian | Rib | M | Adult | 45-55 | 2.1 | 25.4 | 8.9 | 3.3 | -17.3 | 10.3 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coimbra | São João de Almedina | 12th-15th | SJA23 | Christian | Rib | M | Adult | 35-50 | 1.5 | 39.3 | 14.0 | 3.3 | -16.9 | 10.8 |
| Coimbra | São João de Almedina | 12th-15th | SJA24 | Christian | Rib | M | Adult | 50-60 | 2.5 | 28.9 | 10.6 | 3.2 | -17.4 | 9.5 |
| Coimbra | São João de Almedina | 12th-15th | SJA3 | Christian | Rib | M | Adult | 45-60 | 2.9 | 29.0 | 10.1 | 3.4 | -18.3 | 10.7 |
| Coimbra | São João de Almedina | 12th-15th | SJA7 | Christian | Rib | M | Adult | 45-60 | 3.0 | 27.9 | 9.6 | 3.4 | -17.7 | 11.0 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS12PC | Muslim | Rib | F | Adult | 17-27 | 0.6 | 32.1 | 11.7 | 3.2 | -18.9 | 9.9 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS14PC | Muslim | Rib | F | Adult | 55 | 1.3 | 43.3 | 15.4 | 3.3 | -18.5 | 9.6 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS16PC | Muslim | Rib | F | Adult | 40-44 | 5.6 | 43.4 | 15.8 | 3.2 | -18.9 | 9.4 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS19PC | Muslim | Rib | F | Adult | 30-34 | 1.9 | 42.9 | 15.6 | 3.2 | -18.9 | 8.7 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS2PN | Muslim | Rib | F | Adult | 19-35 | 2.9 | 42.5 | 15.5 | 3.2 | -18.7 | 9.4 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS7PC | Muslim | Rib | F | Adult | 17-27 | 1.0 | 37.7 | 13.9 | 3.2 | -19.1 | 9.3 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS1PC | Muslim | Rib | M | Adult | 20-34 | 4.0 | 42.9 | 15.8 | 3.2 | -18.7 | 11.2 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS1PN | Muslim | Rib | M | Adult | 30-34 | 0.7 | 37.9 | 13.7 | 3.2 | -18.8 | 11.2 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS8PC | Muslim | Rib | M | Adult | 22 | 1.9 | 40.4 | 14.7 | 3.2 | -19.4 | 10.0 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS2PC | Muslim | Rib | U | Adult | 20-23 | 0.1 | 42.4 | 15.1 | 3.3 | -18.8 | 9.9 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Castelo de São Jorge | 10th-11th | CAS11PC | Muslim | Rib | U | Juvenile | 13-14 | 7.4 | 44.5 | 16.4 | 3.2 | -18.5 | 8.8 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS11PN | Muslim | Rib | U | Juvenile | 0-2 m | 2.1 | 42.1 | 14.5 | 3.4 | -18.6 | 11.3 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS12PN | Muslim | Right femur | U | Juvenile | 0-1 m | 1.2 | 40.9 | 14.4 | 3.3 | -17.6 | 10.4 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS13PC | Muslim | Rib | U | Juvenile | 9-14 m | 3.0 | 41.7 | 15.0 | 3.2 | -18.0 | 13.1 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS13PN | Muslim | Rib | U | Juvenile | 8-9 m | 1.5 | 33.7 | 12.2 | 3.2 | -18.2 | 11.8 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS14PN | Muslim | Left femur | U | Juvenile | 0-1 m | 3.1 | 42.8 | 15.7 | 3.2 | -17.8 | 11.0 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS15PN | Muslim | Right tibia | U | Juvenile | 0-4 m | 1.3 | 34.9 | 12.4 | 3.3 | -17.9 | 10.5 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS17PC | Muslim | Rib | U | Juvenile | 20-32 m | 3.6 | 41.2 | 15.1 | 3.2 | -18.4 | 10.9 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS10PN | Muslim | Right humerus | U | Juvenile | 0-2 m | 1.4 | 41.9 | 15.1 | 3.2 | -18.7 | 10.1 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS3PC | Muslim | Rib | U | Juvenile | 5 | 3.8 | 44.7 | 16.2 | 3.2 | -18.1 | 10.5 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS4PC | Muslim | Rib | U | Juvenile | 18-30 m | 4.1 | 44.9 | 16.4 | 3.2 | -18.2 | 10.8 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS4PN | Muslim | Rib | U | Juvenile | 22-24 m | 4.8 | 45.1 | 16.4 | 3.2 | -18.4 | 9.4 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS5PC | Muslim | Rib | U | Juvenile | 15-18 | 7.8 | 44.6 | 16.4 | 3.2 | -18.8 | 9.2 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS5PN | Muslim | Rib | U | Juvenile | 12-13 | 2.5 | 42.9 | 15.5 | 3.2 | -17.3 | 10.4 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Castelo de São Jorge | 10th-11th | CAS6PN | Muslim | Rib | U | Juvenile | 1-3 | 3.2 | 39.4 | 14.5 | 3.2 | -18.1 | 12.2 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS7PN | Muslim | Right tibia | U | Juvenile | 3-5 m | 2.7 | 40.3 | 14.3 | 3.3 | -16.5 | 11.4 |
| Lisbon | Castelo de São Jorge | 10th-11th | CAS8PN | Muslim | Rib | U | Juvenile | 3-27 m | 2.6 | 43.4 | 15.6 | 3.3 | -17.8 | 12.5 |
| Lisbon | Calcadinha do Tijolo | 10th-11th | CDT409 | Muslim | Rib | F | Adult | | 5.9 | 44.9 | 16.5 | 3.2 | -18.6 | 9.6 |
| Lisbon | Calcadinha do Tijolo | 10th-11th | CDT425 | Muslim | Fibula | F | Adult | | 3.5 | 39.8 | 14.3 | 3.3 | -18.7 | 10.0 |
| Lisbon | Calcadinha do Tijolo | 10th-11th | CDT421 | Muslim | Rib | M | Adult | | 2.5 | 41.3 | 15.0 | 3.2 | -18.7 | 9.3 |
| Lisbon | Calcadinha do Tijolo | 10th-11th | CDT410 | Muslim | Rib | U | Adult | | 2.7 | 38.6 | 14.0 | 3.2 | -18.9 | 9.6 |
| Lisbon | Calcadinha do Tijolo | 10th-11th | CDT418 | Muslim | Rib | U | Juvenile | 9-10 | 2.3 | 37.8 | 13.6 | 3.2 | -18.6 | 9.3 |
| Lisbon | Largo das Olarias | 12th-15th | BOL 818 | Islamic | Rib | F | Adult | | 30.0 | 36.7 | 13.2 | 3.2 | -18.5 | 8.4 |
| Lisbon | Largo das Olarias | 12th-15th | BOL 824 | Islamic | Rib | F | Adult | | 25.4 | 34.9 | 11.7 | 3.2 | -18.6 | 11.0 |
| Lisbon | Largo das Olarias | 12th-15th | BOL815 | Islamic | Rib | F | Adult | | 28.0 | 36.9 | 13.5 | 3.2 | -18.9 | 9.5 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 1236 | Christian | Rib | F | Adult | | 10.0 | 30.6 | 10.4 | 3.4 | -18.7 | 11.4 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 1250 | Christian | Rib | F | Adult | | 8.4 | 23.3 | 8.6 | 3.2 | -18.1 | 10.2 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 1403 | Muslim | Rib | F | Adult | | 10.3 | 27.6 | 9.4 | 3.4 | -15.8 | 13.1 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Largo das Olarias | 12th-15th | LOL 1443 | Christian | Rib | F | Adult | | 14.8 | 41.6 | 15.1 | 3.2 | -17.7 | 10.8 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 24 | Christian | Rib | F | Adult | | 18.8 | 38.4 | 13.9 | 3.2 | -18.8 | 11.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 29 | Christian | Rib | F | Adult | | 17.1 | 31.4 | 10.9 | 3.4 | -18.0 | 10.9 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 65 | Christian | Rib | F | Adult | | 11.0 | 31.4 | 10.8 | 3.3 | -17.4 | 10.5 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1069 | Christian | Rib | F | Adult | | 26.5 | 36.0 | 12.8 | 3.3 | -19.9 | 6.1 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1219 | Christian | Rib | F | Adult | | 18.5 | 33.0 | 11.9 | 3.2 | -18.8 | 9.1 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1244 | Christian | Rib | F | Adult | | 28.8 | 32.5 | 11.6 | 3.3 | -18.9 | 9.6 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1585 | Muslim | Rib | F | Adult | | 28.4 | 33.0 | 11.9 | 3.2 | -18.4 | 10.4 |
| Lisbon | Largo das Olarias | 12th-15th | LOL18 | Muslim | Rib | F | Adult | | 37.1 | 39.0 | 14.2 | 3.2 | -18.4 | 10.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL422 | Islamic | Rib | F | Adult | | 10.5 | 29.9 | 10.9 | 3.2 | -18.6 | 11.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL629 | Islamic | Rib | F | Adult | | 5.9 | 30.1 | 10.8 | 3.3 | -19.0 | 10.2 |
| Lisbon | Largo das Olarias | 12th-15th | BOL 933 | Islamic | Rib | M | Adult | | 12.1 | 32.8 | 11.5 | 3.4 | -18.8 | 10.1 |
| Lisbon | Largo das Olarias | 12th-15th | BOL 942 | Islamic | Rib | M | Adult | | 10.0 | 30.5 | 11.0 | 3.2 | -19.0 | 9.3 |
| Lisbon | Largo das Olarias | 12th-15th | BOL 943 | Islamic | Rib | M | Adult | | 12.0 | 18.5 | 6.9 | 3.1 | -19.1 | 9.0 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Largo das Olarias | 12th-15th | LOL 1224 | Christian | Rib | M | Adult |  | 14.4 | 35.0 | 12.6 | 3.2 | -18.5 | 10.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 71 | Christian | Rib | M | Adult |  | 33.9 | 39.2 | 13.9 | 3.3 | -17.9 | 11.2 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 74 | Christian | Rib | M | Adult |  | 22.8 | 33.8 | 12.0 | 3.3 | -15.3 | 12.7 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1066 | Muslim | Rib | M | Adult |  | 25.9 | 35.0 | 12.6 | 3.2 | -18.5 | 11.5 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1091 | Christian | Rib | M | Adult |  | 20.0 | 36.0 | 12.6 | 3.3 | -19.1 | 10.2 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1187 | Muslim | Rib | M | Adult |  | 19.7 | 27.0 | 9.7 | 3.2 | -18.7 | 11.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1247 | Christian/Jews | Rib | M | Adult |  | 16.7 | 30.5 | 11.0 | 3.2 | -18.5 | 10.6 |
| Lisbon | Largo das Olarias | 12th-15th | LOL1477 | Muslim | Rib | M | Adult |  | 21.5 | 35.6 | 12.3 | 3.4 | -16.8 | 11.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL21 | Christian | Rib | M | Adult |  | 40.7 | 38.3 | 14.0 | 3.2 | -17.6 | 11.1 |
| Lisbon | Largo das Olarias | 12th-15th | LOL423 | Islamic | Rib | M | Adult |  | 36.5 | 43.2 | 15.8 | 3.2 | -18.3 | 11.3 |
| Lisbon | Largo das Olarias | 12th-15th | LOL437 | Islamic | Rib | M | Adult |  | 43.8 | 41.5 | 15.0 | 3.2 | -18.8 | 11.7 |
| Lisbon | Largo das Olarias | 12th-15th | LOL626 | Islamic | Rib | M | Adult |  | 27.1 | 41.6 | 15.3 | 3.2 | -15.6 | 12.1 |
| Lisbon | Largo das Olarias | 12th-15th | LOL 442 | Islamic | Rib | U | Adult |  | 5.3 | 26.6 | 9.6 | 3.2 | -18.4 | 11.8 |
| Lisbon | Quarteirao dos Lagares | 12th-15th | QDL131 | Islamic | Right fibula | F | Adult |  | 31.7 | 34.0 | 12.1 | 3.3 | -17.2 | 10.0 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Quarteirao dos Lagares | 12th-15th | QDL124 | Islamic | Right femur | F | Adult | | 26.0 | 36.1 | 13.3 | 3.1 | -19.3 | 11.3 |
| Lisbon | Quarteirao dos Lagares | 12th-15th | QDL104 | Islamic | Rib | F | Adult | | 27.9 | 39.5 | 14.4 | 3.2 | -8.2 | 9.5 |
| Lisbon | Quarteirao dos Lagares | 12th-15th | QDL102 | Islamic | Right femur | U | Juvenile | 11-12 | 27.4 | 33.4 | 12.2 | 3.2 | -19.0 | 10.2 |
| Lisbon | Quarteirao dos Lagares | 12th-15th | QDL 134 | Islamic | Right femur | U | Juvenile | 6-8 | 33.8 | 40.3 | 14.8 | 3.2 | -16.6 | 10.8 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF6 | Islamic | Rib | F | Adult | 25+ | 2.9 | 34.5 | 12.2 | 3.3 | -16.9 | 10.8 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF10 | Islamic | Rib | F | Adult | 29+ | 5.0 | 40.4 | 14.5 | 3.2 | -17.6 | 10.4 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF12 | Islamic | Rib | F | Adult | 29+ | 6.0 | 38.6 | 13.5 | 3.3 | -17.9 | 9.9 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF19 | Islamic | Rib | U | Adult | 14-19 | 2.5 | 13.6 | 4.3 | 3.6 | -16.6 | 10.4 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF13 | Islamic | Rib | U | Juvenile | 8-9 | 7.4 | 41.1 | 14.9 | 3.2 | -18.8 | 10.3 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF16 | Islamic | Left tibia | U | Juvenile | 38-40 w | 5.0 | 26.6 | 9.5 | 3.3 | -17.5 | 11.9 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF3 | Islamic | Right femur | U | Juvenile | 5-6 | 5.8 | 39.6 | 14.1 | 3.3 | -19.0 | 9.4 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF9 | Islamic | Right rib | U | Juvenile | 9-10 | 4.6 | 42.0 | 15.1 | 3.3 | -17.2 | 10.0 |
| Setubal | Rua F. A. Flamengo | 980-1150* | FAF17 | Islamic | Right femur | U | Juvenile | 36-40 w | 5.6 | 38.2 | 13.6 | 3.3 | -17.6 | 11.8 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3040 | Christian | Right tibia | F | Adult | | 5.3 | 37.4 | 13.2 | 3.4 | -18.9 | 11.4 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beja | E.S. Diogo Gouveia | 1283-1391* | BEJ3083 | Christian | Rib | F | Adult |  | 2.2 | 34.1 | 12.3 | 3.2 | -18.4 | 13.0 |
| Beja | E.S. Diogo Gouveia | 1300-1405* | BEJ3102 | Christian | Right femur | F | Adult |  | 2.1 | 32.4 | 11.7 | 3.2 | -18.3 | 12.0 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3190 | Christian | Rib | F | Adult |  | 5.3 | 41.0 | 14.7 | 3.2 | -18.0 | 12.1 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ4016 | Christian | Rib | F | Adult |  | 2.8 | 40.1 | 14.5 | 3.2 | -18.5 | 11.5 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ6115 | Christian | Rib | F | Adult |  | 2.7 | 41.7 | 14.6 | 3.3 | -19.2 | 10.8 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ1125 | Christian | Rib | M | Adult |  | 1.3 | 41.0 | 14.7 | 3.2 | -18.1 | 11.5 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3113 | Christian | Rib | M | Adult |  | 1.2 | 43.6 | 15.6 | 3.3 | -18.3 | 11.9 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3164 | Christian | Rib | M | Adult |  | 2.3 | 37.3 | 13.4 | 3.2 | -17.7 | 12.2 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3263 | Christian | Rib | M | Adult |  | 2.7 | 41.9 | 15.4 | 3.2 | -18.3 | 10.8 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3043 | Christian | Left femur | U | Adult |  | 1.7 | 21.1 | 7.7 | 3.2 | -19.8 | 9.0 |
| Beja | E.S. Diogo Gouveia | 1268-1383* | BEJ3259 | Christian | Rib | U | Adult |  | 5.8 | 40.0 | 14.4 | 3.2 | -18.2 | 12.1 |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ4019 | Christian | Rib | U | Adult |  | 2.1 | 26.5 | 9.5 | 3.3 | -18.3 | 12.2 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6177 | Muslim | Rib | F | Adult |  | 1.0 | 22.1 | 7.9 | 3.3 | -19.1 | 11.2 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3176 | Muslim | Rib | F | Adult |  | 3.5 | 41.9 | 15.2 | 3.2 | -19.1 | 10.5 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7047 | Muslim | Rib | F | Adult |  | 2.9 | 43.4 | 15.7 | 3.2 | -19.2 | 10.5 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7125 | Muslim | Rib | F | Adult |  | 1.6 | 41.9 | 15.2 | 3.2 | -19.1 | 10.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7243 | Muslim | Rib | F | Adult |  | 3.2 | 42.7 | 15.6 | 3.2 | -19.1 | 9.9 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1059 | Muslim | Rib | F | Adult |  | 1.5 | 37.5 | 13.8 | 3.2 | -19.0 | 10.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3180 | Muslim | Rib | F | Adult |  | 3.3 | 41.6 | 15.0 | 3.2 | -19.4 | 10.0 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7061 | Muslim | Rib | F | Adult |  | 2.6 | 39.6 | 14.4 | 3.2 | -19.2 | 9.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7143 | Muslim | Rib | F | Adult |  | 5.5 | 24.6 | 8.9 | 3.1 | -18.6 | 10.9 |
| Beja | E.S. Diogo Gouveia | 770-936* | BEJ7278 | Muslim | Rib | F | Adult |  | 5.1 | 42.5 | 15.4 | 3.2 | -19.4 | 12.9 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3282 | Muslim | Rib | F | Adult |  | 2.8 | 39.6 | 14.5 | 3.2 | -19.0 | 10.3 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7094 | Muslim | Right humerus | F | Adult |  | 2.3 | 39.5 | 14.4 | 3.2 | -19.2 | 9.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7010 | Muslim | Rib | F | Adult |  | 0.4 | 26.6 | 9.7 | 3.2 | -19.0 | 9.9 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1065 | Muslim | Rib | F | Adult |  | 1.2 | 41.3 | 14.9 | 3.2 | -19.0 | 10.1 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1081 | Muslim | Rib | F | Adult |  | 3.5 | 41.0 | 15.0 | 3.2 | -19.3 | 10.1 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1092 | Muslim | Rib | F | Adult |  | 2.6 | 42.2 | 15.3 | 3.3 | -19.1 | 11.1 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1096 | Muslim | Rib | F | Adult |  | 0.8 | 34.5 | 12.1 | 3.4 | -19.1 | 10.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ701 | Muslim | Rib | F | Adult |  | 4.6 | 42.3 | 15.4 | 3.2 | -19.0 | 9.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1150 | Muslim | Rib | F | Adult |  | 4.5 | 35.3 | 12.5 | 3.3 | -18.7 | 9.6 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6087 | Muslim | Right tibia | F | Adult |  | 6.6 | 35.5 | 12.9 | 3.2 | -18.7 | 9.5 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3157 | Muslim | Rib | F | Adult |  | 5.0 | 41.9 | 14.0 | 3.8 | -19.7 | 9.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1053 | Muslim | Left femur | M | Adult |  | 2.7 | 44.8 | 16.3 | 3.2 | -18.8 | 10.4 |
| Beja | E.S. Diogo Gouveia | 1016-1153* | BEJ3207 | Muslim | Rib | M | Adult |  | 5.3 | 42.0 | 15.2 | 3.2 | -19.2 | 9.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7006 | Muslim | Rib | M | Adult |  | 3.3 | 45.4 | 16.5 | 3.2 | -18.9 | 9.1 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7173 | Muslim | Rib | M | Adult |  | 4.6 | 40.3 | 14.8 | 3.2 | -18.7 | 10.3 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7311 | Muslim | Rib | M | Adult |  | 1.8 | 43.1 | 15.6 | 3.2 | -19.3 | 10.2 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3024 | Muslim | Rib | M | Adult |  | 2.2 | 37.6 | 13.7 | 3.2 | -19.1 | 11.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3144 | Muslim | Rib | M | Adult |  | 1.2 | 39.2 | 14.2 | 3.2 | -18.8 | 10.4 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1056 | Muslim | Rib | M | Adult |  | -0.1 | 34.1 | 12.1 | 3.3 | -18.7 | 10.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6279 | Muslim | Rib | M | Adult |  | 2.1 | 37.9 | 14.0 | 3.2 | -19.1 | 10.1 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1026 | Muslim | Rib | M | Adult |  | 0.7 | 38.9 | 14.1 | 3.2 | -19.3 | 10.2 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1084 | Muslim | Rib | M | Adult |  | 3.8 | 42.1 | 15.4 | 3.2 | -18.9 | 11.0 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ606 | Muslim | Rib | M | Adult |  | 4.4 | 37.9 | 13.8 | 3.2 | -19.9 | 9.5 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6150 | Muslim | Rib | M | Adult |  | 3.9 | 35.8 | 13.0 | 3.2 | -18.9 | 9.5 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7031 | Muslim | Rib | M | Adult |  | 5.8 | 38.6 | 14.1 | 3.2 | -19.0 | 9.5 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7288 | Muslim | Rib | M | Adult |  | 1.5 | 25.1 | 9.1 | 3.2 | -19.4 | 11.6 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3200 | Muslim | Left fibula | M | Adult |  | 5.1 | 1.1 | 0.3 | 4.7 | -23.0 | 4.1 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6292 | Muslim | Rib | M | Adult |  | 3.1 | 29.6 | 10.4 | 3.3 | -19.0 | 9.8 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ1147 | Muslim | Rib | M | Adult |  | 1.4 | 39.9 | 14.0 | 3.3 | -19.4 | 9.9 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ7298 | Muslim | Left tibia | M | Adult |  | 1.2 | 15.1 | 5.3 | 3.3 | -19.0 | 10.7 |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ6248 | Muslim | Right tibia | U | Adult |  | 3.8 | 38.4 | 13.9 | 3.2 | -19.0 | 10.0 |
| Silves | Largo da Sé | 13th-15th | LSE28 | Christian | Rib | F | Adult |  | 2.0 | 22.0 | 7.9 | 3.2 | -18.5 | 10.9 |
| Silves | Largo da Sé | 13th-15th | LSE3 | Christian | Right fibula | F | Adult |  | 5.2 | 35.1 | 12.7 | 3.2 | -18.0 | 11.0 |
| Silves | Largo da Sé | 13th-15th | LSE31 | Christian | Rib | F | Adult |  | 2.9 | 26.6 | 9.7 | 3.2 | -17.9 | 12.3 |
| Silves | Largo da Sé | 13th-15th | LSE9 | Christian | Rib | F | Adult |  | 3.4 | 37.4 | 13.5 | 3.2 | -17.8 | 11.8 |
| Silves | Largo da Sé | 13th-15th | LSE1 | Christian | Rib | F | Adult |  | 3.4 | 37.7 | 13.6 | 3.2 | -18.1 | 11.5 |
| Silves | Largo da Sé | 13th-15th | LSE17 | Christian | Rib | F | Adult |  | 3.1 | 28.7 | 10.4 | 3.3 | -18.2 | 11.2 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silves | Largo da Sé | 13th-15th | LSE11 | Christian | Rib | F | Adult |  | 1.3 | 29.5 | 10.6 | 3.3 | -18.1 | 10.2 |
| Silves | Largo da Sé | 13th-15th | LSE33 | Christian | Rib | F | Adult |  | 3.6 | 40.8 | 14.8 | 3.2 | -17.6 | 10.6 |
| Silves | Largo da Sé | 13th-15th | LSE45 | Christian | Rib | F | Adult |  | 1.0 | 31.4 | 10.8 | 3.4 | -18.3 | 11.0 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB46 | Christian | Rib | F | Adult |  | 1.7 | 39.2 | 14.0 | 3.3 | -17.8 | 12.3 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB43 | Christian | Rib | F | Adult |  | 2.2 | 39.3 | 14.1 | 3.3 | -18.3 | 11.1 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB61 | Christian | Rib | F | Adult |  | 2.3 | 34.0 | 12.1 | 3.3 | -18.6 | 10.2 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB65 | Christian | Rib | F | Adult |  | 2.1 | 31.2 | 10.8 | 3.3 | -17.8 | 11.5 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB81 | Christian | Rib | F | Adult |  | 4.1 | 40.0 | 14.4 | 3.2 | -16.4 | 12.3 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB21 | Christian | Rib | F | Adult |  | 0.0 | 33.5 | 12.2 | 3.2 | -17.7 | 12.2 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB39 | Christian | Rib | F | Adult |  | 3.3 | 39.7 | 14.5 | 3.2 | -18.8 | 11.2 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB69 | Christian | Rib | F | Adult |  | 5.1 | 33.6 | 12.4 | 3.2 | -18.0 | 10.3 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB10B | Christian | Rib | F | Adult |  | 3.4 | 21.3 | 7.9 | 3.1 | -17.7 | 11.2 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB26 | Christian | Rib | F | Adult |  | 3.2 | 36.0 | 13.1 | 3.2 | -18.9 | 10.5 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB66 | Christian | Rib | F | Adult |  | 2.0 | 28.9 | 10.3 | 3.3 | -18.0 | 11.5 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB68 | Christian | Rib | F | Adult |  | 3.9 | 33.6 | 12.2 | 3.2 | -18.4 | 10.8 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silves | Rua Miguel Bombarda | 13th-15th | RMB8 | Christian | Rib | F | Adult | | 6.4 | 41.8 | 15.3 | 3.2 | -18.1 | 10.2 |
| Silves | Largo da Sé | 13th-15th | LSE4 | Christian | Rib | M | Adult | | | 32.0 | 11.6 | 3.2 | -17.8 | 12.0 |
| Silves | Largo da Sé | 13th-15th | LSE40 | Christian | Rib | M | Adult | | 2.3 | 37.3 | 13.3 | 3.2 | -17.6 | 12.6 |
| Silves | Largo da Sé | 13th-15th | LSE5 | Christian | Rib | M | Adult | | 3.7 | 25.7 | 9.3 | 3.2 | -18.1 | 12.3 |
| Silves | Largo da Sé | 13th-15th | LSE18 | Christian | Rib | M | Adult | | 3.0 | 29.1 | 10.7 | 3.2 | -17.6 | 12.2 |
| Silves | Largo da Sé | 13th-15th | LSE2 | Christian | Rib | M | Adult | | 4.1 | 35.2 | 11.9 | 3.2 | -17.2 | 13.0 |
| Silves | Largo da Sé | 13th-15th | LSE26 | Christian | Rib | M | Adult | | 3.0 | 39.0 | 14.0 | 3.2 | -18.2 | 11.4 |
| Silves | Largo da Sé | 13th-15th | LSE34 | Christian | Left fibula | M | Adult | | 2.8 | 27.0 | 9.8 | 3.2 | -16.4 | 13.5 |
| Silves | Largo da Sé | 13th-15th | LSE44 | Christian | Rib | M | Adult | | 2.9 | 25.7 | 9.3 | 3.2 | -18.3 | 11.1 |
| Silves | Largo da Sé | 13th-15th | LSE70 | Christian | Rib | M | Adult | | 2.8 | 24.9 | 9.0 | 3.2 | -17.0 | 13.4 |
| Silves | Largo da Sé | 13th-15th | LSE59 | Christian | Rib | M | Adult | | 3.8 | 28.9 | 10.5 | 3.2 | -18.3 | 11.3 |
| Silves | Largo da Sé | 13th-15th | LSE32 | Christian | Rib | M | Adult | | 6.0 | 35.4 | 13.0 | 3.2 | -18.2 | 10.3 |
| Silves | Largo da Sé | 13th-15th | LSE10 | Christian | Rib | M | Adult | | 2.4 | 32.4 | 11.5 | 3.3 | -15.5 | 9.4 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB11B | Christian | Rib | M | Adult | | 2.5 | 30.2 | 10.6 | 3.3 | -12.5 | 10.7 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB12B | Christian | Rib | M | Adult | | 1.9 | 34.6 | 12.2 | 3.3 | -18.0 | 10.7 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB4B | Christian | Rib | M | Adult | | 2.4 | 32.8 | 11.4 | 3.3 | -17.9 | 10.9 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB5B | Christian | Rib | M | Adult | | 2.2 | 27.5 | 9.6 | 3.3 | -17.4 | 11.3 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB8B | Christian | Fibula | M | Adult | | 1.1 | 13.0 | 4.2 | 3.6 | -18.9 | 9.5 |
| Silves | Rua Miguel Bombarda | 13th-15th | RMB6B | Christian | Femur | M | Adult | | 1.9 | 18.7 | 6.9 | 3.2 | -18.3 | 10.6 |
| Silves | Rua 25 Abril | 11th-13th | R25A 10 | Islamic | Rib | F | Adult | | 0.9 | 43.4 | 15.8 | 3.2 | -18.9 | 10.6 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silves | Rua 25 Abril | 11th-13th | R25A 47 | Islamic | Rib | F | Adult | | 2.0 | 32.0 | 11.3 | 3.3 | -19.2 | 10.0 |
| Silves | Rua 25 Abril | 11th-13th | R25A 56 | Islamic | Rib | F | Adult | | 2.5 | 26.6 | 9.5 | 3.3 | -18.0 | 10.9 |
| Silves | Rua 25 Abril | 11th-13th | R25A 62 | Islamic | Rib | F | Adult | | 2.5 | 32.6 | 11.7 | 3.2 | -18.5 | 11.2 |
| Silves | Rua 25 Abril | 11th-13th | R25A 80 | Islamic | Rib | F | Adult | | 2.8 | 25.5 | 8.9 | 3.4 | -18.4 | 9.4 |
| Silves | Rua A | 11th-13th | RA13 | Islamic | Rib | F | Adult | | 2.0 | 30.6 | 11.2 | 3.2 | -18.6 | 11.6 |
| Silves | Rua 25 Abril | 11th-13th | R25A 22 | Islamic | Rib | M | Adult | | 1.6 | 30.0 | 10.7 | 3.3 | -18.7 | 13.7 |
| Silves | Rua 25 Abril | 11th-13th | R25A 78 | Islamic | Rib | M | Adult | | 1.7 | 32.5 | 11.8 | 3.2 | -17.7 | 12.8 |
| Silves | Rua 25 Abril | 11th-13th | R25A 30 | Islamic | Rib | M | Adult | | 0.3 | 41.9 | 15.1 | 3.2 | -19.1 | 11.0 |
| Silves | Rua 25 Abril | 11th-13th | R25A 26 | Islamic | Rib | M | Adult | | 1.3 | 37.5 | 13.4 | 3.3 | -19.1 | 9.6 |
| Silves | Rua 25 Abril | 11th-13th | R25A 37 | Islamic | Rib | M | Adult | | 1.4 | 15.4 | 5.4 | 3.3 | -18.9 | 12.4 |
| Silves | Rua 25 Abril | 11th-13th | R25A 5 | Islamic | Rib | M | Adult | | 4.6 | 26.6 | 9.8 | 3.2 | -18.6 | 10.8 |
| Silves | Rua 25 Abril | 11th-13th | R25A 73 | Islamic | Rib | M | Adult | | 2.2 | 15.8 | 5.8 | 3.3 | -18.2 | 12.3 |
| Silves | Rua 25 Abril | 11th-13th | R25A 18 | Islamic | Rib | M | Adult | | 1.0 | 27.2 | 9.6 | 3.3 | -19.0 | 11.1 |
| Silves | Rua 25 Abril | 11th-13th | R25A 87 | Islamic | Rib | M | Adult | | 1.7 | 31.1 | 11.4 | 3.2 | -18.0 | 12.2 |
| Silves | Rua 25 Abril | 11th-13th | R25A 17 | Islamic | Rib | M | Adult | | 2.4 | 35.8 | 12.8 | 3.3 | -18.7 | 11.0 |
| Silves | Rua 25 Abril | 11th-13th | R25A 74 | Islamic | Rib | M | Adult | | 3.0 | 35.1 | 12.5 | 3.3 | -18.5 | 9.8 |
| Silves | Rua 25 Abril | 11th-13th | R25A 86 | Islamic | Rib | M | Adult | | 1.6 | 24.7 | 8.7 | 3.3 | -18.7 | 10.1 |
| Silves | Rua 25 Abril | 11th-13th | R25A 25 | Islamic | Rib | M | Adult | | 3.0 | 34.7 | 12.5 | 3.3 | -18.6 | 11.4 |
| Silves | Rua 25 Abril | 11th-13th | R25A 29 | Islamic | Rib | M | Adult | | 2.5 | 26.1 | 9.2 | 3.3 | -18.8 | 11.2 |
| Silves | Rua 25 Abril | 11th-13th | R25A 33 | Islamic | Rib | M | Adult | | 3.2 | 34.8 | 12.5 | 3.2 | -18.4 | 11.3 |
| Silves | Rua 25 Abril | 11th-13th | R25A 76 | Islamic | Rib | M | Adult | | 2.1 | 31.3 | 11.1 | 3.3 | -18.1 | 11.0 |
| Silves | Rua 25 Abril | 11th-13th | R25A 9 | Islamic | Rib | M | Adult | | 3.0 | 24.1 | 8.4 | 3.4 | -19.1 | 9.9 |
| Silves | Rua A | 11th-13th | RA15 | Islamic | Rib | M | Adult | | 1.1 | 32.2 | 11.6 | 3.2 | -19.1 | 9.9 |
| Silves | Rua A | 11th-13th | RA9 | Islamic | Rib | M | Adult | | 3.6 | 31.6 | 11.5 | 3.2 | -18.7 | 12.0 |
| Loulé | Quinta do Lago | 11th-13th | LU45a | Islamic | Left humerus | M | Adult | | 4.3 | 25.2 | 9.1 | 3.3 | -19.3 | 9.7 |

