University of Évora

ARCHMAT
(ERASMUS MUNDUS MASTER IN ARCHaeological MATerials Science)

Mestrado em Arqueologia e Ambiente (Erasmus Mundus – ARCHMAT)

Diet and dynamic of the first Christians in Algarve during the 13th-14th AD

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Évora, Outubro 2019

Panel of Jury

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Abstract

Diet and dynamic of the first Christians in Algarve during the 13th - 14th AD

Stable isotopes study of carbon, nitrogen and sulfur isotopic systems in bone remains in order to assess diet of a Christian population during the 13th and 14th Centuries AD. The population studied was from a Necropolis excavated in Cacela-a-Velha (Algarve, Portugal) and belonged to the first Christians from the Kingdom of Portugal that settled in the region after the conquest of the Algarve in the first half of the 13th century. This study seeks to provide a better understanding of the food, resources and cultural practices of the already mentioned population, in order to have a wider point of view of the reality lived by this community, and its immediate and regional context during that period of time. Differences were seen among faunal bone collagen samples, making possible to infer distinctions in agricultural practices and trading in the region. The $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ results of human bone collagen evidenced a heterogeneous diet in the population that could be caused by social and political factors.

The study not only would provide isotopic data that could be used for future studies, but also, it provides a deeper perspective of the Christian societies of medieval Iberian Peninsula, since the data was contrasted and complemented with historical and anthropological information. This could be useful to provide a more complex conceptualization of the medieval Iberian cultures.

Keywords: *Stable Isotopes, Diet, Algarve, Christians, Middle Ages*

Resumo

Dieta e dinâmica dos primeiros cristãos no Algarve durante os séculos XIII e XIV

Para avaliar a