| Location | Site | Period (centuries) | Sample No. | Faith | Element | Sex | Age | Estimated age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loulé | Quinta do Lago | 11th-13th | LU65 | Islamic | Rib | M | Adult |  | 4.7 | 35.4 | 12.8 | 3.2 | -17.9 | 11.2 |
| Loulé | Quinta do Lago | 11th-13th | LU71 | Islamic | Rib | M | Adult |  | 2.3 | 25.4 | 8.3 | 3.6 | -16.4 | 11.3 |
| Loulé | Quinta do Lago | 11th-13th | LU45b | Islamic | Rib | M | Adult |  | 3.5 | 32.7 | 11.1 | 3.4 | -18.0 | 10.0 |
| Loulé | Quinta do Lago | 11th-13th | LU59 | Islamic | Tibia | U | Juvenile | 6 m | 5.7 | 35.5 | 12.0 | 3.4 | -16.3 | 14.1 |
| Loulé | Quinta do Lago | 11th-13th | LU48 | Islamic | Rib | U | Juvenile | 18 -24 m | 5.6 | 41.5 | 14.7 | 3.3 | -18.5 | 13.7 |
| Loulé | Quinta do Lago | 11th-13th | LU47 | Islamic | Rib | U | Juvenile | 3-5 | 4.1 | 37.3 | 12.9 | 3.3 | -17.7 | 12.7 |
| Loulé | Quinta do Lago | 11th-13th | LU62 | Islamic | Rib | U | Juvenile | 3-5 | 7.4 | 35.8 | 12.9 | 3.3 | -17.5 | 11.6 |
| Loulé | Quinta do Lago | 11th-13th | LU66b | Islamic | Rib | U | Juvenile | 4-5 | 3.2 | 31.6 | 10.9 | 3.4 | -17.4 | 11.5 |
| Loulé | Quinta do Lago | 11th-13th | LU63 | Islamic | Rib | U | Juvenile | 5-6 | 3.1 | 36.2 | 12.8 | 3.3 | -17.2 | 11.8 |

## B.2: Samples rejected from the dataset

| Location | Site | Period (centuries) | Sample No. | Faith | Sex | Age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ | Reason |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bragança | Laranjal | 10th-14th | LAR107 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR107 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR126 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR135 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR154 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR33 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR38 | Christian | F | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR96 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR134 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR136 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR145 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR168 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR29 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR34 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Bragança | Laranjal | 10th-14th | LAR44 | Christian | M | Adult | - | - | - | - | - | - | No collagen |
| Coimbra | São João de Almedina | 12th-15th | SJA10 | Christian | F | Adult | 0.4 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Coimbra | São João de Almedina | 12th-15th | SJA22 | Christian | F | Adult | 1.7 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Coimbra | São João de Almedina | 12th-15th | SJA9 | Christian | M | Adult | 1.1 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |

| Location | Site | Period (centuries) | Sample No. | Faith | Sex | Age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ | Reason |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | São Jorge Castle | 10th-11th | CAS20PC | Muslim | U | Juvenile | 0.2 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL942 | Muslim | M | Adult | 1.3 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL430 | Muslim | F | Adult | 2 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL1086 | Muslim | U | Juvenile | 3.9 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL1241 | Muslim | U | Juvenile | 6 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL1563 | Christian | F | Adult | 9 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL1008 | Muslim | F | Adult | 1.4 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL1005 | Muslim | M | Adult | 0.1 | - | - | - | - | - | No collagen |
| Lisbon | Largo das Olarias | 12th-15th | LOL1232 | Muslim | M | Adult | 2.5 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Lisbon | Largo das Olarias | 12th-15th | LOL62 | Muslim | M | Adult | 5.2 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |

| Location | Site | Period (centuries) | Sample No. | Faith | Sex | Age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ | Reason |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Largo das Olarias | 12th-15th | LOL59 | Muslim | M | Adult | 0.1 | - | - | - | - | - | No collagen |
| Lisbon | Largo das Olarias | 12th-15th | LOL936 | Muslim | U | Adult | 2.6 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF11 | Muslim | U | Adult | 2.6 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF7 | Muslim | M | Adult | 3.7 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF14 | Muslim | U | Adult | 0.9 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF5 | Muslim | F | Adult | 1.0 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF1 | Muslim | M | Adult | 0.4 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF8 | Muslim | F | Adult | 0.4 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF18 | Muslim | U | Adult | 1.8 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF11 | Muslim | U | Adult | 0.0 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF2 | Muslim | F | Adult | 1.3 | - | - | - | - | - | No collagen |
| Setubal | Rua F.A. Flamengo | 980-1150* | FAF4 | Muslim | U | Juvenile | 3.1 | - | - | - | - | - | Replication error - large differences in C:N ratio between repeat analysis |
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3099 | Christian | F | Adult | 0.3 | - | - | - | - | - | No collagen |

| Location | Site | Period (centuries) | Sample No. | Faith | Sex | Age | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ | Reason |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beja | E.S. Diogo Gouveia | 13th-15th | BEJ3310 | Christian | F | Adult | 0.9 | - | - | - | - | - | No collagen |
| Beja | E.S. Diogo Gouveia | 8th-12th | BEJ3037 | Muslim | M | Adult | 0.6 | - | - | - | - | - | No collagen |
| Silves | Largo da Se | 13th-15th | LSE61 | Christian | U | Juvenile | 0.2 | - | - | - | - | - | No collagen |
| Silves | Rua A | 11th-13th | RA5 | Muslim | M | Adult | 0.3 | - | - | - | - | - | No collagen |

## B.3 Animal samples catalogue

### Catalogue codes:

**Yield (%)**= Percentage yield of collagen
**C/N**: atomic carbon/nitrogen ratio

**Elements:**

**Max=** Maxilla
**Man=**Mandible
**Sca=**Scapula
**Hum=**Humerus
**Rad=**Radius
**Uln=**Ulna
**Ver=**Vertebrae
**Ph=**Phalanx
**Fem=**Femur

**Tib=**Tibia
**Mec=**Metacarpal
**Met=**Metatarsal
**MP=**Metapodial
**Pel=**Pelvis
**Cal=**Calcaneus
**LB=** unidentified long bone

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | $\delta^{13}$C | $\delta^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bragança | Laranjal | 10th-14th | LAR304C | Christian | Hum | Cow | 12.8 | 37.9 | 13.4 | 3.3 | -20.6 | 5.6 |
| Bragança | Laranjal | 10th-14th | LAR318C | Christian | LB | Cow | 6.0 | 40.2 | 14.3 | 3.3 | -20.2 | 5.5 |
| Bragança | Laranjal | 10th-14th | LAR307 | Christian | MP | Cow | 4.7 | 42.4 | 15.5 | 3.2 | -20.2 | 6.0 |
| Bragança | Laranjal | 10th-14th | LAR308 | Christian | MP | Cow | 4.5 | 42.8 | 15.5 | 3.2 | -20.4 | 3.4 |
| Bragança | Laranjal | 10th-14th | LAR313 | Christian | LB | Cow | 3.3 | 42.7 | 15.6 | 3.2 | -19.6 | 6.6 |
| Bragança | Laranjal | 10th-14th | LAR319 | Christian | LB | Cow | 4.3 | 42.1 | 15.3 | 3.2 | -20.5 | 9.3 |
| Bragança | Laranjal | 10th-14th | LAR301 | Christian | LB | Chicken | 5.0 | 40.8 | 14.5 | 3.3 | -20.3 | 6.6 |
| Bragança | Laranjal | 10th-14th | LAR320CH | Christian | LB | Chicken | 4.3 | 37.9 | 13.7 | 3.2 | -20.2 | 9.9 |
| Bragança | Laranjal | 10th-14th | LAR302 | Christian | LB | Sheep | 3.6 | 41.2 | 15.0 | 3.2 | -20.6 | 6.7 |
| Bragança | Laranjal | 10th-14th | LAR314S | Christian | MP | Goat | 5.7 | 43.9 | 15.8 | 3.2 | -20.1 | 5.6 |
| Bragança | Laranjal | 10th-14th | LAR316S | Christian | MP | Goat | 3.2 | 40.2 | 14.4 | 3.3 | -19.9 | 5.0 |
| Bragança | Laranjal | 10th-14th | LAR305 | Christian | MP | Goat | 5.9 | 42.8 | 15.7 | 3.2 | -20.6 | 3.9 |
| Bragança | Laranjal | 10th-14th | LAR309 | Christian | MP | Goat | 4.3 | 40.3 | 14.6 | 3.2 | -19.7 | 4.4 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bragança | Laranjal | 10th-14th | LAR311 | Christian | MP | Goat | 2.0 | 42.3 | 15.4 | 3.2 | -19.3 | 4.3 |
| Bragança | Laranjal | 10th-14th | LAR303 | Christian | Hum | Sus | 5.0 | 41.8 | 15.2 | 3.2 | -20.8 | 7.4 |
| Bragança | Laranjal | 10th-14th | LAR310P | Christian | LB | Pig | 5.2 | 40.2 | 14.6 | 3.2 | -21.2 | 7.7 |
| Bragança | Laranjal | 10th-14th | LAR306 | Christian | LB | Pig | 4.0 | 41.3 | 14.7 | 3.3 | -20.1 | 6.7 |
| Bragança | Laranjal | 10th-14th | LAR312 | Christian | MP | Pig | 4.0 | 45.1 | 16.5 | 3.2 | -20.5 | 4.9 |
| Bragança | Laranjal | 10th-14th | LAR315 | Christian | Ph | Pig | 3.7 | 33.1 | 12.0 | 3.2 | -20.2 | 4.7 |
| Bragança | Laranjal | 10th-14th | LAR317P | Christian | LB | Pig | 3.8 | 35.2 | 12.2 | 3.4 | -20.7 | 7.4 |
| Coimbra | Criptoportico | 9th-11th | CPC 8 C | Christian | Ph | Cow | 4.3 | 37.2 | 13.6 | 3.2 | -20.8 | 5.6 |
| Coimbra | Criptoportico | 9th-11th | CPC 3 C | Christian | Ph | Cow | 6.5 | 39.7 | 14.5 | 3.2 | -20.8 | 5.0 |
| Coimbra | Criptoportico | 9th-11th | CPC 12 C | Christian | Ph | Cow | 2.7 | 38.4 | 13.9 | 3.3 | -21.8 | 6.5 |
| Coimbra | Criptoportico | 9th-11th | CPC 4 CH | Christian | Fem | Chicken | 2.3 | 39.1 | 13.9 | 3.3 | -16.7 | 8.3 |
| Coimbra | Criptoportico | 9th-11th | CPC 1 CH | Christian | Tib | Chicken | 2.6 | 38.5 | 13.6 | 3.3 | -16.4 | 8.1 |
| Coimbra | Criptoportico | 9th-11th | CPC 3 CH | Christian | Fem | Chicken | 9.5 | 40.3 | 14.6 | 3.2 | -12.6 | 9.0 |
| Coimbra | Criptoportico | 9th-11th | CPC 160 G | Christian | Rad | Goose | 5.9 | 43.6 | 15.7 | 3.3 | -21.1 | 10.4 |
| Coimbra | Criptoportico | 9th-11th | CPC 7 H | Christian | Pel | Horse | 6.0 | 32.4 | 11.9 | 3.2 | -22.2 | 1.7 |
| Coimbra | Criptoportico | 9th-11th | CPC 7 P | Christian | Cal | Pig | 2.7 | 37.7 | 13.5 | 3.3 | -21.5 | 6.4 |
| Coimbra | Criptoportico | 9th-11th | CPC 148 C | Christian | Rad | Pig | 7.7 | 38.7 | 14.2 | 3.2 | -20.8 | 7.8 |
| Coimbra | Criptoportico | 9th-11th | CPC 139 P | Christian | Mec | Pig | 6.1 | 40.4 | 14.7 | 3.2 | -22.1 | 8.9 |
| Coimbra | Criptoportico | 9th-11th | CPC 2 P | Christian | Cal | Pig | 3.4 | 34.9 | 12.5 | 3.3 | -21.6 | 5.3 |
| Coimbra | Criptoportico | 9th-11th | CPC 3 C | Christian | Met | Pig | 4.7 | 41.7 | 15.3 | 3.2 | -20.3 | 3.6 |
| Coimbra | Criptoportico | 9th-11th | CPC 3 S | Christian | Ph | Goat | 6.2 | 42.2 | 15.2 | 3.2 | -20.7 | 5.7 |
| Coimbra | Criptoportico | 9th-11th | CPC 6 S | Christian | Ph | Goat | 1.3 | 35.2 | 12.8 | 3.2 | -19.9 | 3.1 |
| Coimbra | Criptoportico | 9th-11th | CPC 5 S | Christian | Rad | Goat | 4.6 | 40.7 | 14.7 | 3.2 | -20.7 | 6.4 |
| Coimbra | Criptoportico | 9th-11th | CPC 198 S | Christian | Rad | Goat | 4.1 | 39.8 | 14.5 | 3.2 | -21.2 | 7.0 |
| Coimbra | Criptoportico | 9th-11th | CPC10 S | Christian | Cal | Goat | 4.7 | 40.4 | 14.7 | 3.2 | -20.1 | 4.9 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Praça da Figueira | 14th | 1173BB | Multi-faith | LB | Cat | 9.4 | 36.5 | 13.1 | 3.2 | -19.0 | 6.9 |
| Lisbon | Praça da Figueira | 12th | 1254B | Multi-faith | Fem | Cat | 7.5 | 44.0 | 16.1 | 3.2 | -18.5 | 8.9 |
| Lisbon | Praça da Figueira | 3rd-4th | 8204C | Multi-faith | Rib | Cow | 4.5 | 36.3 | 13.3 | 3.2 | -21.5 | 5.0 |
| Lisbon | Praça da Figueira | 3rd-4th | 8605C | Multi-faith | Sca | Cow | 1.1 | 26.1 | 9.3 | 3.3 | -20.3 | 5.4 |
| Lisbon | Praça da Figueira | 3rd-4th | 8584C | Multi-faith | Rib | Cow | 5.2 | 38.9 | 14.1 | 3.2 | -21.4 | 6.5 |
| Lisbon | Praça da Figueira | 3rd-4th | 8521C | Multi-faith | Ver | Cow | 3.0 | 33.7 | 12.2 | 3.2 | -21.3 | 5.7 |
| Lisbon | Praça da Figueira | 3rd-4th | 7500C | Multi-faith | Rib | Cow | 4.7 | 39.5 | 14.2 | 3.3 | -20.9 | 6.0 |
| Lisbon | Praça da Figueira | 3rd-4th | 4179C | Multi-faith | MP | Cow | 1.7 | 24.5 | 8.9 | 3.2 | -21.8 | 5.8 |
| Lisbon | Praça da Figueira | 12th | 3602C | Multi-faith | Tib | Cow | 8.7 | 42.3 | 15.4 | 3.2 | -20.2 | 5.3 |
| Lisbon | Praça da Figueira | 14th | 1227C | Multi-faith | Tib | Cow | 7.3 | 43.5 | 15.0 | 3.2 | -21.7 | 4.9 |
| Lisbon | Praça da Figueira | 14th | 1184C | Multi-faith | Tib | Cow | 7.3 | 41.4 | 15.1 | 3.2 | -20.8 | 4.9 |
| Lisbon | Praça da Figueira | 14th | 1164S | Multi-faith | MP | Cow | 0.8 | 33.1 | 11.9 | 3.2 | -20.9 | 11.1 |
| Lisbon | Praça da Figueira | 14th | 1177C | Multi-faith | Tib | Cow | 6.4 | 42.5 | 15.5 | 3.2 | -21.3 | 8.3 |
| Lisbon | Praça da Figueira | 3rd-4th | 8507B | Multi-faith | Hum | Chicken | 4.6 | 35.0 | 12.6 | 3.2 | -18.4 | 8.0 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Praça da Figueira | 3rd-4th | 8504B2 | Multi-faith | LB | Chicken | 3.3 | 42.7 | 15.4 | 3.2 | -19.9 | 9.6 |
| Lisbon | Praça da Figueira | 3rd-4th | 8504B | Multi-faith | LB | Chicken | 16.3 | 40.7 | 14.3 | 3.3 | -18.5 | 10.7 |
| Lisbon | Praça da Figueira | 3rd-4th | 8503B | Multi-faith | Rad | Chicken | 2.6 | 42.0 | 15.0 | 3.3 | -19.3 | 8.0 |
| Lisbon | Praça da Figueira | 3rd-4th | 8211B | Multi-faith | LB | Chicken | 5.6 | 36.0 | 12.9 | 3.3 | -19.1 | 10.6 |
| Lisbon | Praça da Figueira | 3rd-4th | 8510M | Multi-faith | Fem | Dog | 0.5 | 33.4 | 12.3 | 3.2 | -15.6 | 14.1 |
| Lisbon | Praça da Figueira | 3rd-4th | 3833D | Multi-faith | Tib | Dog | 0.9 | 37.9 | 13.6 | 3.2 | -18.4 | 9.4 |
| Lisbon | Praça da Figueira | 3rd-4th | 8584S | Multi-faith | MP | Goat | 2.5 | 37.9 | 13.8 | 3.2 | -20.0 | 4.7 |
| Lisbon | Praça da Figueira | 3rd-4th | 8541S | Multi-faith | Man | Goat | 9.3 | 42.2 | 15.4 | 3.2 | -20.0 | 4.0 |
| Lisbon | Praça da Figueira | 3rd-4th | 8521S2 | Multi-faith | Man | Goat | 4.7 | 35.0 | 12.6 | 3.2 | -20.6 | 10.6 |
| Lisbon | Praça da Figueira | 3rd-4th | 8299H | Multi-faith | Tib | Horse | 1.3 | 36.1 | 13.1 | 3.2 | -18.4 | 6.0 |
| Lisbon | Praça da Figueira | 3rd-4th | 8659P | Multi-faith | Man | Pig | 1.4 | 33.3 | 11.8 | 3.3 | -21.0 | 6.6 |
| Lisbon | Praça da Figueira | 3rd-4th | 8581P | Multi-faith | Man | Pig | 3.8 | 29.8 | 10.9 | 3.2 | -20.5 | 7.2 |
| Lisbon | Praça da Figueira | 3rd-4th | 8541P | Multi-faith | Man | Pig | 2.2 | 37.0 | 13.5 | 3.2 | -18.9 | 6.3 |
| Lisbon | Praça da Figueira | 12th | 1374P | Multi-faith | Ph | Pig | 4.1 | 21.1 | 7.1 | 3.4 | -19.1 | 4.9 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Praça da Figueira | 12th | 1269P | Multi-faith | Man | Pig | 3.9 | 42.3 | 15.2 | 3.3 | -20.2 | 7.1 |
| Lisbon | Praça da Figueira | 14th | 1177P | Multi-faith | Man | Pig | 6.1 | 41.6 | 15.2 | 3.2 | -20.4 | 7.7 |
| Lisbon | Praça da Figueira | 14th | 1173B | Multi-faith | LB | Rabbit | 2.0 | 39.5 | 14.2 | 3.2 | -21.6 | 5.2 |
| Lisbon | Praça da Figueira | 3rd-4th | 8521B | Multi-faith | LB | Raven | 8.8 | 44.0 | 16.1 | 3.2 | -19.4 | 8.6 |
| Lisbon | Praça da Figueira | 3rd-4th | 4311S | Multi-faith | Man | Sheep | 3.1 | 22.8 | 8.1 | 3.3 | -21.3 | 4.5 |
| Lisbon | Praça da Figueira | 3rd-4th | 8504S | Multi-faith | Man | Sheep | 4.3 | 36.4 | 13.3 | 3.2 | -20.8 | 5.1 |
| Lisbon | Praça da Figueira | 3rd-4th | 8513S | Multi-faith | MP | Sheep | 3.6 | 28.0 | 10.2 | 3.2 | -21.6 | 8.3 |
| Lisbon | Praça da Figueira | 14th | 1173S | Multi-faith | Tib | Sheep | 4.1 | 41.4 | 15.1 | 3.2 | -20.0 | 5.1 |
| Lisbon | Praça da Figueira | 3rd-4th | 8507S | Multi-faith | MP | Sheep | 8.0 | 42.0 | 15.4 | 3.2 | -20.5 | 9.9 |
| Lisbon | Praça da Figueira | 12th | 2076F | Multi-faith | Ver | Shark | 1.3 | 40.5 | 14.2 | 3.3 | -11.9 | 11.9 |
| Lisbon | Praça da Figueira | 3rd=4th | 9106F | Multi-faith | Ver | Hake | 4.4 | 39.9 | 14.9 | 3.2 | -12.0 | 14.4 |
| Lisbon | Casa da Severa | 13th-14th | LS226S | Multi-faith | MP | Cow | 3.4 | 39.8 | 13.6 | 3.4 | -19.9 | 6.6 |
| Lisbon | Casa da Severa | 13th-14th | LS221S | Multi-faith | MP | Cow | 1.5 | 34.7 | 12.0 | 3.4 | -20.8 | 5.3 |
| Lisbon | Casa da Severa | 13th-14th | LS226C | Multi-faith | Man | Cow | 4.1 | 27.9 | 10.3 | 3.2 | -20.3 | 5.5 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ13C | δ15N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Casa da Severa | 13th-14th | LS221C | Multi-faith | Rib | Cow | 5.5 | 32.6 | 12.0 | 3.2 | -21.1 | 5.7 |
| Lisbon | Casa da Severa | 13th-14th | LS216C | Multi-faith | Tib | Cow | 1.2 | 24.2 | 8.8 | 3.2 | -21.0 | 5.5 |
| Lisbon | Casa da Severa | 13th-14th | LS21AC | Multi-faith | Tib | Cow | 1.5 | 25.0 | 8.6 | 3.4 | -20.7 | 5.1 |
| Lisbon | Casa da Severa | 13th-14th | LS2 9C | Multi-faith | Tib | Cow | 6.1 | 39.3 | 14.3 | 3.2 | -20.8 | 5.8 |
| Lisbon | Casa da Severa | 13th-14th | LS214C2 | Multi-faith | MP | Cow | 6.4 | 37.3 | 13.7 | 3.2 | -21.4 | 6.6 |
| Lisbon | Casa da Severa | 13th-14th | LS21C | Multi-faith | Rib | Cow | 4.5 | 25.7 | 8.4 | 3.6 | -21.6 | 7.2 |
| Lisbon | Casa da Severa | 13th-14th | LS220C | Multi-faith | Rib | Cow | 4.5 | 31.7 | 11.3 | 3.4 | -21.3 | 6.5 |
| Lisbon | Casa da Severa | 13th-14th | LS221B | Multi-faith | Fem | Chicken | 6.6 | 41.4 | 15.1 | 3.2 | -20.2 | 6.4 |
| Lisbon | Casa da Severa | 13th-14th | LS221B | Multi-faith | Sca | Chicken | 7.5 | 37.0 | 13.1 | 3.3 | -18.4 | 7.9 |
| Lisbon | Casa da Severa | 13th-14th | LS2 7P | Multi-faith | LB | Dog | 3.8 | 41.7 | 15.0 | 3.2 | -17.1 | 15.0 |
| Lisbon | Casa da Severa | 13th-14th | LS2 16P? | Multi-faith | Ph | Pig | 3.3 | 28.6 | 10.4 | 3.2 | -20.5 | 6.3 |
| Lisbon | Casa da Severa | 13th-14th | LS28S | Multi-faith | Man | Goat | 6.0 | 37.8 | 13.7 | 3.2 | -20.1 | 3.8 |
| Lisbon | Casa da Severa | 13th-14th | LS226S2 | Multi-faith | Tib | Sheep | 3.8 | 39.4 | 14.5 | 3.2 | -20.5 | 5.6 |
| Lisbon | Casa da Severa | 13th-14th | LS202S | Multi-faith | Tib | Sheep | 1.8 | 35.8 | 12.6 | 3.3 | -20.7 | 6.2 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lisbon | Casa da Severa | 13th-14th | LS223S | Multi-faith | Man | Sheep | 1.3 | 34.0 | 11.5 | 3.5 | -19.5 | 5.9 |
| Lisbon | Casa da Severa | 13th-14th | LS229S | Multi-faith | MP | Sheep | 5.3 | 35.0 | 12.8 | 3.2 | -21.1 | 6.0 |
| Lisbon | Casa da Severa | 13th-14th | LS27S | Multi-faith | Tib | Sheep | 4.9 | 39.8 | 14.4 | 3.2 | -20.1 | 5.4 |
| Lisbon | Casa da Severa | 13th-14th | LS24S | Multi-faith | Tib | sheep | 6.0 | 38.3 | 13.6 | 3.4 | -21.5 | 6.3 |
| Lisbon | Casa da Severa | 13th-14th | LS216S2 | Multi-faith | MP | Ovicaprid | 2.4 | 16.7 | 5.8 | 3.3 | -20.5 | 5.3 |
| Lisbon | Casa da Severa | 13th-14th | LS24B2 | Multi-faith | Ver | Seabream | 4.6 | 39.7 | 14.8 | 3.1 | -11.6 | 10.7 |
| Setubal | Palmela Castle | 8th-12th | CP 1CH | Muslim | Fem | Chicken | 4.4 | 41.1 | 14.4 | 3.3 | -18.3 | 7.2 |
| Setubal | Palmela Castle | 8th-12th | CP 3CH | Muslim | Tib | Chicken | 6.7 | 40.1 | 14.4 | 3.2 | -18.3 | 8.7 |
| Setubal | Palmela Castle | 8th-12th | CP 2CH | Muslim | Rad | Chicken | 11.0 | 43.3 | 15.6 | 3.2 | -18.7 | 9.1 |
| Setubal | Palmela Castle | 8th-12th | CP 4CH | Muslim | Fem | Chicken | 6.0 | 40.1 | 14.2 | 3.3 | -19.6 | 7.5 |
| Setubal | Palmela Castle | 8th-12th | CP1 | Muslim | Ph | Goat | 7.4 | 43.8 | 7.6 | 3.3 | -20.2 | 15.7 |
| Setubal | Palmela Castle | 8th-12th | CP2 | Muslim | Ph | Goat | 9.5 | 40.8 | 14.6 | 3.3 | -20.1 | 5.0 |
| Setubal | Palmela Castle | 8th-12th | CP5 | Muslim | Rad | Goat | 7.9 | 44.0 | 15.7 | 3.2 | -18.7 | 8.8 |
| Setubal | Palmela Castle | 8th-12th | CP 15S | Muslim | Rad | Goat | 8.2 | 41.9 | 15.3 | 3.2 | -20.5 | 3.6 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | $\delta^{13}C$ | $\delta^{15}N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Setubal | Palmela Castle | 8th-12th | CP 1H | Muslim | Pel | Horse | 5.1 | 36.2 | 13.0 | 3.2 | -21.5 | 4.7 |
| Setubal | Palmela Castle | 8th-12th | CP4 | Muslim | Ph | Sheep | 6.8 | 42.7 | 15.7 | 3.2 | -20.8 | 6.3 |
| Setubal | Palmela Castle | 8th-12th | CP7 | Muslim | Ph | Sheep | 2.2 | 31.1 | 10.6 | 3.4 | -20.5 | 7.0 |
| Setubal | Palmela Castle | 8th-12th | CP 2C | Muslim | Ph | Cattle | 3.8 | 35.5 | 12.6 | 3.3 | -20.6 | 5.6 |
| Setubal | Palmela Castle | 8th-12th | CP 4C | Muslim | Ph | Cattle | 8.2 | 37.8 | 13.7 | 3.2 | -21.1 | 5.2 |
| Setubal | Palmela Castle | 8th-12th | CP 3C | Muslim | Ph | Cattle | 7.8 | 41.1 | 15.0 | 3.2 | -21.2 | 5.5 |
| Setubal | Palmela Castle | 8th-12th | CP 5C | Muslim | Ph | Cattle | 2.5 | 17.6 | 6.4 | 3.2 | -20.2 | 6.5 |
| Setubal | Palmela Castle | 8th-12th | CP 1C | Muslim | Ph | Cattle | 2.4 | 26.2 | 9.3 | 3.3 | -21.0 | 6.3 |
| Setubal | Palmela Castle | 8th-12th | CP 3DR | Muslim | LB | Red deer | 6.0 | 24.9 | 9.1 | 3.2 | -20.7 | 3.7 |
| Setubal | Palmela Castle | 8th-12th | CP 1DR | Muslim | LB | Red deer | 6.6 | 33.6 | 12.1 | 3.2 | -20.5 | 3.0 |
| Setubal | Palmela Castle | 8th-12th | CP 2P | Muslim | Cal | Pig | 8.0 | 42.6 | 15.5 | 3.2 | -20.5 | 5.8 |
| Setubal | Palmela Castle | 8th-12th | CP 4P | Muslim | Rad | Pig | 7.3 | 41.3 | 14.9 | 3.2 | -21.4 | 6.2 |
| Setubal | Palmela Castle | 8th-12th | CP 5P | Muslim | Cal | Pig | 7.9 | 22.3 | 8.1 | 3.2 | -21.2 | 6.3 |
| Setubal | Palmela Castle | 8th-12th | CP 3P | Muslim | Mec | Pig | 6.1 | 36.6 | 13.1 | 3.3 | -21.0 | 5.5 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silves | Largo da Se | 11th-15th | LSE 2081S | Multi-faith | Met | Sheep | 3.3 | 18.0 | 6.4 | 3.3 | -20.9 | 7.2 |
| Silves | Rua 25 Abril | 11th-15th | R25A 603C | Multi-faith | Rib | Cow | 1.6 | 35.4 | 12.9 | 3.2 | -21.1 | 7.2 |
| Silves | Rua 25 Abril | 11th-15th | R25A 603S | Multi-faith | Mec | Goat | 8.1 | 39.0 | 14.3 | 3.2 | -20.8 | 6.3 |
| Silves | Rua A | 11th-15th | RA3017C | Multi-faith | LB | Cow | 2.0 | 32.3 | 11.7 | 3.2 | -20.5 | 4.0 |
| Silves | Rua A | 11th-15th | RA5005C | Multi-faith | LB | Cow | 2.8 | 30.1 | 11.1 | 3.2 | -19.0 | 10.7 |
| Silves | Rua A | 11th-15th | RA4063 D | Multi-faith | LB | Dog | 5.8 | 37.9 | 13.5 | 3.3 | -20.5 | 7.5 |
| Silves | Rua A | 11th-15th | RA4035S | Multi-faith | Met | Goat | 5.2 | 38.9 | 14.4 | 3.2 | -20.1 | 4.2 |
| Silves | Rua A | 11th-15th | RA4034S | Multi-faith | Rad | Goat | 1.9 | 33.3 | 12.1 | 3.2 | -20.4 | 4.3 |
| Silves | Rua A | 11th-15th | RA3010P | Multi-faith | Hum | Pig | 11.4 | 32.4 | 12.1 | 3.1 | -19.7 | 3.6 |
| Silves | Rua A | 11th-15th | RA4063S | Multi-faith | Met | Sheep | 3.4 | 34.8 | 12.5 | 3.2 | -21.0 | 6.6 |
| Silves | Rua A | 11th-15th | RA3020S | Multi-faith | Tib | Sheep | 4.3 | 34.5 | 12.7 | 3.2 | -21.2 | 6.4 |
| Silves | Rua A | 11th-15th | RA4031 C | Multi-faith | Rib | Cow | 8.9 | 42.1 | 15.3 | 3.2 | -21.6 | 6.1 |
| Silves | Rua A | 11th-15th | RA3020 C | Multi-faith | Sca | Cow | 2.9 | 31.9 | 11.4 | 3.3 | -20.9 | 6.6 |
| Silves | Rua A | 11th-15th | RA4018C | Multi-faith | Rib | Cow | 5.5 | 39.9 | 14.4 | 3.2 | -20.8 | 6.1 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Silves | Rua A | 11th-15th | RA3038 D | Multi-faith | LB | Dog | 7.4 | 35.0 | 12.7 | 3.2 | -20.8 | 3.4 |
| Silves | Rua A | 11th-15th | RA4018S | Multi-faith | Met | Sheep | 7.2 | 40.9 | 15.0 | 3.2 | -21.8 | 6.8 |
| Silves | Rua Miguel Bombarda | 11th-15th | RMB 2008 C | Multi-faith | Rib | Cow | 2.7 | 35.3 | 12.8 | 3.2 | -21.5 | 7.3 |
| Silves | Rua 25 Abril | 11th-15th | R25A 802F | Multi-faith | Ver | Tope shark | 3.1 | 28.8 | 9.9 | 3.4 | -12.5 | 9.8 |
| Silves | Rua 25 Abril | 11th-15th | R25A 340F1 | Multi-faith | Ver | Seabass | 1.1 | 12.7 | 4.1 | 3.5 | -10.6 | 12.2 |
| Loulé | Quinta do Lago | 11th-13th | LU7 C | Muslim | Sca | Cattle | 8.0 | 41.8 | 15.2 | 3.2 | -19.9 | 7.2 |
| Loulé | Quinta do Lago | 11th-13th | LU12 C | Muslim | Man | Cattle | 3.9 | 38.8 | 14.1 | 3.2 | -20.6 | 6.6 |
| Loulé | Quinta do Lago | 11th-13th | LU17 C | Muslim | SCa | Cattle | 7.3 | 44.4 | 16.1 | 3.2 | -19.4 | 7.1 |
| Loulé | Quinta do Lago | 11th-13th | LU4 C | Muslim | Ph | Cattle | 4.9 | 43.3 | 15.7 | 3.2 | -19.2 | 7.3 |
| Loulé | Quinta do Lago | 11th-13th | LU1 CH | Muslim | Hum | Chicken | 7.0 | 40.3 | 14.1 | 3.3 | -19.1 | 10.1 |
| Loulé | Quinta do Lago | 11th-13th | LU19 CH | Muslim | Hum | Chicken | 6.9 | 42.2 | 15.0 | 3.3 | -17.6 | 9.1 |
| Loulé | Quinta do Lago | 11th-13th | LU23 CH | Muslim | MP | Chicken | 7.1 | 44.0 | 15.5 | 3.3 | -15.1 | 11.2 |
| Loulé | Quinta do Lago | 11th-13th | LU11 CH | Muslim | Fem | Chicken | 9.6 | 42.8 | 15.2 | 3.3 | -18.0 | 10.5 |
| Loulé | Quinta do Lago | 11th-13th | LU14 D | Muslim | Uln | Dog | 4.3 | 44.4 | 15.8 | 3.3 | -16.9 | 10.5 |

| Location | Site | Period (centuries) | Sample No. | Context | Element | Species | Yield (%) | %C | %N | C:N | δ$^{13}$C | δ$^{15}$N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loulé | Quinta do Lago | 11th-13th | LU21 | Muslim | Met | Goat | 4.4 | 42.9 | 15.6 | 3.1 | -19.9 | 5.7 |
| Loulé | Quinta do Lago | 11th-13th | LU20 | Muslim | Man | Goat | 4.8 | 40.8 | 14.6 | 3.3 | -19.5 | 3.5 |
| Loulé | Quinta do Lago | 11th-13th | LU8 | Muslim | Rad | Goat | 3.6 | 43.0 | 15.3 | 3.3 | -19.1 | 5.4 |
| Loulé | Quinta do Lago | 11th-13th | LU10 S | Muslim | Man | Goat | 6.6 | 37.1 | 13.5 | 3.2 | -17.3 | 5.0 |
| Loulé | Quinta do Lago | 11th-13th | LU3 S | Muslim | Man | Goat | 1.6 | 9.9 | 3.4 | 3.4 | -20.5 | 4.4 |
| Loulé | Quinta do Lago | 11th-13th | LU24 H | Muslim | Tib | Horse | 2.0 | 28.2 | 10.2 | 3.3 | -13.9 | 6.5 |
| Loulé | Quinta do Lago | 11th-13th | LU22 R | Muslim | Fem | Rabbit | 7.0 | 40.5 | 14.2 | 3.3 | -21.8 | 5.8 |
| Loulé | Quinta do Lago | 11th-13th | LU15 S | Muslim | Man | Sheep | 6.0 | 39.8 | 14.3 | 3.2 | -17.5 | 6.1 |
| Loulé | Quinta do Lago | 11th-13th | LU13 | Muslim | Man | Seabream | 2.4 | 39.3 | 14.3 | 3.2 | -11.9 | 10.3 |
| Loulé | Quinta do Lago | 11th-13th | LU6 | Muslim | Man | Seabream | 0.7 | 36.4 | 12.5 | 3.4 | -12.0 | 10.1 |

**B.4** Summary tables of $\delta^{13}C$ and $\delta^{15}N$ values of cow, sheep, goat, chicken and sheep from each site. Standard deviation is calculated where the sample number is at least 3. Where a species is represented by one sample, the raw value is given.

Cow

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal 10th-14th | 6 | -20.6 | -19.5 | 1.1 | -20.2±0.4 | 3.4 | 9.3 | 5.9 | 6.1±1.9 |
| Coimbra 9th-11th | 3 | -21.8 | -20.8 | 1 | -21.1±0.5 | 5.0 | 6.5 | 1.5 | 5.7±0.7 |
| Lisbon 4th-12th | 11 | -21.8 | -20.2 | 1.6 | -21.1±0.5 | 4.9 | 11.1 | 6.2 | 6.3±1.9 |
| Lisbon 13th-15th | 11 | -21.6 | -19.9 | 1.7 | -20.9±0.5 | 5.1 | 7.2 | 2.1 | 6.1±0.8 |
| Setubal 8th-12th | 5 | -21.2 | -20.2 | 1 | -20.8±0.4 | 5.2 | 6.5 | 1.3 | 5.8±0.6 |
| Silves 11th-15th | 7 | -21.6 | -19.0 | 2.6 | -20.8±0.9 | 4.0 | 10.7 | 6.7 | 6.8±2.0 |
| Loulé 11th-13th | 4 | -20.6 | -19.2 | 1.4 | -19.8±0.6 | 6.6 | 7.3 | 0.7 | 7.1±0.3 |

Sheep

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal 10th-14th | 1 | - | - | | -20.5 | - | - | | 6.7 |
| Coimbra 9th-11th | - | - | - | - | - | - | - | - | - |
| Lisbon 4th-12th | 5 | -21.6 | -20.0 | 1.6 | -20.8±0.6 | 4.5 | 9.9 | 5.4 | 6.6±1.0 |
| Lisbon 13th-15th | 6 | -21.5 | -19.5 | 2 | -20.6±0.7 | 5.4 | 6.3 | 0.9 | 5.9±0.3 |
| Setubal 8th-12th | 2 | -20.8 | -20.5 | 0.3 | -20.8 | 6.3 | 7.0 | 0.7 | 6.7 |
| Silves 11th-15th | 4 | -21.8 | -20.9 | 0.9 | -21.2±0.4 | 6.4 | 7.2 | 0.8 | 6.7±0.3 |
| Loulé 11th-13th | 1 | - | - | - | -17.5 | - | - | - | 6.1 |

Goat

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | δ13C/‰ | | | | δ15N/‰ | | | |
| Site | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal 10th-14th | 5 | -20.6 | -19.3 | 1.3 | -19.9±0.4 | 3.9 | 5.6 | 1.7 | 4.7±0.6 |
| Coimbra 9th-11th | 5 | -21.2 | -19.9 | 1.3 | 20.5±0.2 | 3.1 | 7.0 | 3.9 | 5.4±1.5 |
| Lisbon 4th-12th | 3 | -20.6 | -20.0 | 0.6 | -20.2±0.4 | 4.0 | 10.6 | 6.6 | 6.5±3.6 |
| Lisbon 13th-15th | 1 | - | - | - | -20.1 | - | - | - | 3.8 |
| Setubal* 8th-12th | 3 | -20.5 | -18.7 | 1.8 | -19.9±0.8 | 3.6 | 8.8 | 5.2 | 5.8±2.7 |
| Silves 11th-15th | 3 | -20.8 | -20.1 | 0.7 | -20.4±0.3 | 4.2 | 6.3 | 2.1 | 4.9±1.2 |
| Loulé 11th-13th | 6 | -20.5 | -17.3 | 3.2 | -19.1±1.2 | 3.5 | 5.7 | 2.2 | 4.8±0.8 |

Chicken

| | | δ$^{13}$C/‰ | | | | δ$^{15}$N/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal 10th-14th | 2 | -20.3 | -20.2 | 0.1 | -20.2 | 6.6 | 9.9 | 3.3 | 8.2 |
| Coimbra 9th-11th | 3 | -16.7 | -12.6 | 4.1 | -15.2±2.3 | 8.1 | 9.0 | 0.9 | 8.5±0.5 |
| Lisbon 4th-12th | 5 | -19.9 | -18.4 | 1.5 | -19.0±0.6 | 8.0 | 10.7 | 2.7 | 9.4±1.3 |
| Lisbon 13th-15th | 4 | -22.0 | -15.8 | 6.2 | -19.1±2.6 | 5.2 | 10.1 | 4.9 | 7.4±2.1 |
| Setubal 8th-12th | 4 | -19.6 | -18.3 | 1.3 | -18.7±0.6 | 7.2 | 9.1 | 1.9 | 8.1±0.9 |
| Silves 11th-15th | - | - | - | - | - | - | - | - | - |
| Loulé 11th-13th | 4 | -19.1 | -15.1 | 4.0 | -17.5±1.7 | 9.1 | 11.2 | 2.1 | 10.2±0.8 |

Pig

| | | $\delta^{13}C$/‰ | | | | $\delta^{15}N$/‰ | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | No. | Min | Max | Range | Mean ±1σ | Min | Max | Range | Mean ±1σ |
| Laranjal 10th-14th | 6 | -21.1 | -20.1 | 1 | -20.6±0.4 | 4.7 | 7.7 | 3 | 6.5±1.3 |
| Coimbra 9th-11th | 5 | -22.0 | -20.3 | 1.7 | -21.2±0.7 | 3.6 | 8.9 | 5.3 | 6.4±2.0 |
| Lisbon 4th-12th | 6 | -21.0 | -18.9 | 2.1 | -20.0±0.8 | 4.9 | 7.7 | 2.8 | 6.6±1.0 |
| Lisbon 13th-15th | 1 | - | - | - | -20.5 | - | - | - | 6.3 |
| Setubal 8th-12th | 4 | -21.4 | -20.5 | 0.9 | -21.0±0.4 | 5.5 | 6.3 | 0.8 | 5.9±0.4 |
| Silves 11th-15th | 1 | - | - | - | -19.7 | - | - | | 3.6 |
| Loulé 11th-13th | - | - | - | - | - | - | - | - | - |

# APPENDIX C: Publications

# High status diet and health in Medieval Lisbon: a combined isotopic and osteological analysis of the Islamic population from São Jorge Castle, Portugal

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**Keywords**: Muslim, diet; medieval, Portugal; stable isotopes; paleopathology

**Short abstract** (word total: 215)

This paper presents the first bioarchaeological study of Islamic diet and lifeways in medieval Portugal. Stable isotopes of $\delta^{13}C$ and $\delta^{15}N$ and osteological and paleopathological analyses are combined to explore the diet and health status of 27 human individuals buried within São Jorge Castle, Lisbon (11th-12th century), interpreted as a high status population. Human isotopic data are considered alongside an animal baseline comprised of 30 specimens sampled from nearby Praça da Figueira, including the main domesticates and fish.

Isotopic data indicate an age and sex related difference in diet among the population, suggesting a difference in food access between females and children compared to males. Palaeopathological analysis indicated a low prevalence of non-specific stress indicators such as Harris lines (HL), linear enamel hypoplasia (LEH) and *cribra orbitalia* (CO) in this population in comparison to other Medieval populations. LEH is only present in adults.

These results suggest the presence of socio-cultural patterning relating to the organisation of the Islamic family, where women and men occupied different places within the society and in the household. The paper demonstrates the utility of a combined osteological and isotopic approach to understand the lifeways of Islamic populations in Medieval Iberia at large, as well as illuminate the lifeways of understudied segments of the population.

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## 1. INTRODUCTION

This study applies a combination of bioarchaeological techniques to explore a human skeletal assemblage from São Jorge Castle, Lisbon, dating to the time of Islamic rule (8th-13thC). Osteological and paleopathological analysis, together with carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopic analysis of human and animal bone collagen are employed to explore the diet and lifeways of this high status population (Fig. 1). The standard Muslim burial custom entails the use of dedicated areas for burial, usually located outside the city walls with no discrimination based on social status (Insoll 1999:169). The unusual location of these interments, within the Castle itself, suggests these individuals might have had a privileged treatment at death and therefore belonged to an elevated social status, with possible links to the Islamic ruling family. The archaeological excavation and associated finds provide a chronology for the use of this site between the 10th and 11th century, at the height of Islamic rule in Lisbon. This assemblage thus provides a unique opportunity to explore the dietary habits and overall health status of a specific group of individuals within Lisbon's Medieval Muslim community.

Isotopic research into Medieval diet among Islamic populations in Iberia is growing, specifically in Spain. Research has been undertaken on individuals from Valencia and Aragon (Salazar-Garcia et al. 2014, 2016; Alexander et al. 2015; Guede et al. 2015), a small assemblage from Granada (Jiménez-Brobeil et al. 2016) and the Balearic Islands of Mallorca (Garcia et al. 2004; Cau Ontiveros et al. 2016), Ibiza and Formentera (Fuller et al. 2010; Nehlich et al. 2012; Pickard et al. 2017). Regarding Portuguese material, a recent article explored the diet of a group of Late Antique Christian individuals from Monte da Cegonha (Saragoça et al. 2016). However, no research has been published on Portuguese Islamic material to date.

### 1.1 Osteology, lifeways and diet

The combination of osteology and stable isotopes analysis offers different but complimentary data sets, which allow us to investigate medieval lifeways more holistically in terms of diet and health. Pathological alterations such as dental enamel hypoplasias, cribra orbitalia, Harris lines or periostitis are the bone/teeth insults commonly investigated in sub-adults and adults in past populations. These lesions are considered signs of non-specific stress and are used to produce an overall, but approximate idea of the community health, thus this paper assess specific pathological conditions (eg. scurvy and rickets) to reconstruct the health profile of the population (Mays 2013).

This study aims to identify potential variations in dietary habits and lifeways within the Muslim social elite. Notably, this represents the first application of stable isotope analysis to examine diet for an Islamic population in Portugal, adding a new body of data to the understanding of medieval diet on the Western edge of the Iberian Peninsula. This paper demonstrates the potential of a combined bioarchaeological approach to understand medieval lifeways, and to shed light onto specific segments of the society that were traditionally understudied or misrepresented in the historical sources (i.e. women and children).

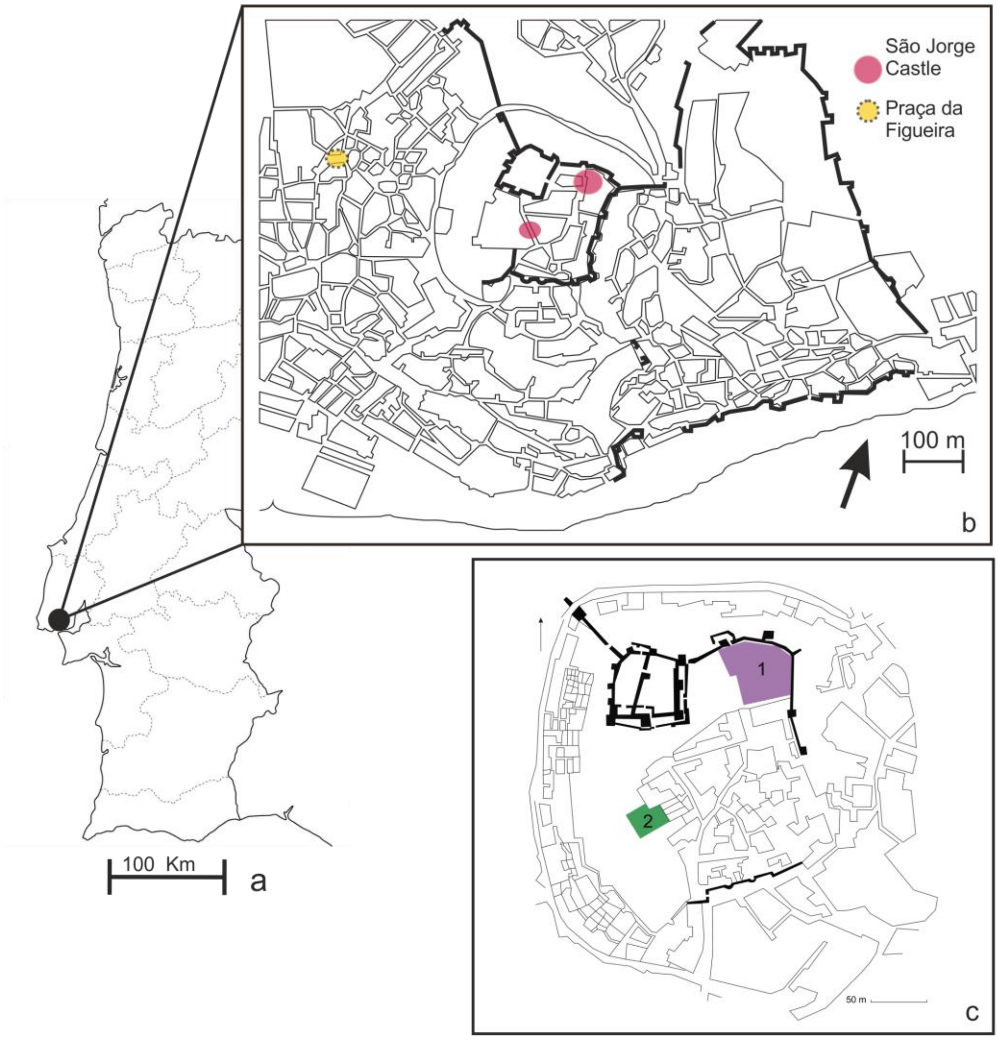

**Fig. 1** a) location of Lisbon in Portugal, b) location of São Jorge Castle (human remains) and Praça da Figueira (animal remains), (adapted from Planta da cidade de Lisboa 1650, copia de Carvalho Jr. in Silva, 1884); c) Sites of Praça Nova (1) and Palácio das Cozinhas (2) (adapted from Drawing by Rita Nobre Neto da Silva (2014) based on municipal open-source cartography Câmara Municipal de Lisboa, 2012).

### 1.2 Site context

This study is primarily focussed on skeletal materials from Islamic burials from São Jorge Castle (SJC), located on a hilltop in the centre of present day Lisbon (fig.1).

A settlement with defensive walls was established here in the Roman period (Bugalhão 2009:385), commanding a strategic location at the confluence of the River Tagus and the Atlantic Ocean. The area is surrounded by fertile territory and has convenient access to the interior by river, making this site particularly appealing to Muslim settlers in 714 CE (Picard 2000:25). However, the role of Lisbon in the first years of Islamic rule was marginal until the 9th century. Its major expansion, testified by the construction of later defensive walls, took place between the 11th and 12th centuries (Torres 1994). The castle is mentioned in Christian sources that describe Lisbon immediately after the conquest; however, its foundation is yet to be attributed to a specific date. The building that stands today has undergone vast restoration and is, in fact, a Medieval Christian fortress, with later 16th and 17th century additions (Melo 2014:46).

Archaeological excavation undertaken within the Castle site recovered several stratified structures pertaining to different chronologies, indicating a long lasting occupation from the Iron Age to the post-medieval period. However, the publication of data from the excavation focuses mainly on the later medieval period under Christian rule (Gaspar and Gomes 2001; Gomes et al. 2003).

The faunal remains included in this study were excavated from the nearby site of Praça da Figueira in Lisbon. Praça da Figueira has a notable place in the history of Lisbon´s archaeology. Excavations of the Modern Age Royal Hospital of All Saints between 1960 and 1971 and more recent works between 1999 and 2001 revealed a long diachronic use of the site, from a Late Bronze Age small settlement (circa 10th - 9th BCE) to the modern day. Late Antique/ post-Roman occupation was recorded and other structures dated to the Islamic period (11th – 12th C), were identified, along with later medieval activity associated with a nearby Dominican convent (13th C onwards). Archaeological evidence for 7th - mid 11th century is scarce but significant evidence was found for the second half of 11th C, consistent with agricultural use of the land. However, during the early 12th C, a swift change occurred in the eastern part of the area where blocks of houses and roads were built. This suburban expansion attests to the enlargement of Muslim Lisbon in the few decades that preceded the Christian conquest by the coalition of Northern European Crusaders and the Portuguese king (1147 CE). Some of the excavated suburban Muslim houses were kept in use after the Christian conquest, while others were abandoned. By the early 13th century, only two of them were still occupied, and most of the area regained its previous agricultural vocation.

### 1.3 Archaeological evidence for diet in Medieval Iberia and Lisbon

Much of what is known about medieval diet comes from historical accounts that usually focus on Christian Europe. While a handful of cookbooks and health treatise survived from the late medieval period concerning Islamic Spain, no information is given on the territories of modern day Portugal (Rosenberger 1999:222; Weiss Adamson 2004:117). Variety appears to be the basic feature of early medieval diet at all social levels; however, qualitative and quantitative differences existed between various social groups, and food played an important role in reinforcing group identities at the time (Montanari 1999:169). Arab cuisine focused mostly on meat from domestic animals, fowl and game, accompanied by vegetables and a variety of flat breads in the East or semolina flour couscous in the Maghreb. Animal fat, especially from mutton was widely used (Rosenberger 1999:214). Although the principles of Arab cuisine can be generally applied to the Islamic west, the Iberian Peninsula developed its own variations due to the assimilation of previous culinary traditions, namely those imported by Phoenicians, Greeks and Romans (Adamson 2004:115-116). In the absence of specific historical sources for the Portuguese territories, archaeological research plays a crucial role in shedding light onto dietary habits and food preferences shown by the Islamic community of the West.

The use of plants in the diet of medieval Muslims and Christians, including imports, is widely documented in historical sources. Although they describe the main products consumed in Medieval Christian Portugal, these can be applied, with some approximation, to the late Islamic period. In a few cases, the link between the persistence of Islamic customs or products is evident, for example in the existence of walled gardens and orchards in the surrounding urban areas that were well irrigated and manured. Vegetables and legumes were grown in these gardens, following Islamic customs, with fruits trees and flowers (Marques 1987:100). Three types of wheat are mentioned: common wheat in its winter (*Triticum vulgare hibernum*) and summer (*Triticum aestivum*) varieties, emmer wheat (*Triticum dicoccum)* and durum wheat (*Triticum durum*) introduced by the Muslims to the Iberian Peninsula and referred in the sources as Moorish wheat (Marques 1962:80). A number of vegetables and plants are referred to such as cabbages, spinach, turnips, radish, lettuce, carrots, aubergines, peas, fava beans, lentils, onions, garlic, parsley, saffron, flaxseed, chickpeas, lupines and grass pea (Marques 1987:100-101). These plants are $C_3$ plants; however, $C_4$ plants were known and grown, such as millet and sorghum. Historical sources mention millet in both forms (*Panicum miliaceum* and *Setaria italica*). While the first type was widely used to produce mixed-grain bread in the Christian north, foxtail millet was mainly employed for animal consumption (Catarino 1998:78). Although these two crops are mentioned, little is known about their role in the medieval everyday diet and specifically how often and in what quantities they were consumed. In this regard, stable isotope analysis can inform on their inclusion in the human and animal diet.

Historical sources providing lists of crops and vegetables are a useful indication of the availability of specific species; however, the texts should be handled with caution for two main reasons. The first one is a recurrent problem in dealing with historical sources that describe aspects of daily life, as they typically only refer to the diet of higher social classes and during specific events. While this is a confounding factor in exploring diet of lower classes, it is beneficial to this population of likely higher status. Secondly, the treatises were compiled from different cookbooks and prescriptions from all parts of the Islamic world, meaning that references to plants in Al-Andalus sources are not necessarily proof of their cultivation or availability on a regional level. Archaeobotanical studies are therefore of primary importance to determine the regional availability.

There is, unfortunately, a scarcity of paleobotanical data for the Islamic period in Portugal, mostly due to the time sensitive nature of emergency and commercial archaeology excavations. However, several contexts have been analysed from southern Portugal, including both rural and urban sites (Queiroz and Mateus 2012). Two assemblages are known for Islamic Lisbon: NARC (Núcleo Arqueológico dos Correeiros) and Praça D. Pedro IV. A high concentration of fruit seeds and remains of vegetables was found in NARC including melon, cucumber, carrots, flax seeds, parsley, strawberries, plums, grapes and figs. Aromatic plants such as mint, celery, common vervain and cumin were recorded especially in Praça D. Pedro IV with ruderal species including goosefoot, annual mercury, purslane and common nettle (Queiroz 1999; Bugalhão and Queiroz 2006; Queiroz and Mateus 2012). Surprisingly, in both Lisbon contexts, there was no trace of leguminous plants or cereals, although they are widely mentioned in historical sources (Rei 2017:70-71). This misrepresentation, especially in comparison to other Islamic sites in Southern Portugal, is linked to the nature of the sites, that especially for NARC, was linked to a possible fruit processing and transformation industry (Bugalhão and Queiroz 2006). Since stable isotope analysis of collagen cannot inform on the consumed fruit and vegetables, these findings are a valuable contribution to explore variety in the medieval diet, although in this case they do not reveal the cereal staples, which are usually found as charred cereal remains in silos.

Historical sources mention a high reliance on herbivores such as cattle, sheep and goat and also birds such as chickens and partridge (Catarino 1998:126; Gonçalves 1989:294). Dairy and eggs would also have been widely consumed, and were a substantial part of the protein intake of the lower classes (Catarino 1998:130-131). Wild animals like rabbists and hares were consumed by all social classes as they were very abundant in Portugal (Gonçalves 2004). Fish  consumption was common (eg. sardines and tuna): inshore and coastal fishes are an easy catch and may have supplemented the diet of the lower classes in those areas (Catarino 1998:142; Gonçalves 2004). In terms of zooarchaeological evidence for diet, animal bones from five sites in Lisbon have been studied, four of which have been published and include material of Islamic chronology: Sé (Moreno-García and Davis 2011); São Jorge castle (Moreno-García 2008 unpublished); NARC (Bugalhão et al. 2008; Moreno García and Gabriel 2001); Lisbon western quarter (Bugalhão et al. 2008) and Largo da Severa (Valente and Marques 2017). Four of these sites date between 9th to 12th C and resulted from different waste activities in

Islamic Lisbon. The consumption pattern portrayed at these sites adheres to other Islamic cities in Portugal such as Santarém (Moreno-García and Davis 2001; Davis 2006), Alcácer do Sal (Moreno-García and Davis 2001), Mértola (Morales Muñiz 1993; Antunes 1996, Moreno-García and Pimenta 2012), Mesas do Castelinho (Cardoso 1993), Évora (Costa and Lopes 2010), Silves (Davis et al. 2008) with a predominance of sheep/goat, followed by cattle and rabbit. Zooarchaeological studies of faunal assemblages from Islamic sites showed a high predominance of ovicaprids as the most represented species, followed by rabbit. Only two sites show different species as being the most common: pig in Torre Vedras (Gabriel 2003) and cow in Conimbriga (Detry et al. 2014). The presence of pig is quite surprising though somehow common in Islamic sites (Detry et al. 2014:101). This is usually explained as pig breeding for Christian consumption or wild boar hunting, a practice that was permitted in case of need, and still exists in modern Maghreb tribes (Simoons 1961). Cattle is common and is usually the second or third most represented species across all sites. The assemblage from São Jorge Castle itself is rather small and therefore it is hard to judge how representative it is. It is interesting to note, however, that unlike other Islamic fortresses in Portugal, there is no trace of larger hunted animals such as deer that are considered a sign of high status diet and found at similar sites elsewhere e.g. Paderne, Palmela, Salir and Sintra (Pereira 2013; Fernandes et al. 2012; Cardoso and Fernandes 2012; Martins 2013; Coelho 2012).In terms of age at death, evidence indicates that sheep/goat were slaughtered for consumption at a younger age whereas cattle were older, perhaps consumed after their agricultural use as draught animals was over, in accordance to the suggestions of Arabic culinary treatises (Nasrallah 2007).

## 2. MATERIALS

Within São Jorge Castle, 35 individuals were excavated from two sites, Praça Nova (PN) and Palácio das Cozinhas (PC). Each individual was assessed for sex and age and the recurrence of three non-specific stress markers were recorded, linear enamel hypoplasia (LEH), Harris lines (HL) and cribra orbitalia (CO) as outlined below. Samples of 27 individuals were taken for stable isotope analysis of collagen $\delta^{13}C$ and $\delta^{15}N$, with preference to more complete skeletons with well-preserved ribs (Table 1). Five Islamic individuals excavated from Calçadinha do Tijolo (CDT), Alfama, Lisbon, were also analysed using stable isotope analysis to provide a low status comparison to the high-status individuals from SJC. A full report of the excavation, dietary and anthropological study has been published elsewhere (Filipe et. al 2017).

**Table 1** List of analysed individuals from São Jorge Castle (SJC). Codes: I - Indeterminate; IA - Indeterminate adult; INA - Indeterminate Non-adult; NB – newborn;LEH - linear enamel hypoplasia; HL - Harris lines; CO - cribra orbitalia; SIA - stable isotopes analysis.

| Individual codes | Age (y.o.) | Sex | LEH | HL | CO | SAI |
|---|---|---|---|---|---|---|
| CSJ.PC.1 | IA | M |  |  |  | x |
| CSJ.PN.1 | 30-49 | M | ✓ |  | ✓ | ✓ |
| CSJ.PN.2 | 18-29 | F | ✓ |  | ✓ | ✓ |
| CSJ.PC.2 | 18-29 | I |  |  |  | ✓ |
| CSJ.PC.3 | 6-11 | NA | ✓ | ✓ | ✓ | ✓ |
| CSJ.PC.4 | 0.16-5 | NA |  | ✓ |  | ✓ |
| CSJ.PN.4 | 0.16-5 | NA | ✓ |  |  | ✓ |
| CSJ.PC.5 | 12-17 | NA | ✓ |  |  | ✓ |
| CSJ.PN.5 | 12-17 | NA | ✓ |  |  | ✓ |
| CSJ.PC.6 | IA | M |  |  |  |  |
| CSJ.PN.6 | 0.16-5 | NA | ✓ | ✓ | ✓ | ✓ |
| CSJ.PC.7 | 18-29 | F | ✓ |  |  | ✓ |
| CSJ.PN.7 | 0.16-5 | NA |  |  |  | ✓ |
| CSJ.PC.8 | 18-29 | M | ✓ |  | ✓ | ✓ |
| CSJ.PN.8 | 0.16-5 | NA | ✓ |  | ✓ | ✓ |
| CSJ.PC.9 | IA | M |  | ✓ |  |  |
| CSJ.PN.9 | FOETUS | NA |  | ✓ |  |  |
| CSJ.PN.10 | NB | NA | ✓ |  |  | ✓ |
| CSJ.PC.11 | 12-17 | NA | ✓ |  | ✓ | ✓ |
| CSJ.PN.11 | NB | NA |  |  |  | ✓ |
| CSJ.PC.12 | 18-29 | F |  |  |  | ✓ |
| CSJ.PN.12 | NB | NA |  |  |  | ✓ |
| CSJ.PC.13 | 0.16-5 | NA |  |  | ✓ | ✓ |
| CSJ.PN.13 | 0.16-5 | NA |  |  |  | ✓ |
| CSJ.PC.14 | >50 | F |  | ✓ |  | ✓ |

| | | | | | | |
|---|---|---|---|---|---|---|
| CSJ.PN.14 | NB | NA | | ✓ | | ✓ |
| CSJ.PC.15 | FOETUS | NA | | ✓ | | |
| CSJ.PN.15 | NB | NA | | | | ✓ |
| CSJ.PC.16 | 30-49 | F | | | | ✓ |
| CSJ.PC.17 | 0.17-5 | NA | ✓ | | ✓ | ✓ |
| CSJ.PC.18 | INA | NA | | | | |
| CSJ.PC.19 | 30-49 | F | | | | ✓ |
| CSJ.PC.20 | NB | NA | | ✓ | | ✓ |
| CSJ.PC.21 | IA | I | | | | |
| CSJ.PC.22 | IA | F | | | | |

Animal bone samples from a range of taxa (n=38) were collected from waste pits associated with domestic contexts excavated in Praça da Figueira under the direction of Dr. Rodrigo Banha da Silva. To increase sample size, animals were sampled from layers dating from the Roman to the late Medieval period (1st-14th centuries).

## 3. METHODS

### 3.1 Preservation, paleodemographic and paleopathological assessment

The anatomical preservation index (API) and the bone representation index (BRI) were calculated for all individuals, following Dutour (1989) and Garcia (2005/2006), in order to assess if there were differences in preservation regarding sex and age, which could bias the demographic profile of the sample. The skeleton was divided in 44 anatomical parts classified between 0 (bone not preserved) and 1 (bone present and complete). For the vertebral column, pelvic girdle, ribs, hands and feet a ratio between the number of preserved bones and the bones that should have been present was computed (BRI). The quality of the periosteum was not quantified.

Paleodemographic data were collected by standard methods as outlined below. Individuals were assembled in age groups according to the following categories: foetus (under 39 weeks); newborns (from 40 weeks until the first month); infants (2 months to 5 years old); children (6 to 11); juveniles (12 to 17); young adults (18 to 29); middle-aged adults (30 to 49) and old adults (>50).

For non-adults, age at death was estimated primarily through dental development (Liversidge et al. 1993; Liversidge and Molleson 1999). In the absence of teeth, the length of long bones shafts and skeleton maturation were used to provide an age estimation (Cardoso 2005; Scheuer, Black and Schaefer 2009). Adult age estimation was performed following multiple methods such as the evaluation of the pubic symphysis (Brooks and Suchey 1990), the auricular surface (Lovejoy et al. 1985) and the sternal end of the ribs (İşcan et al. 1985; İşcan et al. 1984). In younger adults, the medial epiphysis of the clavicle was analysed to provide a more specific age according to the state of fusion observed (Cardoso 2008). For sex estimation, the method proposed by Bruzek (2002) was used. In the absence of the pelvic girdle the skull and post-cranial bones were used (Walrath et al. 2004; Cardoso 2000; Silva 1995).

Macroscopic assessment of all skeletons was undertaken by Sara Gaspar and Susana Garcia to detect abnormal bone formations that could be related to a pathological process. All bones were systematically analysed to detect signs of infectious diseases like tuberculosis or leprosy; metabolic diseases (e.g. scurvy, osteoporosis or vitamin D deficiency) according to Ortner (2003), Matos and Santos (2006) and Matos (2009). The presence of periostitis in the anterior tibia was systematically investigated. Carious cavities were recorded in all erupted deciduous and permanent teeth according to Hillson (2001). The assessment of Harris Lines (HL) was performed using adults and non-adult tibiae. Data were collected by x-ray analysis with consideration of the indications of Mays (1995). Distal ends of left tibiae were classified in relation to the presence/absence of HL and in reference of the total number of lines observed: 1) tibia with one line; 2) tibia with two or three lines; 3) tibia with four or more lines. The right tibia was used in the absence of the left one.

Linear Enamel Hypoplasia (LEH) is represented by a transverse line or groove across the tooth enamel (King et al. 2005) and was recorded in the anterior permanent dentition, from both adults and non-adults. Each anterior tooth was macroscopically observed under a strong light and was classified in relation to the presence/absence of LEH and the number of lines were counted. Only teeth with dental wear up to and including stage 5 were analysed (Smith, 1984). Individuals with two or more anterior teeth with observable defects were considered LEH positive. The codes were: 1) tooth without hypoplasia; 2) tooth with one line; 3) tooth with two or more lines.

Signs of hematological disorders (e.g. anaemia) were searched in all available orbits in adults and non-adults older than 6 months. Orbital lesions were classified according with Stuart-Macadam (1985) as: 1) light; 2) moderate; 3) severe.

All statistical analyses were carried out using SPSS version 20 and 22. Due to the small sample size, non-parametric tests were used to assess associations between variables. The differences in the prevalence of the stress markers between age and sex groups were assessed with $X^2$ test and the Yate’s correction was applied.

### 3.2 Collagen extraction and stable isotope analysis

Rib bones were sampled from each adult skeleton. In the non-adult skeletons, ribs were not always present or were fragmented, therefore long bones such as tibia, femur and humerus were preferred. The bones were only collected if they were incomplete and whenever the antimere was present and in good state of preservation. Collagen was extracted following a modified Longin (1971) method including an ultrafiltration step (Brown et al. 1988). The samples (~0.4 g) were mechanically cleaned with a scalpel blade and demineralised in acid (0.6M HCl at 5°C for up to 7 days). The resulting demineralised bone was gelatinised in HCl at pH 3 for 48h at 80°C. The gelatinised fraction was ultrafiltered to isolate the higher molecular weight collagen (>30 kDa) which was then frozen (~ -20°C) and lyophilized. The collagen samples were analysed in duplicate using isotope ratio mass spectrometry (IRMS) with a Sercon 20-22 at the BioArCh facilities, University of York. Isotopic values are reported following standard practice as the ratio of the heavier isotope to the lighter one (δ values in parts per mille ‰) relative to internationally defined standards for carbon $^{13}C/^{12}C$ (VPDB: Vienna Pee Dee Belemnite) and nitrogen $^{15}N/^{14}N$ (AIR) following the equation [$\delta = (R_{sample} - R_{standard})/R_{standard} \times 1000$].The analytical error for $\delta^{13}C$ and $\delta^{15}N$ was ± 0.2‰ as determined by analysis of internal laboratory standards coupled with every run. The accuracy of measurements was monitored using international and in house standards with well-known isotopic composition (in-house Fish gelatine: δ13C -15.5±0.1, δ15N 14.3±0.2; Cane sugar IA-R006: δ13C -11.8±0.1; Caffeine IAEA 600: δ13C -27.8±0.1, δ15N 0.8±0.1; Ammonium Sulfate IAEA N2: δ15N 20.4±0.2).

Statistical analyses of the isotopic data were conducted using SPSS with p values <0.05 considered significant. Due to the small sample size, only the non-parametric Mann-Whitney U test for equal median was used to compare groups.

## 4. RESULTS

### 4.1 Preservation, paleodemographic and paleopathological profile

This collection presents a moderate Anatomical Preservation Index (API); on average 38% of the bones were present to be analysed. Non-adults were better preserved (43%) than adults (31%) and males (53%) were better preserved than females (42%).

Fig. 2 illustrates the demographic profile of the population. The sample is composed of a total of 35 individuals, 21 non-adults and 14 adults. Of the non-adults, thirteen were less than 2 years at the time of death, 3 were between 2 and 6 years and 5 were older than 6 years old.

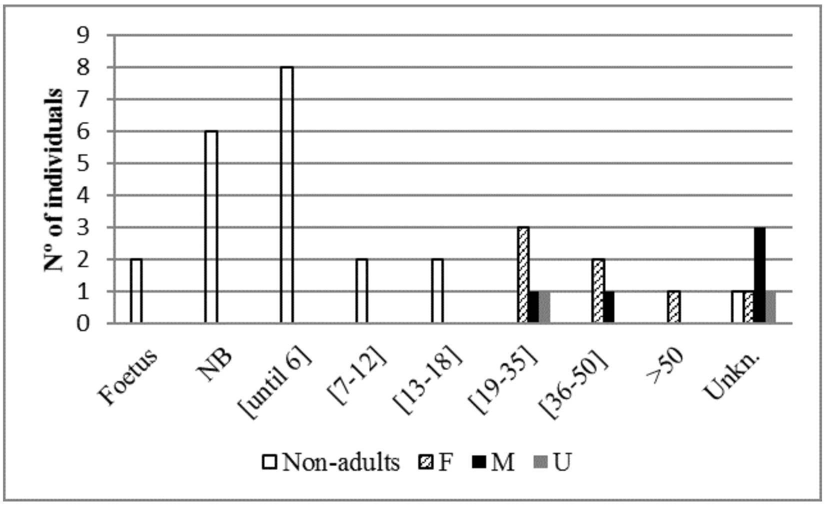

**Fig. 2** illustrates the demographic profile of the population. The sample is composed of a total of 35 individuals, 21 non-adults and 14 adults. Thirteen had less than 2 years at the time of death, 3 had between 2 and 5.9 years and 5 were older than 6 years old.

The adult sample is composed of 5 young adults, 3 middle-aged adults and 1 old adult. The age-at-death was undetermined in 5 adults. Fifty percent of the adults are females (n=7) and 36.0% are males (n=5). However, sex was not estimated in 2 individuals due to poor preservation.

The non-adults present more stress indicators than the adults (table 2), although the difference is not significant ($p > 0.05$). The exception is the prevalence of LEH, which affected 33.3% of the non-adults (n=3) and 75.0% of the adults (n=3). Harris lines were scored in 7 non-adults and 2 adults and only one of the non-adults presented HL. From all available orbits, 6 belonged to non-adults (older than 6 months) and 3 to adults. Half of the non-adults exhibit cribra orbitalia (CO), while it was absent in the adult sample.

**Table 2** Prevalence of stress indicators by age and sex including LEH (linear enamel hypoplasia), HL (Harris lines), CO (Cribra orbitalia). N, number of total individuals available; n, number of individuals with the stress markers.

| | Non-adults | | | Adults | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Females | | | Males | | | | | |
| | N | n | % | N | n | % | N | n | % | N | n | % |
| LEH | 9 | 3 | **33.3** | 2 | 1 | **50.0** | 2 | 2 | **100** | 12 | 6 | **50.0** |
| HL | 7 | 1 | **14.3** | 1 | 0 | **00.0** | 1 | 0 | **00.0** | 9 | 1 | **11.1** |
| CO | 6 | 3 | **50.0** | 1 | 0 | **00.0** | 2 | 0 | **00.0** | 8 | 2 | **25.0** |

No cases of infectious diseases such as tuberculosis or leprosy were identified. Signs of scurvy, osteoporosis or vitamin D deficiency (rickets and osteomalacia) were also not observed. From the 9 non-adults with erupted permanent teeth, 3 exhibited cariuos cavities (33.3%) and only 1 male individual had a cavited lesion. It is worth to mention that in the São Jorge Castle sample only 4 adults have teeth preserved. The sample size is too small to warrant statistical comparison. .

### 4.2 Stable isotope analysis

All samples passed collagen quality criteria (%C, %N, C:N, De Niro, 1985; van Klinken, 1999) and sufficient collagen was extracted in all samples (>1% yield) apart from one case (CSJ.PC.20). This sample was not included in the analysis. It should be noted that the use of ultrafilters is known to substantially decrease collagen yields (Jørkov et al. 2007).

A summary of the stable isotope data including mean and standard deviation of the main species, adult and non-adult individuals is provided in Table 3. The human and animal stable isotope data are listed in Tables 4 and 5 and plotted together in Figure 3.

**Table 3** Summary of isotopic data for adults (>18yrs) and non-adults (<18 yrs) from São Jorge Castle (10th-11th centuries) and animals from Praça da Figueira (1st-14th centuries)

| | | $\delta^{13}C_{VPDB}$ (‰) | | | | $\delta^{15}N_{AIR}$ (‰) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site/species | n | Min | Max | Range | Mean ± 1σ | Min | Max | Range | Mean ± 1σ |
| SJC adults | 10 | -19.4 | -18.5 | 0.9 | -18.9 ± 0.3 | 8.6 | 11.2 | 2.6 | 9.9 ± 0.8 |
| SJC non-adults | 17 | -18.8 | -16.5 | 2.2 | -18.1 ± 0.6 | 8.4 | 13.1 | 4.3 | 10.9 ± 1.2 |
| *B. taurus* (cattle) | 10 | -21.8 | -20.2 | 1.6 | -21.1 ± 0.5 | 4.9 | 11.1 | 6.2 | 6.3 ± 1.9 |
| *O. aries* (sheep) | 5 | -21.6 | -20.0 | 1.6 | -20.8 ± 0.6 | 4.5 | 9.9 | 5.4 | 6.6 ± 2.4 |
| *C. hircus* (goat) | 3 | -20.6 | -20.0 | 0.6 | -20.2 ± 0.6 | 4.0 | 10.6 | 6.7 | 6.5 ± 3.6 |
| *Sus* (pig/wild boar) | 6 | -21.0 | -18.9 | 2.1 | -20.0 ± 0.8 | 4.9 | 7.7 | 2.8 | 6.6 ± 1.0 |
| *Gallus* (chicken) | 5 | -19.9 | -18.4 | 1.4 | -19.0 ± 0.6 | 8.0 | 10.7 | 2.7 | 9.4 ± 1.3 |

Despite the wide chronology for the animal samples, there is no chronological pattern to the data. All domestic animals exhibit a diet based on $C_3$ plants with no trace of $C_4$ plants. Herbivores from all periods exhibit widely ranging $\delta^{15}N$ values (4.0 to 11.1 ‰, range 7.1 ‰). Nitrogen isotope signatures for chickens are very close to the human individuals from SJC which indicates that they were fed on domestic food waste. Both food scraps and insects, typically included in the chicken diet, have enriched nitrogen isotope values (Reitz et al. 2016) and a similar pattern of human and chicken values have been found at a late medieval Muslim site (Alexander et al. 2015). The two pigs of Islamic chronology plot similarly to the herbivores and pigs from other periods, therefore indicating that they may possibly be wild, however we cannot be certain since pigs have shown very variable isotope values in previously analysed medieval assemblages (Halley and Rosvold 2014). The single dog exhibits surprising enrichment in both $^{13}$C and $^{15}$N in comparison to both animals and humans. The isotopic values suggest a diet based on marine resources, which is unique among the individuals sampled here. However, this is a juvenile (unfused femur) and therefore may retain a nursing signal; furthermore, the dog derives from Roman contexts and so may not be indicative of Medieval subsistence or husbandry in the city.

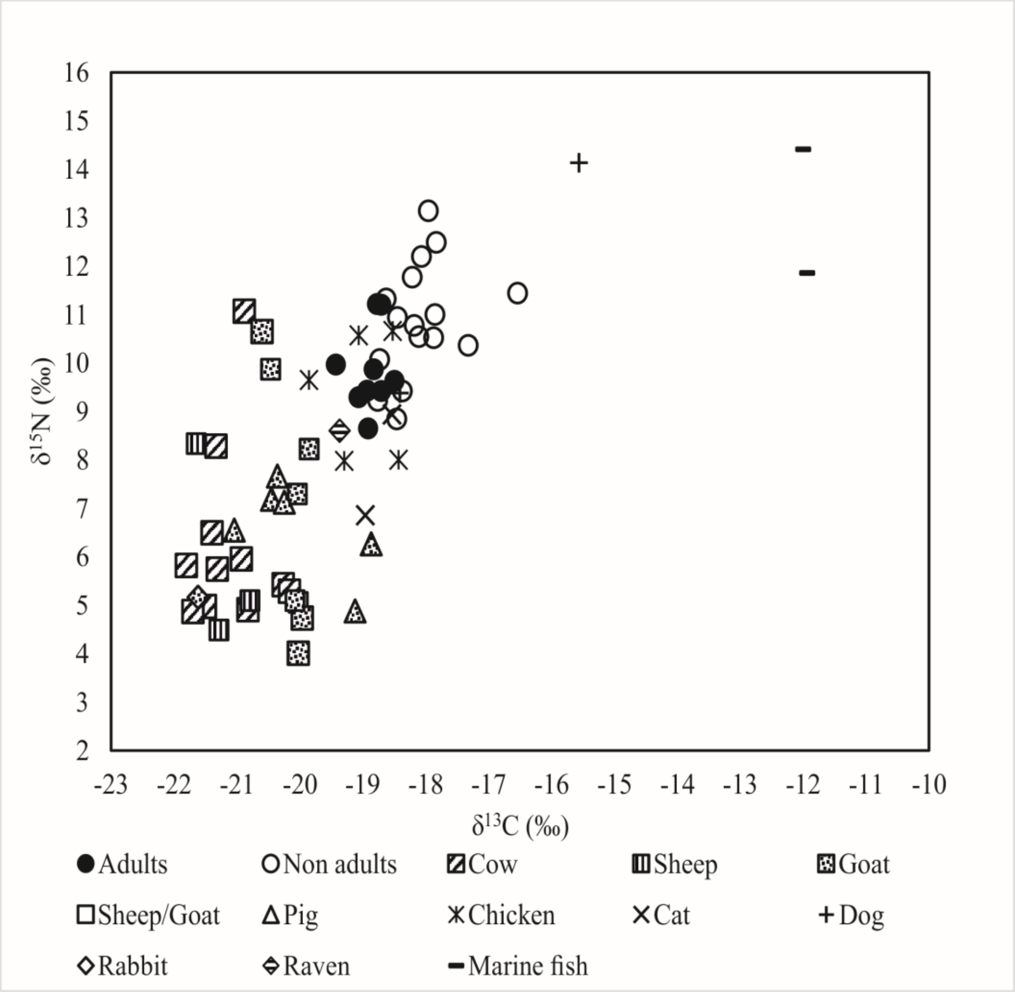

**Fig. 3** Plot of $\delta^{13}$C and $\delta^{15}$N values for the Muslim individuals from São Jorge Castle (10th-11th centuries) and animals from Praça da Figueira (10th-11th centuries)

Perhaps the most notable feature of the human results is that despite the coastal location of Lisbon, marine resources do not appear to play a major role in the human diet, with humans possessing carbon and nitrogen isotope values indicative of a terrestrial, $C_3$-based diet. The trophic level offset between humans and herbivores is within the expected range of 3-5‰ (Bocherens and Drucker 2003). Male values are on average 1.8‰ higher in $\delta^{13}$C and 4.5 ‰ in $\delta^{15}$N compared to the herbivores, while female values are 1.9 ‰ higher in $\delta^{13}$C and 3.1 ‰ in $\delta^{15}$N. Although males were consuming higher trophic level protein, females were still eating animal products. When the population is divided by sex, males are enriched in $^{15}N$ compared to the females (Fig. 4). The difference is significant for $\delta^{15}N$ but not for $\delta^{13}C$ (two samples Mann-Whitney U test, p= 0.02 and p= 0.89 respectively). In contrast, Muslim individuals from the Lisbon suburb (Calçadinha do Tijolo - CDT), do not indicate a sex related difference in diet. Males and females from CDT have similar values of both $\delta^{13}C$ and $\delta^{15}N$ and plot with the females from the SJC.

A second clear trend is shown by adult and non-adult individuals that display a significant difference in both their $\delta^{13}C$ and $\delta^{15}N$ values (two-sample Mann-Whitney U test, p= 0.00 and p= 0.04 respectively). The non-adults show a typical breastfeeding signal (Millard 2000; Jay et al. 2008) with individuals of less than 3 years of age showing enriched $^{13}C$ and $^{15}N$ (Fig. 4). The individuals older than 3 years seem to have a similar diet to the female individuals.

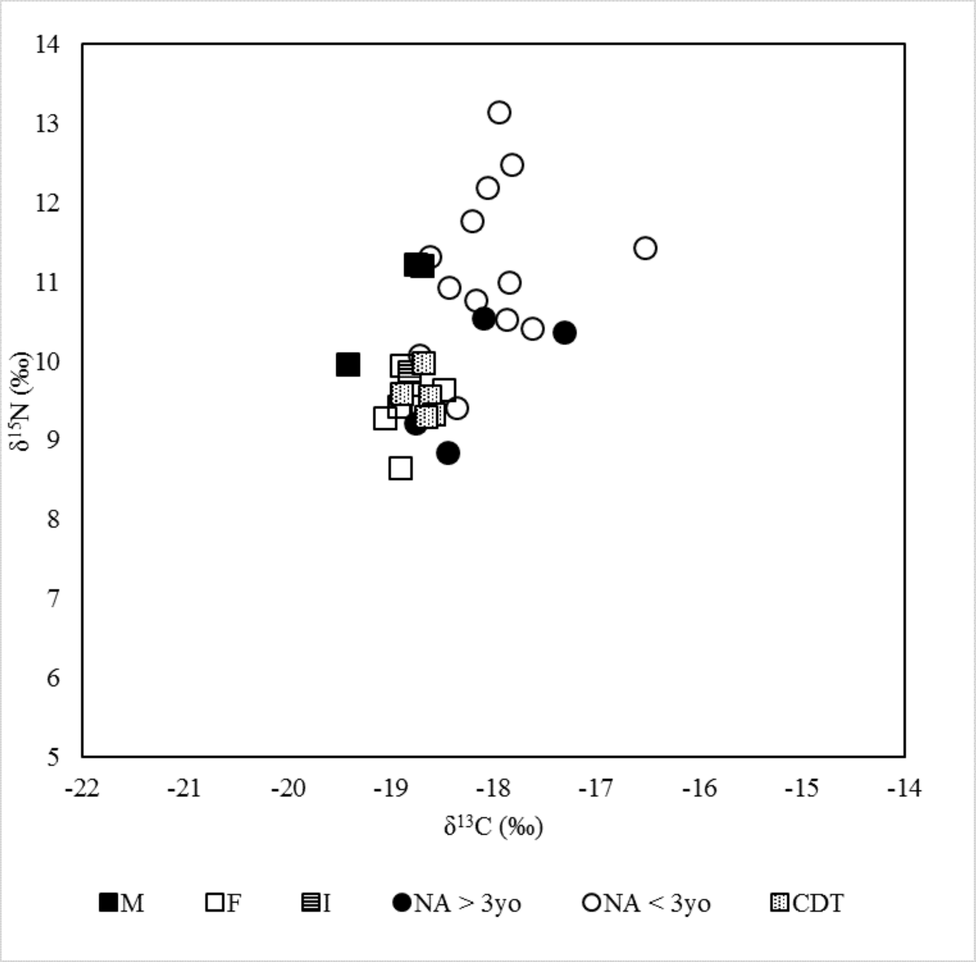

**Fig. 4** Plot of $\delta^{13}C$ and $\delta^{15}N$ values of the SJC individuals divided by sex and age groups: males (M), females (F), indeterminate sex (I), non-adults (NA). A comparative sample of Muslim individuals from urban Lisbon (Calçadinha do Tijolo) is included.

**Table 4** Values of $\delta^{13}$C and $\delta^{15}$N of the humans with indication of sex and age at death.

| Site | Sample | Sex | Age | $\delta^{13}C_{VPDB}$ (‰) | $\delta^{15}N_{AIR}$ (‰) | C/N | %Col |
|---|---|---|---|---|---|---|---|
| Praça Nova | 1 | M | 30-49 | -18.8 | 11.2 | 3.23 | 0.74 |
| | 2 | F | 18-29 | -18.7 | 9.4 | 3.22 | 2.91 |
| | 4 | I | 0.16-5 | -18.4 | 9.4 | 3.20 | 4.79 |
| | 5 | I | 12-17 | -17.3 | 10.4 | 3.2 | 2.52 |
| | 6 | I | 0.16-5 | -18.1 | 12.2 | 3.18 | 39.40 |
| | 7 | I | 0.16-5 | -16.5 | 11.5 | 3.27 | 2.72 |
| | 8 | I | 0.16-5 | -17.8 | 12.5 | 3.26 | 8.8 |
| | 10 | I | NB | -18.7 | 10.1 | 3.22 | 1.43 |
| | 11 | I | NB | -18.6 | 11.3 | 3.38 | 2.14 |
| | 12 | I | NB | -17.6 | 10.4 | 3.31 | 1.23 |
| | 13 | I | NB | -18.2 | 11.8 | 3.23 | 1.51 |
| | 14 | I | NB | -17.8 | 11.0 | 3.18 | 3.10 |
| | 15 | I | NB | -17.9 | 10.5 | 3.29 | 1.30 |
| Palácio das Cozinhas | 1 | M | IA | -18.7 | 11.2 | 3.16 | 3.98 |
| | 2 | I | 18-29 | -18.8 | 9.9 | 3.29 | 0.12 |
| | 3 | I | 6-11 | -18.1 | 10.5 | 3.21 | 3.75 |
| | 4 | I | 0.16-5 | -18.2 | 10.8 | 3.20 | 4.10 |
| | 5 | I | 12-17 | -18.8 | 9.2 | 3.17 | 7.78 |
| | 7 | F | 18-29 | -19.1 | 9.2 | 3.15 | 0.99 |
| | 8 | M | 18-29 | -19.4 | 10.0 | 3.22 | 1.90 |
| | 11 | I | 12-17 | -18.4 | 8.8 | 3.17 | 7.41 |
| | 12 | F | 18-29 | -18.9 | 9.9 | 3.19 | 0.64 |
| | 13 | I | 0.16-5 | -17.9 | 13.1 | 3.25 | 2.96 |
| | 14 | F | >50 | -18.5 | 9.6 | 3.33 | 1.33 |
| | 16 | F | 30-49 | -18.9 | 9.4 | 3.2 | 5.59 |
| | 17 | I | 0.16-5 | -18.4 | 10.9 | 3.19 | 3.56 |
| | 19 | F | 30-49 | -18.9 | 8.6 | 3.21 | 1.91 |
| | ~~20~~ | ~~I~~ | ~~0.16-5~~ | | | | ~~0.2~~ |

**Table 5** Values of $\delta^{13}$C and $\delta^{15}$N of the faunal remains (Praça da Figueira).

| Site | Sample | Period | Taxon | $\delta^{13}C_{VPDB}$ (‰) | $\delta^{15}N_{AIR}$ (‰) | C/N | %Col |
|---|---|---|---|---|---|---|---|
| Praça da Figueira | 8605C | 1st-3rd | *B. taurus* | -20.3 | 5.4 | 3.31 | 1.09 |
| | 8584C | 1st-3rd | *B. taurus* | -21.4 | 6.5 | 3.21 | 5.22 |
| | 8521C | 1st-3rd | *B. taurus* | -21.3 | 5.7 | 3.21 | 3.04 |
| | 8204C | 1st-3rd | *B. taurus* | -21.5 | 5.0 | 3.18 | 4.51 |
| | 7500C | 1st-3rd | *B. taurus* | -20.9 | 6.0 | 3.26 | 4.66 |
| | 4179C | 1st-3rd | *B. taurus* | -21.8 | 5.8 | 3.20 | 1.73 |
| | 3602C | 12th | *B. taurus* | -20.2 | 5.3 | 3.19 | 8.74 |
| | 1227C | 14th | *B. taurus* | -21.7 | 4.9 | 3.20 | 7.34 |
| | 1184C | 14th | *B. taurus* | -20.8 | 4.9 | 3.19 | 7.32 |
| | 1177C | 14th | *B. taurus* | -21.3 | 8.3 | 3.20 | 6.42 |
| | 1164S | 14th | *B. taurus* | -20.9 | 11.1 | 3.23 | 4.12 |
| | 8584S | 1st-3rd | *C. hircus* | -19.9 | 4.7 | 3.21 | 2.49 |
| | 8541S | 1st-3rd | *C. hircus* | -20.0 | 4.0 | 3.20 | 9.26 |
| | 8521S2 | 1st-3rd | *C. hircus* | -20.6 | 10.6 | 3.24 | 4.71 |
| | 4311S | 1st-3rd | *O. aries* | -21.3 | 4.5 | 3.29 | 3.13 |
| | 8504S | 1st-3rd | *O. aries* | -20.8 | 5.1 | 3.20 | 4.35 |
| | 8507S | 1st-3rd | *O. aries* | -20.5 | 9.9 | 3.19 | 7.99 |
| | 8513S | 1st-3rd | *O. aries* | -21.6 | 8.3 | 3.23 | 3.57 |
| | 1173S | 14th | *O. aries* | -20.0 | 5.0 | 3.20 | 4.10 |
| | 8211B | 1st-3rd | *G. gallus* | -19.1 | 10.6 | 3.31 | 5.61 |
| | 8504B2 | 1st-3rd | *G. gallus* | -19.8 | 9.6 | 3.23 | 3.34 |
| | 8504B | 1st-3rd | *G. gallus* | -18.5 | 10.7 | 3.32 | 14.27 |
| | 8507B | 1st-3rd | *G. gallus* | -18.4 | 8.0 | 3.23 | 4.61 |
| | 8503B | 1st-3rd | *G. gallus* | -19.3 | 8.0 | 3.25 | 2.65 |
| | 8541P | 1st-3rd | *Sus domesticus* | -18.9 | 6.3 | 3.20 | 2.25 |
| | 8581P | 1st-3rd | *Sus domesticus* | -20.4 | 7.2 | 3.18 | 3.75 |
| | 8659P | 1st-3rd | *Sus domesticus* | -21.0 | 6.5 | 3.26 | 1.44 |
| | 1269P | 12th | *Sus domesticus* | -20.2 | 7.1 | 3.25 | 3.86 |
| | 1374P | 12th | *Sus domesticus* | -19.1 | 4.9 | 3.43 | 4.14 |
| | 1177P | 14th | *Sus domesticus* | -20.3 | 7.7 | 3.19 | 6.13 |
| | 8510M | 1st-3rd | *C. familiaris* | -15.6 | 14.1 | 3.17 | 0.49 |
| | 3833D | 1st-3rd | *C. familiaris* | -18.4 | 9.4 | 3.22 | 0.85 |
| | 1254B | 12th | *F. catus* | -18.5 | 8.9 | 3.17 | 7.5 |
| | 1173BB | 14th | *F. catus* | -18.9 | 6.9 | 3.25 | 9.4 |
| | 8299H | 1st-3rd | *Equus sp.* | -18.3 | 6.0 | 3.23 | 1.26 |
| | 1173B | 14th | *O. cuniculus* | -21.6 | 5.2 | 3.23 | 2.02 |
| | 8521B | 1st-3rd | *Corvus corax* | -19.4 | 8.6 | 3.19 | 8.75 |
| | 9106F | 1st-3rd | *M. merluccius* | -12.0 | 14.4 | 3.16 | 4.42 |
| | 2076F | 12th | *G. galeus* | -11.9 | 11.9 | 3.32 | 1.33 |

## 5. DISCUSSION

### 5.1 Paleopathological assessment

The São Jorge Castle collection presents low frequencies of ‘stress’ markers. As observed in other collections, the frequency of LEH in the SJC collection is higher in the adult sample and the CO frequency is higher in the non-adult sample (Robles et al. 1996; Herrscher 2001; Garcia 2007). Higher frequencies of LEH have been interpreted in bioarchaeology as an indicator of temporary growth disruption associated with a state of illness, undernutrition or both (Goodman 1991; King et al. 2005; Ritzman et al. 2008). Although the frequency of LEH is higher in the adult sample, it reflects the first 6 years of development of individuals. Thus, any event that could explain the formation of LEH had to occur in this timeframe and always reflects the experience of some developmental constraints. The non-adults with LEH were older than the ones without, but the small size of the samples demands that the results of the LEH and also of the other stress markers be interpreted with caution.

For instance, as observed in other collections, the frequency of CO is higher in the non-adult sample in comparison with the adult sample (Herrscher 2001; Garcia 2007). There are many possible causes associated with CO. The traditional explanation linked the occurrence of CO with iron deficiency anaemia (Stuart-Macadam 1985) derived either from a deficient intake of iron, a difficulty in its absorption, or significant losses. Other explanations are based in the hereditary transmission of haemolityc diseases as sickle cell anaemia or thalassaemia. Although recent discussion had questioned the validity of iron deficiency explanations (Walker et al. 2009), many authors have advocated the importance of not excluding them, and to take into account the diversity of contexts for the interpretations (Walker 1986; Blau 2001; Facchini et al. 2004; Oxenham and Cavill 2010; McIlvaine 2015). The funerary context of this sample indicates that these individuals were privileged in Islamic society since they were buried inside the walls of the Lisbon castle. The results of the stable isotope analysis indicated that two individuals with CO showed a breast-feeding pattern and women and older children exhibited a diet that incorporated lower trophic level protein than males. It may mean that maternal iron levels were already low and this resulted in higher frequencies of CO in these children.

The lack of evidence of any infectious disease, including non-specific ones, and the low frequencies of stress markers are in keeping with the high-status nature of the population. Poor nutrition which may be expected in low-status populations is often linked to elevated levels of infectious disease and stress (Larsen 2002). Nevertheless, this collection is characterized by being greatly represented by young non-adults that, although simulate a “disease-free” population, died before adulthood. The problem of a selective mortality (Wood et al. 1992) should be considered, at least as a theoretical concern. However, studies have been consistent in demonstrating that enamel linear hypoplasias are more frequent in populations representative of a lower socio-economic status (Goodman and Rose 1991; Goodman 1993; Geber 2014). In populations with high fertility and high mortality, it is expected to find that around 40% of the archaeological cemetery are non-adults, but in the Lisbon sample, 60% of the individuals are under 18 years of age. This pattern emerges when there is an excess of mortality triggers by starvation or other acute health crisis (Geber 2016). However, interpretation of this biased mortality profile is hampered by the small number of individuals in this population.

The expression of caries lesions (30.8%) in individuals with erupted permanent teeth is lower than that observed in other populations such as Later Medieval Christians from Portugal and Muslims from Spain For instance, in São Martinho, Leiria the prevalence, in individuals with deciduous permanent erupted teeth was 56% and 19% in non-adults with permanent dentition. Adults from São Martinho had a prevalence of 84% (Garcia, 2007). The same is observed comparing the values with the Islamic collection of Xarea, where the prevalence of caries affects 73% of adults (Robledo 1998). The relationship between caries and diet has long been investigated and there are many studies that agree that there is a relationship between the ingestion of fermentable carbohydrates and an increase in the metabolic activity of cariogenic bacteria (Powel 1985; Moynihan and Petersen 2004). On the other hand, proteins and dietary fats seem to have a protective effect against caries (Mundorff-Shrestha et al. 1994) due to their basic nature (opposing to the acid nature of carbohydrates) that slows the bacteria activity (Powell 1995, Costa 1980). The low prevalence of caries in the population from the Castle may be the result of consumption of moderate amounts of carbohydrates alongside regular consumption of animal proteins and dietary fats which complements the results of the stable isotope analysis which indicates a reliance on animal products in the diet.,

### 5.2 Dietary patterns: stable isotope analysis

Despite the uncertainty related to the long chronology of the faunal remains, husbandry practices for the main domestic species seem to be constant in Lisbon throughout time. The majority of the domestic species show an herbivorous diet based on $C_3$ plants. Notably, a few individuals (two cows, two sheep and one goat) have enriched $\delta^{15}N$ values. This wide range in $\delta^{15}N$ values for herbivores can occur for a number of reasons. Environmental factors such as temperature, aridity, coastal proximity and isotopic composition of plants (Amundson et al. 2003; Hartman 2011) but also specific human land use practices such as manuring, can shift the baseline values (Fraser et al. 2011). Animals that are reared near urban centres are more likely to show enriched $\delta^{15}N$ values (Hedges et al. 2005; Reitz et al. 2016). Metabolic and physiological pathways between different species could also affect $\delta^{15}N$ values; however this is not the case in Lisbon, since a wide range of values is exhibited among individuals of the same species (Itahashi et al. 2014). The variation in herbivore values can also indicate a wider provisioning area. From historical sources, it is known that animals consumed in urban areas were not always reared near the settlements (Catarino 1998:39). Toponyms in the surrounding of Lisbon, with particular mention of the areas upstream of the river Tagus for the Muslim and Christian period, suggest the existence of pastures (Gomes Barbosa 1995:20; Catarino 1998:34). Thus, these differences in herbivore diet suggest distinct management strategies and/or provenance for these individuals.

The adult diet of this high status population is prominently terrestrial and based on $C_3$ plants as suggested by historical sources. Although $C_4$ plant consumption has been found in isotopic studies of

Medieval Muslim populations from Valencia (Salazar-Garcia et al. 2014; Alexander et al. 2015) and in late antique and medieval populations in Galicia (Lopéz-Costas and Müldner 2016; López-Costas 2012), there is no indication of their inclusion in the diet of the humans or animals from Lisbon. This is despite historical records indicating that they were available. Crops such as millet and sorghum may have been considered to be low-status crops (García-Sánchez 1996:223; Alexander et al. 2015) and the lack of evidence for them in the diet, especially among the SJC individuals may reflect the privileged status of this population.

In terms of animal proteins, given the aforementioned wide range in nitrogen isotope values, it is difficult to pin down specific species that were consumed. It is likely that herbivores played a significant part in the diet of these individuals, with omnivores like chickens supplementing the diet of some, particularly those with higher nitrogen isotope values. The isotopic evidence indicates that marine fish were not a significant part of the diet. This is surprising given the location of Lisbon and its intrinsic relationship with both the sea and the river Tagus. However, limited consumption of low trophic level fish that typically live near the coast would not be detected by isotopic analysis. As well, dietary models indicate that a terrestrial based diet could include up to 20% marine protein without raising bone collagen $\delta^{13}$C values, therefore underrepresenting marine food unless consumed in substantial amounts (Hedges 2004; Milner 2004). Freshwater fish, although is a plausible and abundant resource in the Tagus River, was probably not widely consumed. In this regard cultural and religious preferences should also be considered. The Quran does not prohibit the consumption of fish; however, some sections of Islam did consider it unlawful, mainly in the Eastern Shia tradition (Pellat et al. 2012). Arab authors, following their Greek predecessors, had different opinions on the benefit of fish; however, it was commonly believed that fish were less nutritious than meat and generally not as good for human consumption (García-Sánchez 1986:259). Fish recipes are also very scarce in medieval Andalusian cookbooks, usually accounting for 4-10% of the presented recipes (García-Sánchez 1986:264-265). The only medieval Portuguese cookbook available unfortunately dates to the late medieval Christian period (Manuppella 1987). A lack of zooarchaeological data also hinders the assessment of the consumption of marine resources in Islamic Lisbon. Sieving is not routinely carried out due to the time constraints that recovery processes imposed on rescue and commercial archaeology in the city.

### Sex related trends in diet

When considering the diet of this population in relation to sex, women and men display a different diet (Fig.4), with males generally possessing higher $\delta^{15}$N than females. This could indicate that males derived a greater proportion of their dietary protein from animal rather than plant sources in comparison to females or that they consumed higher trophic level protein from chickens or potentially freshwater fish, which would also serve to enrich $^{15}$N values (Hedges and Reynard 2007). This sex difference in food consumption can be an expression of family organization and use of domestic space in a high status context where men and women may not have necessarily eaten together. Historical sources from as early as the 11th century describe specific spaces for women within a household or palace in Al-Andalus (Díez Jorge 2002:159). In the household, the man was required to provide a separate room for his wife and a separate house if he married a second wife (Pérez Ordoñez 2009:5). A series of norms and regulations about the use of domestic space are reported (Marín 2000:237), but these regulations were more feasible in large, high status household with many rooms. This connection between family and domestic architecture has been studied in medieval Morocco. The centralized structure of the houses in Maghreb with equal cells surrounding a central space is said to reflect the family structure of its inhabitants: wives and children are relatively equal to each other but subordinate to the male head of the household (Fortress 2000). This hierarchy might also be reflected in terms of access to specific foods among the higher social classes. In the case of lower status nuclear, one-room houses common across Islamic settlements, such as those excavated in Praça da Figueira (Díez Jorge 2002:161), it is probable that men and women were more likely to share space and food. In a similar vein, medium and lower-status women were less restricted in their daily activity, being free to wander in public spaces and use the public baths, unlike women of high status (Coope 2013, Lachiri 1993). This may be why there is no sex difference detected among low status individuals.

In terms of female-specific diets, historical sources provide scarce information on the women in Al-Andalus and even less on their diet; however, medical recommendations are provided on the consumption of specific foods for women during specific periods of their life, especially during pregnancy and breastfeeding (García-Sánchez 2006). Women were encouraged to consume high calorific food such as fats, sugars and carbohydrates in order to put on weight for aesthetic and fertility purposes (García-Sánchez 2006:217). The Kitāb al-Tabīj, an Andalusian cookbook compiled by an anonymous author in the 13th century, includes a few recipes referred to as 'food for women' that had exactly this purpose (Martinelli 2012). In this case, the diet shown by the SJC women could fit this scenario with lower proportion of animal protein consumed. In medieval Cairo men were said to eat street food very often because of its quality and because they did not like to eat what women cooked in the house (Lewicka 2011:120). One reason for this might have been the prejudice that menstruating women had a negative influence on the quality of the food. However, it seems that the allocation of food preparation in all its stages could vary considerably between different locations throughout the Islamic world. In Baghdad women are said to exclusively prepare meals for the household and are the only ones to undertake the traditional preparation of couscous in the Maghreb (Waines 1987). In terms of a typical high-status male diet, one could infer that the entirety of etiquette manuals and cookery books were actually intended for higher-status male individuals and are therefore a reliable source of information. The Arab-Islamic table, as much as its European counterpart, was dominated by men, and women were not taking part. They could watch the banquet from a shielded area or eating in their part of the house (Visser 2012: 279, Lewicka 2011:401).

When this high status population is compared with a contemporaneous Muslim urban population from Calçadinha do Tijolo (CDT), female individuals have a very similar diet to these lower status individuals that include both females and males (Fig.4). This sex related difference does not seem to affect the urban population in Lisbon. Therefore, rather than the high-status females from the castle exhibiting a unique diet, it appears that high status males are more distinctive in their eating habits compared to the rest of the urban population of the time. This difference for the high status male individuals could be linked to their activities taking place outside the home and them potentially having access to a wider range of foodstuffs. Although similar patterns have been recorded elsewhere in Muslim Spain with males consuming higher trophic level proteins (possibly riverine fish) in Tauste, for example (Guede et al. 2017), a sex difference in diet is not a common trend among isotopic datasets for Mulism populations from Spain (Fuller et al. 2010; Salazar-García et al. 2014, 2016; Alexander et al. 2015). The small sample sizes from Lisbon hamper any definite conclusions regarding diet and sex.

### Age related trends in diet

The weaned non-adults of this population share a similar diet to the female individuals. There are few explicit references in historic literature for culinary products shared by women and children. Women and children were considered of different physiological nature (children were hot and humid, while women were colder and drier), therefore this similar food consumption is not associated with the humoral theories (Oliveira 2007:31). However, childcare is traditionally entrusted to women and it is likely that physical proximity would have prompted the consumption of similar meals. To the best of our knowledge, it is the first time a similar trend is shown by isotopic data in an Islamic population and further exploration of non-adult diet is needed to assess the prevalence of this practice.

Breastfeeding, although sometimes performed by wet-nurses among high status families, was considered by Christian and Muslim medieval societies of vital importance to child development and health (Giladi 1998:108; Shahar 1990:57; Winer 2008). Our results show that the majority of the non-adults under the age of three were still breastfed in accordance with medical and historical sources from both the Muslim and Christian world, which suggested breastfeeding to at least until two years of age (Baumgarten 2004; Fildes 1986). When compared to other archaeological Medieval populations, the individuals from SJC appear to follow a similar pattern of enriched nitrogen isotope values compared to the females' mean value of their respective populations (Fig. 5). This is the expected signature for breastfeeding and weaning and can be observed across all sites. The nitrogen isotope ratios start to decrease at SJC around two years of age, as would be expected from historical sources, while at other sites such as Grenoble, Fishergate, Raunds and Tauste the weaning period seems to occur slightly later. However, a lack of individuals between the age of two and six years old at SJC could mask a similar pattern and prevent a more precise estimate of the weaning age of this Muslim population. Incremental dentine layers analysis may have served to pinpoint weaning times with greater precision (King et al. 2018); however, sampling restrictions did not permit destructive analysis of dentition. It should also be borne in mind that due to the 'osteological paradox' (Wood et al. 1992; Beaumont et al. 2015) the non-adults here are non-survivors that may not reflect the dietary practice of the 'healthy' population (Beaumont et al. 2015).

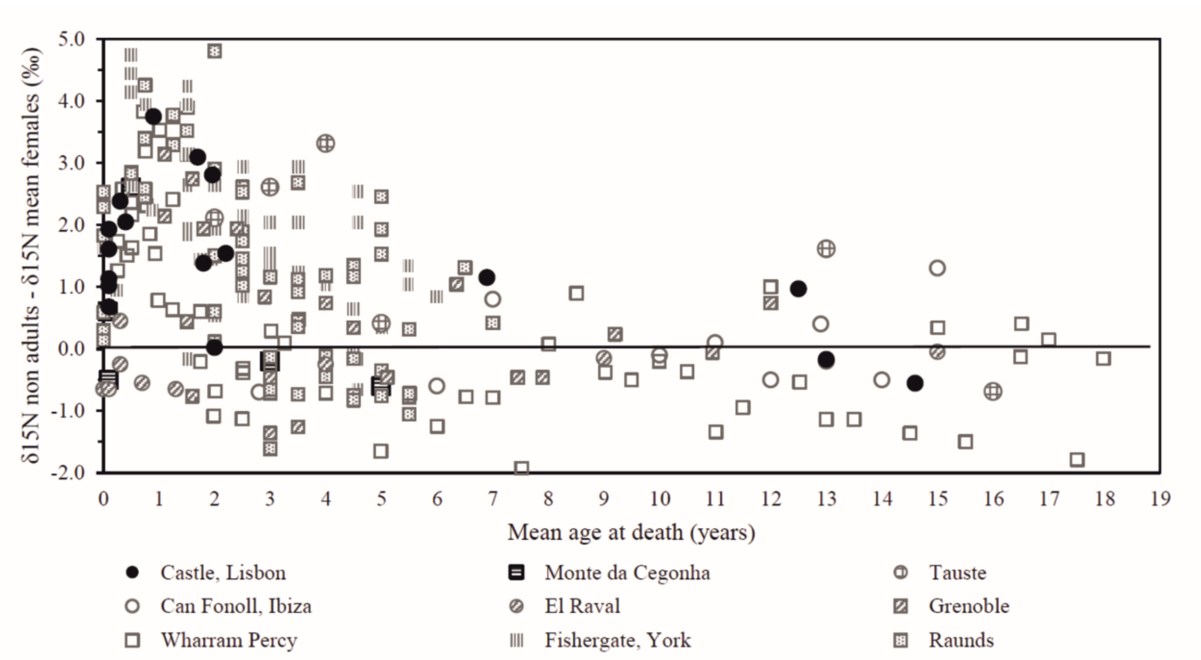

**Fig. 5** Breastfeeding and weaning pattern of non-adult individuals from SJC, Lisbon and Monte da Cegonha compared to other Muslim and Christian populations from Spain, France and UK. The comparative sites are Monte da Cegonha, Portugal (Saragoça et al. 2016), Tauste, Spain (Guede et al. 2017), Can Fonoll, Ibiza, Spain (Pickard et al. 2017), El Raval, Spain (Salazar-García et al. 2014), Grenoble, France (Herrscher 2003), Wharram Percy, UK (Richards et al. 2002), York, UK (Burnt 2013), Raunds, UK (Haydock et al. 2013).

## Diet and status

Status played an important role in food access, both in terms of quantity, quality and variety of the available resources. High status people not only had easier access to a greater quantity of food but also to a wider selection of products. Previous studies on medieval population in Sweden (Linderholm et al. 2008, Bäckström et al. 2017), UK (Müldner and Richards 2007, Müldner et al. 2009), Italy (Reitsema and Vercellotti 2012) and France (Colleter et al. 2017) have explored the influence of status on diet, examining the correlation between isotopic values and graves goods or burial type. In these previous examples, more high status individuals consumed marine protein and/or higher trophic level terrestrial protein. Although the small sample size constitutes a limitation in the SJC assemblage, the sex-related difference in diet that was found in this population may be an expression of its social status, further supported by the lack of any sex related difference in diet in the urban population of Calçadinha do Tijolo.

Contemporaneous (10th-13th centuries) medieval high status individuals have been recently analysed from the Royal Houses of Castile and Aragon (Jiménez-Brobeil et al. 2016; Martínez-Jarreta et al. 2017). The Royal members showed higher $\delta^{15}$N compared to other medieval Spanish populations suggesting the inclusion of higher trophic level protein such as pig and freshwater fish. Although the difference between female and male $\delta^{15}$N values is not significant, males have higher $\delta^{15}$N mean (12.8‰ ±1.3) than females (11.3‰ ±1.7). While the Spanish royal members, both females and males, showed higher $\delta^{15}$N values compared to contemporaneous populations; in Lisbon, this status-related difference can be seen in males only, similarly to what was found at Whithorn Cathedral Piory (Müldner et al. 2009), Fishergate, York (Müldner and Richards 2007) and Brittany (Colleer et al. 2017).

### Wider comparison with the Iberian dataset

The two Lisbon populations (SJC and Calçadinha do Tijolo) were compared to contemporaneous populations from the Iberian Penninsula (Fig. 6). The comparison indicates that there is an extremely similar diet shared by 9th-11th century Lisbon and the Portuguese Late Antique individuals from Monte das Cegonhas suggesting the continuation of dietary practice between the Late Antique and the Islamic period. More widely, similar mean isotopic values are exhibited by contemporaneous Muslim populations from Tossal de les Basses (Alicante), the Balearic Islands, and a Late Antique population from Madrid (Salazar-García et al. 2016; Nehlich et al. 2012; Cau Ontiveros et al. 2016, Pickard et al. 2017, Lubritto et al. 2017). The stark difference between Portuguese sites and data from Galicia is notable (López-Costas and Müldner 2016), with the latter exhibiting higher $\delta^{13}$C values despite the fact that both geographic areas overlook the Atlantic coast and may be assumed to have similar diets, or at least more similar than populations from the Mediterranean coast of Iberia. Isotopic data have indicated that $C_4$ crops and marine resources were heavily relied upon at least from the Roman period which would both serve to increase $\delta^{13}$C values, however this cannot be seen along the Portuguese coast during the Early medieval period (López-Costas and Müldner 2016). It should be borne in mind that some of the differences here will be not only related to cultural preferences but will also be linked to the environment and climate in each region and any differences may reflect baseline rather than dietary shifts. This is particularly relevant for Tauste, where the consumption of freshwater resources and/or the presence of individuals from more arid climates might have affected the nitrogen isotope values.

The $^{15}$N enrichment exhibited by two males (SK nos.) may alternatively be explained by a possible different geographical origin. Individuals from arid climates tend to possess higher $\delta^{15}$N values (e.g. Schwarcz et al., 1999; Dupras and Schwarcz, 2001). During this period of Islamic rule in Iberia it is highly likely that people were moving from North Africa to the Iberian Peninsula, facilitated by their shared political (and cultural) systems. However, available historical sources lack specific information on this issue. Further analysis of isotopes such as strontium, oxygen or possibly ancient DNA would be needed to explore the theme of mobility at a deeper level.

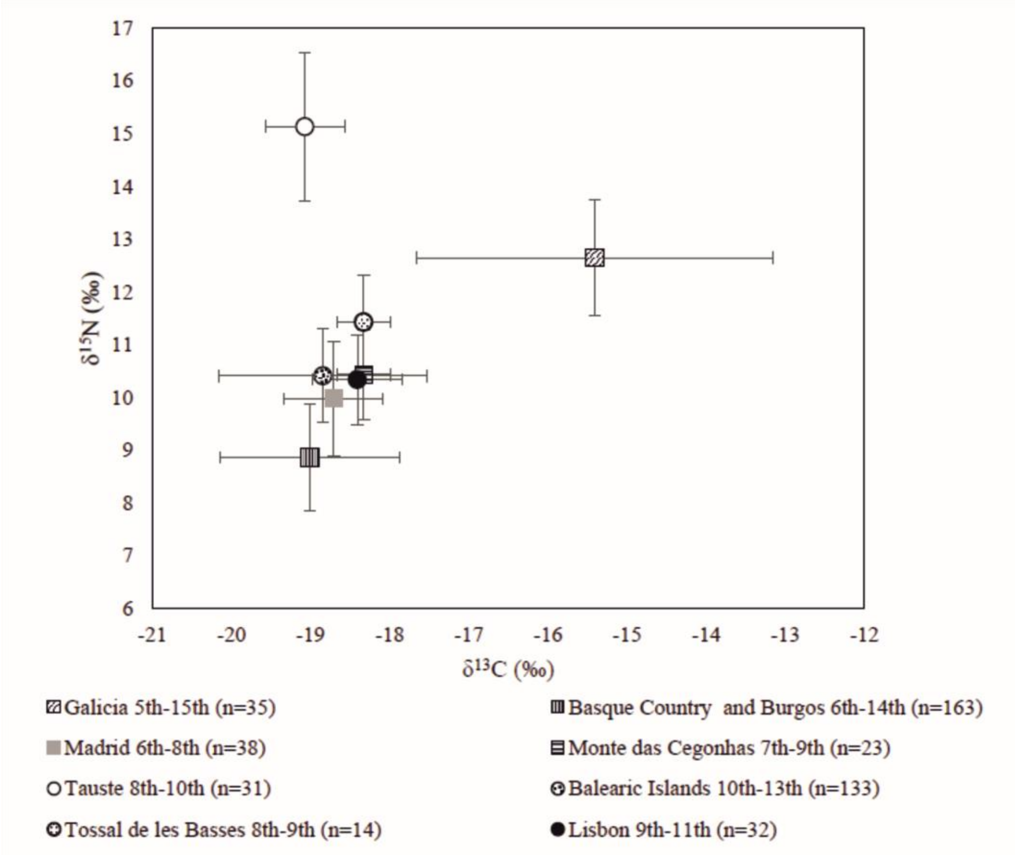

**Fig. 6** Comparison of Lisbon populations (SJC and Calçadinha do Tijolo) with other medieval Iberian populations. The values are presented as a mean, error bars represent ± 1σ.

## 6. CONCLUSION

The São Jorge Castle collection is composed of some young and mature adult individuals of both sexes, although non-adults are in greater number. The frequencies of stress indicators were found to be low and followed a common pattern of age distribution in respect to LEH and CO. LEH is more common in older individuals, and CO and HL in young individuals. The absence of evidence of infectious diseases (including non-specific) and the low frequency of stress markers may reflect the high-status nature of the population. However, the small samples size demands caution during the interpretation of the results.

The isotopic results indicate a terrestrial, $C_3$ based economy. The isotopic signature of the animals, although representing a long chronology, does not show significant changes over time, suggesting a certain degree of continuity in economy and animal husbandry practices between the Roman and Medieval periods in Lisbon. Again, however, the sample size is small and further analyses could explore this observation more fully. All domestic animals were fed or grazed on $C_3$ plants, although some variation due to climate, environmental and physiological factors might have affected the nitrogen isotope values of certain individuals. Results for humans suggested a sex-based difference in diet, with females and non-adults relying on lower trophic level proteins compared to males. In addition, females and non-adults showed a very similar diet, implying that the close proximity of these two groups may have prompted communal consumption practices. These patterns, absent in other Islamic urban populations published from Iberia thus far, may reflect the strict division of sex and age groups in the Islamic household predominantly followed by the higher classes. There is no difference, however, between the privileged females analysed from the castle and males and females from the general population buried outside the castle at Calçadinha do Tijolo. Although the sample size is small, a tentative shift towards high status males exhibiting enrichment in $^{15}N$ is proposed, following a trend seen among other sites in Medieval Europe. The combined bioarchaeological approach used here offers the first detailed insight into the lifeways of high status Islamic populations from Iberia. A major investment in similar studies of other Islamic collections will provide valuable information to allow a better understanding of life and death across Islamic society in al-Andalus.

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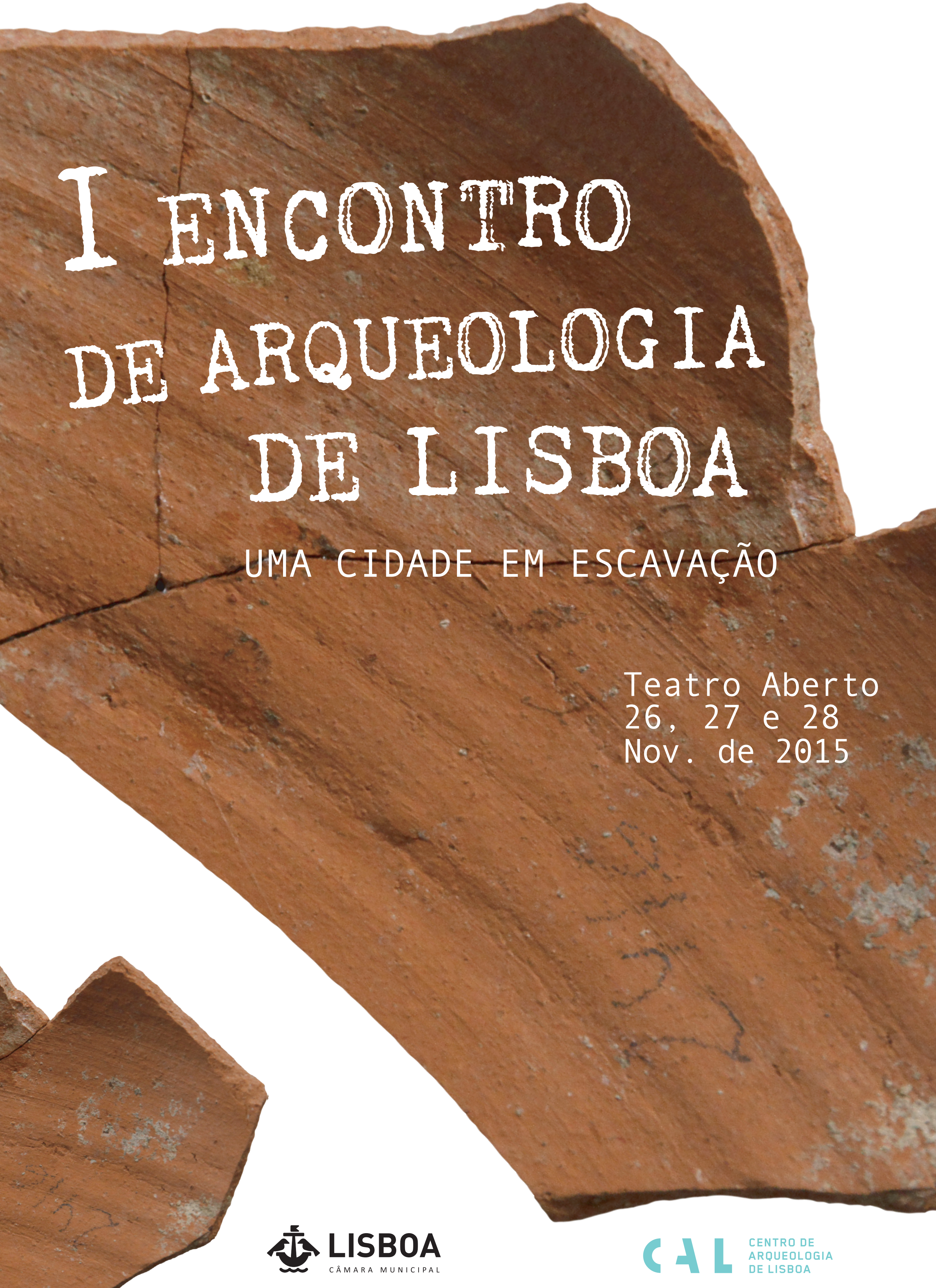

# I ENCONTRO DE ARQUEOLOGIA DE LISBOA

UMA CIDADE EM ESCAVAÇÃO

Teatro Aberto
26, 27 e 28
Nov. de 2015

LISBOA
CÂMARA MUNICIPAL

CAL
CENTRO DE
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# ÍNDICE

# A ARQUEOLOGIA DOS ESPAÇOS, A IDENTIDADE E A FISIONOMIA DA CIDADE

RESUMO:

São numerosas as fontes históricas que nos informam sobre o valor simbólico da comida nas sociedades medievais islâmicas. Este envolve a sua preparação, processo e a continuidade do uso de determinados alimentos na dieta alimentar. A proibição de alguns alimentos revela dados sobre o género e a idade, que permitem compreender a classe social e a comunidade religiosa em que estavam inseridos. As análises dos isótopos de C (δ13C) e N (δ15N) foram aplicadas às presentes necrópoles islâmicas de Lisboa.

Os resultados do presente ensaio perspectivam-se como uma via para o estudo histórico e social-económico da cidade islâmica de Lisboa, providenciando uma análise directa sobre a dieta alimentar e consumo de alimentos pelas comunidades medievais islâmicas que habitavam a cidade.

PALAVRAS-CHAVE:

Arqueobiologia, necrópoles islâmicas, alimentação, análise de isótopos.

ABSTRACT:

There are numerous historical sources that give us information relating the symbolic value of food in the Islamic medieval societies. It involves the preparation, process and continuous use of certain foods in their diet. The prohibition of certain foods reveals data concerning gender and age, allowing to explore social and religious dynamics of the community they live in. Stable isotope analysis of C (δ13C) and of N (δ15N) were applied to the present Islamic necropolis of Lisbon.

The results of the present investigation are leading us into the historical and social-economical information to study the Islamic city of Lisbon, providing a direct evidence of diet and food consumption within the Islamic medieval communities that lived in the city.

KEY WORDS:

Archaeobiology, islamic necropolis, diet, isotope analysis.

*Necrópole de Alfama.*
Individuo em decúbito dorsal

# 3.9 PERSPECTIVAS ARQUEOBIOLÓGICAS SOBRE A NECRÓPOLE ISLÂMICA DE ALFAMA

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## 1. Introdução

À imagem de outras cidades medievais islâmicas, a Lisboa Muçulmana (séculos VIII-XII) segue o modelo de implantação tipificada dos campos mortuários num espaço extramuros junto a um eixo viário de acesso preferencial à medina.

Nesta perspectiva, a identificação de um conjunto de cinco inumações (formalmente consonante com o ritual funerário prescrito pela religião do Corão) durante os trabalhos arqueológicos desenvolvidos no imóvel sito Calçadinha do Tijolo 37-43, Alfama, contribuí para o conhecimento da paisagem urbana de Lisboa. A sua localização topográfica numa plataforma natural a meio caminho entre o Mosteiro de São Vicente de Fora e uma das portas de entrada na urbe medieval islâmica – as Portas do Sol – vai de encontro ao modelo de cidade privilegiado pela civilização muçulmana.

Numa abordagem preliminar, a análise das dietas alimentares através do método de Isótopos permite-nos ensaiar uma proposta socioeconómica e cultural sobre os indivíduos depositados no necrotério oriental.

## 2. Síntese Histórica

Durante o período de dominação medieval islâmica, a cidade de Lisboa adapta a anterior cenografia romano imperial de tradição mediterrânica ao novo modelo operativo de urbe islâmica medieval. Neste sentido, o processo de urbanização islâmico definia um espaço de poder político e religioso – a alcáçova; e um espaço urbano habitacional – a medina.

Unificados dentro da muralha que os envolvia, a denominada "Cerca Moura", são vários os relatos narrativos muçulmanos sobre o périplo amuralhado muçulmano.

*Al-Himari*, um autor do século XIII, na sua descrição sobre a cidade islâmica de Lisboa relata: "*A sua porta ocidental está sobrepujada por arcadas duplas sobre colunas de mármore, fixas em pedras (também) de mármore. É a maior das suas portas. Lisboa tem uma outra porta que se abre a Oeste: chamam-na Porta do Postigo; ela domina uma vasta pradaria, atravessada por dois cursos de água que se lançam no mar. No sul, encontra-se outra porta, a Porta do Mar , na qual penetram as ondas, ao subir e descer da maré, subindo na muralha a uma altura de três braças (sic). A leste, a chamada Porta das Termas, As termas estão perto dela e do mar e nelas [correm] duas águas: água quente e água fria; e quando a maré sobe encobre-as. E uma outra porta oriental, conhecida como a Porta do Cemitério*" (SIDARUS, REI, 2001, p. 58).

Analisando a anterior descrição, o autor muçulmano ao descrever as portas de entrada e saída da urbe lisboeta informa o leitor sobre os limites físicos e geográficos do traçado fortificado islâmico e os nomes comummente usados pela população na designação das portas, relacionadas intimamente com o que se encontrava nas suas proximidades. Por conseguinte, o estudo das fontes escritas medievais permite-nos identificar a Porta do Cemitério com a atual Porta do Sol, localizada no extremo setentrional do percurso oriental da "Cerca Moura".

Sendo que a Porta do Sol, abria-se para o *almocavar* muçulmano (cemitério) que se estendia pelas encostas de São Vicente. É precisamente neste local de encosta que o presente arqueossítio se situa, num espaço extramuros portanto.

No ano de 1147, a cidade de Lisboa é conquistada aos muçulmanos pelo rei D. Afonso Henriques com a ajuda de cruzados cristãos. É precisamente um cruzado inglês, que participa no domínio de Lisboa, que realiza uma das melhores descrições da urbe em período medieval e, uma vez mais, relata a existência de cemitérios junto à porta setentrional do circuito defensivo (BRANCO, 2001).

O olhar cristão sobre o "sarraceno", signo de uma vertente missionária, destaca a sacralização dos espaços anteriormente devotos ao Islão e a fundação de edifícios religiosos movidos pela propaganda da supremacia política cristã. Neste último caso enquadra-se a construção da Igreja e Convento de São Vicente de Fora, precisamente no local onde el-rei assentou o acampamento militar e junto da capela onde os cruzados flamengos enterraram os seus mortos (FERREIRA, 1995, p. 8-13).

A desativação da necrópole terá ocorrido muito possivelmente após a conquista cristã de Lisboa. A sua confirmação é-nos dada no século XIII quando nas proximidades do Mosteiro de São Vicente, se instalou a cinco de Agosto de 1290, o *Estudo Geral*, estabelecendo-se aí o bairro habitacional de estudantes e professores, criado pelo rei D. Diniz – "*tudo o que ficava entre a porta do sol, e Santo Estevão de Alfama, que por respeito chamarão o bairro dos escholares*" (*apud* CASTILHO, 1936, p. 202). De acordo com a supracito, estas residências estudantis instalar-se-iam possivelmente no local da intervenção espraiando-se sucessivamente pela freguesia de Santo Estevão.

Todavia, passados poucos anos, as Escolas Gerais são transferidas para Coimbra, e as casas principais são ocupadas pela Casa da Moeda motivando a construção de edifícios nobres e palacianos nas suas adjacências (SILVA, ALMEIDA, 1987, p. 525; *Idem*, 1994, p. 250). A construção da Cerca Fernandina, entre 1373 e 1375, provedora de defesa e proteção a estes espaços, anteriormente arrabaldes, beneficiou também a instalação das elites lisboetas nesta parte da cidade (SILVA, 1987, vol. I, p. 15). Este movimento de urbanização aristocrata percorre transversalmente a Idade Moderna até ao terramoto de 1755.

## 3. Intervenção Arqueológica

A análise prévia das fontes cartográficas, precisamente do Atlas da Carta Topográfica de Lisboa (FOLQUE, 1856-58), possibilitou a percepção de que a área intervencionada correspondia a um espaço ajardinado desde, pelo menos, a segunda metade do século XIX, algo que também se refletiu no registo arqueológico. Consideramos assim, a "longa" previvência da zona de jardim como factor de importância na preservação do contexto arqueológico funerário.

A escavação arqueológica incidiu sobre toda a área ajardinada, cerca de 60 m2, e permitiu confirmar uma das premissas relativas à cidade islâmica de Lisboa: a localização do campo mortuário, a oriente, inúmeras vezes referido nas crónicas históricas.

Estratigraficamente, com a remoção de um depósito de aterro contemporâneo, foi possível observar o nível de geológico [411], consistindo num solo pouco coerente e pouco compacto, de coloração amarelada. Curioso foi notar numa leve diferença de natureza sedimentar, ao nível da coloração e da textura, o que nos alertou para a possibilidade de sepulturas escavadas diretamente no substrato geológico. Este facto confirmou-se quando, após delimitação do sepulcro [408] e remoção do sedimento de enchimento [409a], se identificou o primeiro esqueleto de um indivíduo depositado em decúbito lateral direito [409], e deposição de pequeno ossário [415], junto ao local onde se encontraria o crânio [409].

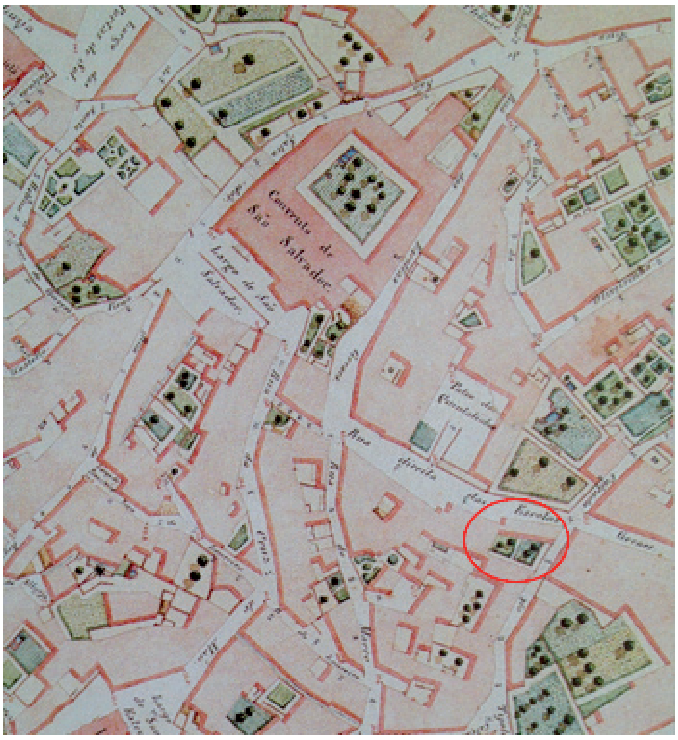

Figura 1 – Localização do arqueossítio a vermelho no mapa de Lisboa de Filipe Folque realizado em 1856-58 (FOLQUE, 1856-58).

Imediatamente a sudeste da inumação [409], definiu-se a sepultura [413] e posteriormente o que restava do esqueleto [410].

Sequencialmente, identificaram-se mais duas sepulturas escavadas diretamente no substrato geológico, a [416] e [419] observando-se a presença de vestígios osteológicos humanos, [418] e [421] respectivamente.

Relativamente a este conjunto de quatro sepulturas verificamos a sua afectação a norte pela vala de fundação [404] da empena setentrional do edifício atual. No que concerne à vala de fundação [404] o seu enchimento [405] foi depositado aí após a construção da fachada sul do edifício, nomeadamente durante o século XVII, de acordo com as materialidades arqueológicas exumadas e analisadas. Numa fase posterior da intervenção arqueológica colocou-se à vista uma outra inumação islâmica, designada pela unidade estratigráfica [425] localizada a noroeste da primeira sepultura descoberta [408]. No que diz respeito ao seu estado de conservação, a presente sepultura é, de facto, no conjunto de inumações identificadas, a mais completa pois a sua localização afastada da empena norte permitiu a sua preservação.

A sua dispersão espacial confina-se a uma área restrita impedindo a formulação de hipóteses sobre a extensão do campo funerário. No entanto, a importância da sua descoberta fornece mais uma peça do puzzle para o conhecimento dos espaços extramuros lisboetas, especificamente sobre o lado oriental.

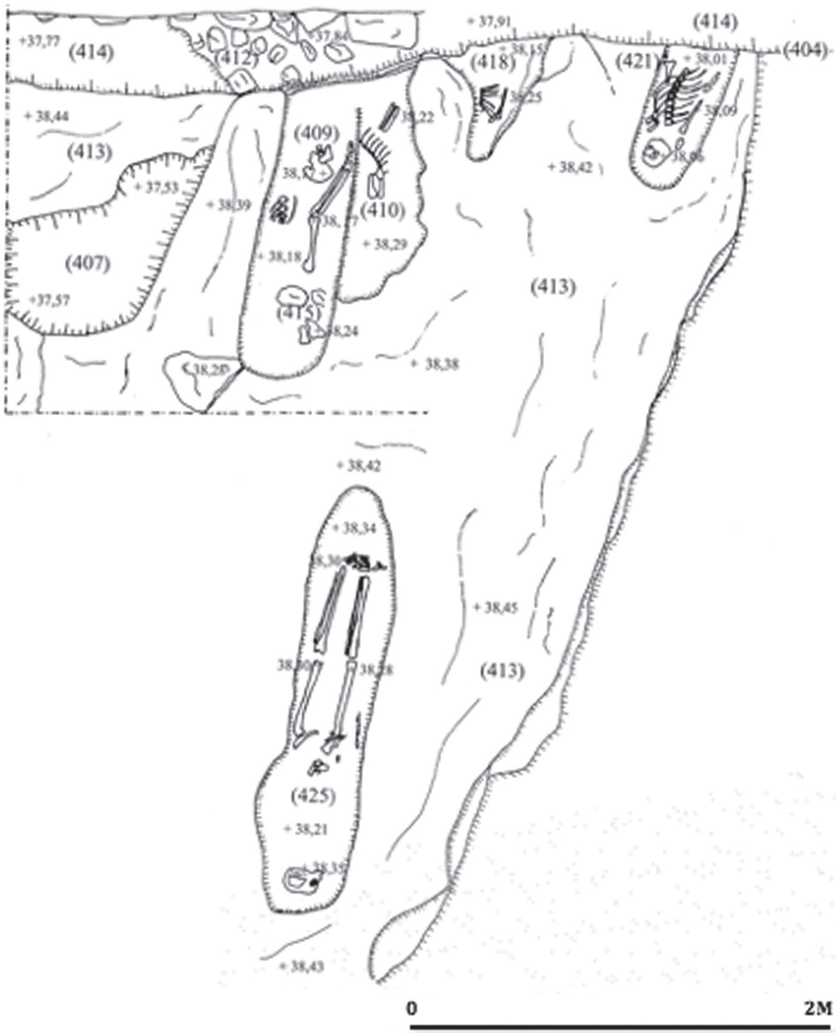

Figura 2 – Plano Final da Intervenção Arqueológica.

### 4. Ritual Funerário

Como em todas as culturas é a religião que dita os hábitos fúnebres, de acordo com as crenças próprias da mesma. A população islâmica apresenta hábitos muito específicos no que toca ao processo de tratamento e enterramento dos mortos. Os corpos são limpos e levados para ser enterrados - *al-Dafin*. São colocados em fossas simples escavadas no solo, sem a presença de caixão, deitados sobre o lado direito (decúbito lateral direito). A sepultura deve ser perpendicular à linha recta do local para a Qiblah – Meca, e a face deve sempre estar voltada na direcção da mesma. Existem dois tipos de sepulturas tradicionais – Al-Shaqq e Al-Lahed – a primeira é a vala simples e a segunda implica uma bancada lateral inferior, onde é colocado o corpo de modo a ficar protegido sob uma área não escavada. A propositada não colocação de qualquer tipo de espólio - adorno ou outro – baseia-se na ideia de um enterramento humilde e simples, desprovido de pretensões. Este facto também dificulta a aferição cronológica e diacronia ocupacional da presente necrópole.

A necrópole da Calçadinha do Tijolo é caracterizada pela tipologia simples das sepulturas escavadas na rocha, sem espólio associado, estando os indivíduos em deposição primária em decúbito lateral direito com orientação SO-NE e face virada a Este (apenas com exceção do indivíduo [425] que se encontrava em decúbito dorsal).

O repovoamento natural de uma área urbana visível na reestruturação posterior do espaço levou a que vários vestígios de esqueletos tenham sido parcialmente removidos ou destruídos para construção de novas estruturas. Uma consequência deste reaproveitamento é o facto dos enterramentos sepultados estarem bastante incompletos. Apenas uma das sepulturas apresentava reutilização funerária, com um pequeno ossário junto ao crânio.

Tafonomicamente o substrato geológico onde foram escavadas as sepulturas é de características bastante porosas pelo que o elevado grau de humidade é visível nos ossos, formando alterações que mimetizam os processos osteóliticos. A constante presença de raízes terá também influenciado o estado dos ossos, assim como apoia a presença de água no substrato. Os ossos apresentam-se assim frágeis, quebradiços e porosos e com extensão das manchas de cor devidas à presença de metais. As raízes, por sua vez, provocam quebras *postmortem* e fragilidades.

Figura 3 – Individuo [425] em decúbito dorsal.

Figura 4 – Ossário [415] junto a crânio de [409].

## 5. Material e métodos

O material osteológico foi avaliado em campo, posteriormente recolhido, limpo com o auxílio de escovas moles e ensacado em sacos de plástico furado.

Foi efectuado o perfil biológico para cada indivíduo, sendo a diagnose sexual dos adultos definida com base na morfologia dos ossos coxal (W.E.A, 1980; BUIKSTRA, UBELAKER, 1994; BRUZEK, 2002) e do crânio (FEREMBACH *et alii*,1980; W.E.A, 1980; BUIKSTRA, UBELAKER, 1994; BRUZEK, 2002), na osteometria dos ossos longos (WASTERLAIN, 2000) e dos ossos do pé (SILVA, 1995). A idade à morte em adultos foi conseguida apenas num caso, com a aplicação do método morfológico da extremidade esternal da 4ª costela (ISCAN,1984) e para o único não-adulto com base no comprimento das diáfises (MARESH, 1970).

A análise dentária foi baseada no esquema dentário FDI e a patologia determinada pelos parâmetros de WASTERLAIN (2000).

As únicas evidências patológicas possíveis de determinar foram degenerativas – osteoartrite (AO) e entesopatias. Nos casos das primeiras utilizámos a escala de 3 graus de CRUBÉZY, MORLOCK e ZAMMIT (1985), sendo as lesões entesiais classificadas em graus de 0 a 5 segundo CRUBÉZY (1988; *apud* CUNHA, UMBELINO, 1995).

No caso do ossário foi efectuado o NMI (número mínimo de indivíduos) com base em HERRMANN e colegas (1990, *apud* SILVA, 1998).

### 5.1. Análise

O conjunto estudado é composto por quatro (4) indivíduos adultos, um (1) não-adulto e um pequeno ossário.

Dos quatro elementos adultos temos dois esqueletos femininos jovens, um indivíduo masculino e um adulto muito incompleto.

| U.E (unidade estratigráfica) | Sexo | Idade | Patologias |
|---|---|---|---|
| 409 | Feminino | Adulto jovem | - |
| 410 | - | Adulto | - |
| 415 | Ossário | Adulto | - |
| 418 | - | 9 a 10 anos | - |
| 421 | Masculino | 54 a 64 anos | Patologia degenerativa |
| 425 | Feminino | - | Patologia oral |

Tabela 1 – Listagem de elementos funerários.

No conjunto adulto apenas conseguimos apurar a idade à morte no indivíduo masculino, com base na epífise da 4°a costela – 54 a 64 anos (ISCAN, 1984). Dada a sua idade é natural a existência de patologia degenerativa. Apresenta inícios de artroses - Grau 1 de CRUBÉZY, MORLOCK e ZAMMIT (1985) nas omopla-

Figura 5 – Indivíduo [421].

Figura 6 – Esterno com artrose de grau 2 e entesopatia de grau 3 na tuberosidade radial d indivíduo [421].

tas – cavidade glenóide, cúbito direito – epífise proximal, clavícula esquerda, úmeros – epífises distais; e artrose de grau 2 no esterno, na ligação do manúbrio com o corpo. Revelou também uma entesopatia de grau 3 de Crubézy (1988, *apud* CUNHA e UMBELINO, 1995) na tuberosidade radial, da inserção do músculo *bíceps brachii*. Quanto à dentição foi recuperada apenas parte do crânio, e com ela um pequeno fragmento do lado direito da mandibula. Dele podemos apenas mencionar a perda *ante-mortem* do 3° molar inferior direito (n°48 FDI).

No entanto um dos indivíduos jovens femininos [425] apresenta grande parte da dentição, como podemos observar na tabela 1. Podemos verificar que mesmo jovem o indivíduo apresenta já graus de desgaste em toda a dentição, sendo alguns bastante elevados, assim como perda de dentes *ante-mortem*.

| | | | |
|---|---|---|---|
| 11 | Perda PM | Desgaste grau 4 | 21 |
| 12 | Desgaste grau 4 | Desgaste grau 3 | 22 |
| 13 | Desgaste grau 8 | Desgaste grau 5 | 23 |
| 14 | Perda PM | Zona não recuperada | 24 |
| 15 | Desgaste grau 9 – desaparecimento da coroa | Zona não recuperada | 25 |
| 16 | Perda AM | Zona não recuperada | 26 |
| 17 | Desgaste grau 8 | Zona não recuperada | 27 |
| 18 | Perda PM | Zona não recuperada | 28 |
| 48 | Zona não recuperada | Zona não recuperada | 38 |
| 47 | Desgaste grau 6 | Zona não recuperada | 37 |
| 46 | Desgaste grau 6, tártaro grau 1 | Zona não recuperada | 36 |
| 45 | Perda AM | Zona não recuperada | 35 |
| 44 | Desgaste grau 7 | Zona não recuperada | 34 |
| 43 | Perda PM | Zona não recuperada | 33 |
| 42 | Perda AM | Perda AM | 32 |
| 41 | Perda AM | Perda AM | 31 |

Tabela 2 – Esquema dentário FDI – análise Wasterlein, 2000.
(Legenda: AM – *ante mortem*; PM – post mortem)

O indivíduo não-adulto encontrava-se bastante incompleto sendo possível o cálculo da idade apenas com base no comprimento da clavícula.

O pequeno ossário encontrava-se à cabeceira do indivíduo [409], e é composto por um úmero, omoplata e pedaço de osso longo (pode ou não ser parte do úmero). O NMI determinado é de um (1) indivíduo adulto ou sub-adulto.

### 5.2. Os Isótopos estáveis no estudo da dieta das comunidades islâmicas de Lisboa

A alimentação, longe de ser apenas uma componente biológica necessária à vida humana, assume uma forte conotação simbólica nas sociedades do passado. Todos os aspectos relativo à dieta, entre os quais a escolha dos produtos, a preparação e o consumo ou não-consumo de determinados alimentos têm um papel importante na construção das identidades, sendo influenciados por numerosos aspectos socioculturais entre os quais a posição social, a faixa etária, o sexo e a crença religiosa. Dado que a dieta não pode dissociar-se das expressões comportamentais de uma população, com a sua investigação procura-se então aportar uma nova perspectiva sobre as comunidades muçulmanas que viviam em Lisboa sob o poder islâmico.

As análises de isótopos estáveis de carbono (δ13C) e nitrogénio (δ15N) no colagénio de ossos humanos é um método amplamente usado nos estudos arqueológicos e antropológicos, vivenciando uma grande expansão nas últimas duas décadas, graças também a uma sempre maior interdisciplinaridade das investigações bioarqueológicas. O princípio subjacente a esta técnica biomolecular baseia-se na fisiologia dos ossos, que ao longo da vida de um individuo, vão fixando os sinais relativos à composição isotópica dos alimentos ingeridos (AMBROSE, 1993). Os sinais isotópicos da dieta são portanto incorporados nos tecidos corporais, como o osso e mais especificadamente o colagénio, através do metabolismo e preservados depois da morte. As quantidades de isótopos de carbono e nitrogénio variam de forma previsível entre específicas categorias de alimentos que formam as cadeias alimentares em ambientes terrestres e aquáticos. Além disso, os isótopos estáveis de carbono variam entre famílias de plantas com diferentes estratégias fotossintéticas, permitindo assim distinguir, por exemplo, o consumo de trigo (planta C3) do milho (planta C4) (SMITHSS, EPSTEIN, 1971). Os isótopos de nitrogénio reflectem a posição de um individuo na cadeia alimentar, com valores mais altos para os organismos ao topo da cadeia alimentar e mais baixos para os organismos que se alimentam na base da mesma. Portanto através das análises das variações dos isótopos de carbono e nitrogénio entre categorias alimentares é possível identificar a origem das fontes dos nutrientes alimentares (proteínas, carbohidratos, lípidos) e reconstruir a dieta das populações do passado (KATZENBERGK *et alii,* 2007).

Este é o objectivo do presente trabalho, tendo-se recorrido para o efeito de análises dos isótopos estáveis de carbono (δ13C) e nitrogénio (δ15N) dos restos ósseos provenientes da escavação da Calçadinha do Tijolo. Os dados dos restos humanos são comparados com os valores da fauna de contexto islâmico proveniente da Praça da Figueira em Lisboa. Os dados provenientes dos indivíduos do Castelo de São Jorge e do Largo das Olarias, apresentados durante a comunicação, não são incluídos neste trabalho porém são objecto dum trabalho de próxima publicação.

### 5.3. Metodologia

A análise dos isótopos estáveis de carbono e de azoto no colagénio dos restos humanos foi realizada em cinco amostras (Tabela 1) nos laboratórios de arqueologia biomolecular (BioArCh) do Departamento de Arqueologia, da Universidade de York, na Inglaterra, sob a coordenação da Doutora Michelle Alexander. A análise desenvolveu-se em acordo com o protocolo de extracção de colagénio actualmente utilizado na Universidade de York, baseado no método de Longin (1971) com a adição de uma ultrafiltração, como sugerido por BROWN *et alii* (1988). Os espécimes foram tratados pela extracção de colagénio e as amostras analisadas com o auxílio de um espectrómetro de massa Sercon 20-22 Isotope Ratio mass spectometer (IRMS).

### 5.4. Resultados e discussão das análises da paleodieta

Os resultados da análise dos isótopos estáveis esta representada nas figuras 7 e 8, enquanto os valores numéricos estão incluídos na Tabela 3.

| Esq. | Osso | Sexo | Idade | %C | %N | C:N | δ13C ‰ | δ15N ‰ |
|---|---|---|---|---|---|---|---|---|
| CDT409 | Costela | F | Adulto | 44.86 | 16.48 | 3.18 | -18.62 | 9.55 |
| CDT425 | Fíbula | F | Adulto | 39.84 | 14.26 | 3.25 | -18.68 | 9.98 |
| CDT421 | Costela | M | Adulto | 41.28 | 15.03 | 3.22 | -18.66 | 9.30 |
| CDT410 | Costela | I | Adulto | 38.62 | 14.014 | 3.21 | -18.89 | 9.59 |
| CDT418 | Costela | I | Não-adulto | 37.79 | 13.56 | 3.24 | -18.58 | 9.33 |

M – individuo masculino; F – individuo feminino; I – individuo de sexo indeterminado

Os erros associados aos valores de δ13C e de δ15N são respectivamente ±0.04 ‰ e ±0.10 ‰.

Tabela 3 – Tabela 1. Resultados isotópicos de indivíduos humanos da Calçadinha do Tijolo (valores de δ13C e de δ15N (‰)).

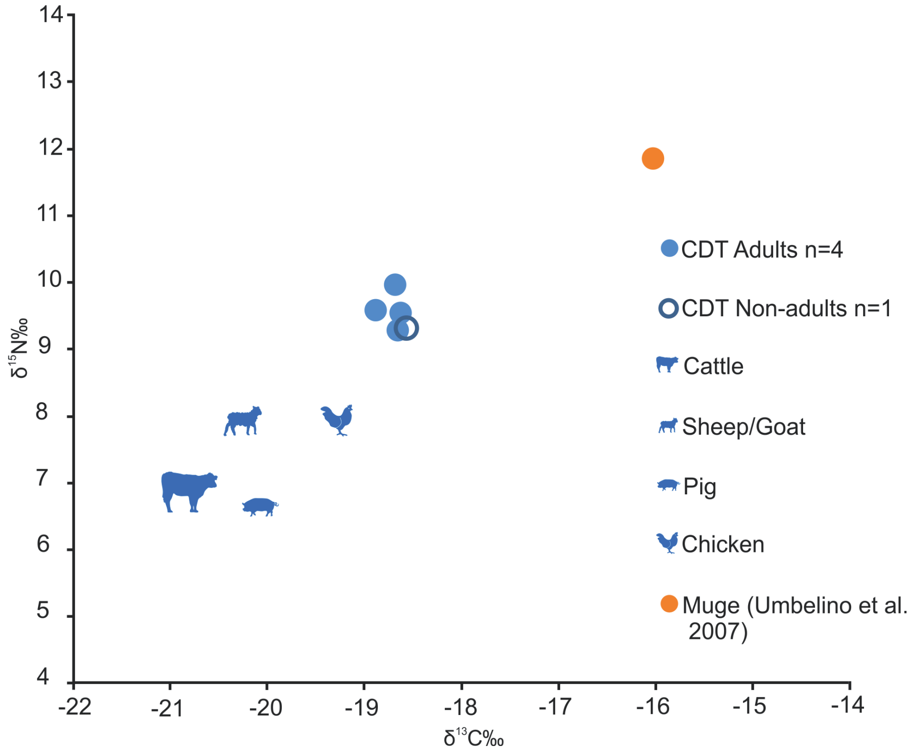

Figura 7 – Dieta da população islâmica da Calçadinha do Tijolo, representada em relação aos dados da fauna proveniente dos contextos islâmicos da Praça da Figueira. Os valores médios das populações mesolíticas de Muge estão aqui representados para fins comparativos como exemplo de uma dieta marinha em Portugal (in UMBELINO, 2007).

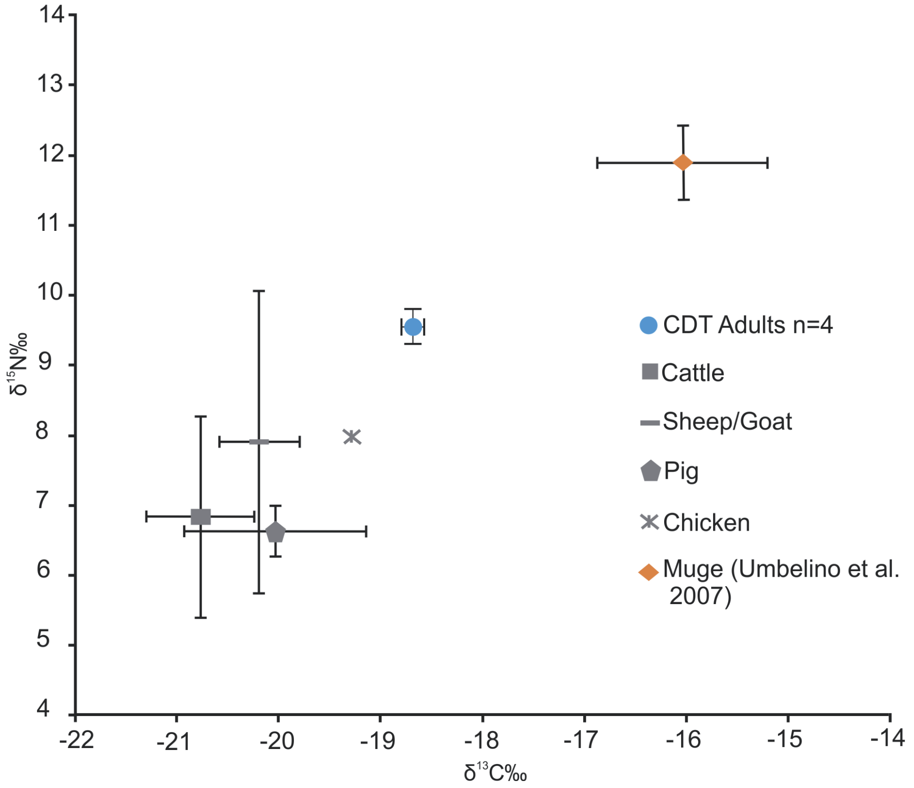

Figura 8 – Valores médios dos isótopos de carbono e azoto para os indivíduos humanos e a fauna com os relativos valores do desvio padrão.

Os resultados das análises isotópicas mostram uma alimentação muito similar entre os indivíduos incluídos neste trabalho. Ambos os reduzidos valores do desvio padrão de carbono (δ13C) e azoto (δ15N ) indicam o alto nível de homogeneidade da dieta, incluindo também a única criança presente nesta amostra. Este individuo não-adulto tem uma idade estimada de 9.5 anos e mostra uma dieta similar àquela dos indivíduos adultos, sugerindo que nesta idade as crianças tivessem já abandonado a dieta infantil e beneficiassem da mesma alimentação dos adultos. Não existem diferenças apreciáveis entre categorias de sexo ou idade.

A dieta deste grupo aparenta ser de origem terrestre com consumo de proteínas animais e plantas C3. O ligeiro incremento dos valores de carbono (δ13C) em relação à fauna local, pode sugerir a inclusão na dieta de recursos de origem marinha ou plantas C4, que apresentam valores mais positivos de carbono. Contudo, os valores isotópicos do nitrogénio (δ15N) resultam demasiado baixos para apoiar a tese de uma dieta à base de peixe, mesmo considerando o consumo de espécies muito pequenas situadas na primeira parte da cadeia alimentar, como a sardinha. Outra opção pode ser o consumo de moluscos, que não afectariam os níveis de nitrogénio. De qualquer das maneiras, as fontes históricas informam sobre os alimentos mais consumidos e apreciados na cozinha islâmica e animais como cabra, carneiro e ovelha aparecem com grande frequência tanto nas receitas quanto nos conjuntos de fauna destes períodos (FLADRIN *et alii,* 1999; PEREIRA, 2014). Colocando de lado esta primeira opção, o aumento dos valores de carbono (δ13C) pode ser o resultado da  integração na alimentação destes indivíduos de plantas C4 ,como o milho-painço e o sorgo. Ainda assim, quando os dados são comparados com os recentes estudos de ALEXANDER *et alii* (2015) sobre as comunidades mudéjares na Espanha medieval, as quais mostram um consumo de plantas C4, os valores aqui apresentados parecem mais adequados a uma dieta terrestre que inclui herbívoros e plantas C3. Os únicos dados publicados sobre a paleodieta em Portugal, pertencem ao trabalho de UMBELINO *et alii* (2007) sobre as populações mesolíticas dos concheiros de Muge e são incluídos nos diagramas para fins comparativos. Não obstante a dificuldade de comparar indivíduos de cronologias tão diferentes, sendo os indivíduos de Muge caracterizados por uma dieta de origem marinha, fornecem um imediato auxílio visual na análise da contribuição de recursos marinho na dieta do grupo de muçulmanos, proveniente da Calçadinha do Tijolo. Ao comparar as amostras de Lisboa com os indivíduos de Muge parece mais claro ainda que estes indivíduos islâmicos mantivessem uma alimentação composta principalmente de recursos terrestres.

## 6. Conclusões

O fenómeno de instalação do cemitério extramuros, em estreita ligação com as Portas do Sol e numa área a oriente da cidade medieval islâmica de Lisboa, reproduz a organização e identidade do tecido urbano de matriz medieval muçulmana. O facto de a prática religiosa de inumação islâmica desprover os indivíduos de espólio cultural contribui para uma difícil aferição cronológica no que concerne à data de enterramento dos indivíduos e consequente formação e amortização desta necrópole.

Contudo, as alusões literárias analisadas sugerem a existência de cemitérios nas encostas de São Vicente de Fora desde o século XI (SIDARUS, REI, 2001, p.71), apesar de a ausência de indícios documentais para os séculos antecessores não invalidarem a formação prévia do campo mortuário.

A anulação funcional do espaço funerário terá como limite cronológico máximo os finais do século XIII com a implantação das Escolas Gerais nesta zona.

Nesta linha de pensamento, a necrópole da Calçadinha do Tijolo permite-nos ensaiar uma cronologia apontada para o período de dominação muçulmana.

Em termos antropológicos parece tratar-se claramente de uma realidade que retrata os costumes funerários islâmicos. Tal análise da antropologia funerária é apoiada pela análise à alimentação destes indivíduos.

O conjunto é, infelizmente, demasiado pequeno e demasiado fragmentado e incompleto para podermos tirar elações populacionais.

Sem grandes evidências patológicas podemos apenas dar como nota para futuras investigações a ligação entre o indivíduo jovem de elevada patologia de desgaste dentário como o elemento onde a análise isotópica demonstrou ser o que apresenta um maior consumo de proteínas animais. Ainda que a carne em si não seja comummente vista como um elemento que provoque elevados graus de desgaste, é ainda assim um alimento ácido (tal como o queijo, farinha branca e fruta cítrica) passível de causar desgaste (COX, MAYS, 2000, p. 232). Esta ligação, ainda que ténue, pode manifestar-se significativa, uma vez que para populações medievais e anteriores é possível analisar o desgaste como uma função da idade (HILLSON, 2005).

Importa salientar que as interpretações apresentadas são relativas aos indivíduos aqui analisados e não refletem necessariamente o comportamento alimentar de toda a população. Dada a falta de dados isotópicos do colagénio de indivíduos humanos do mesmo período histórico em Portugal, resulta difícil contextualizar estes primeiros resultados no padrão do domínio islâmico no país, e particularmente em Lisboa.

De qualquer maneira, os trabalhos que estão actualmente em desenvolvimento, e o crescente interesse no quadro socioeconómico desta fase na Península Ibérica, ajudarão a preencher as lacunas do actual conhecimento sobre a vida e morte das comunidades muçulmanas em Portugal.

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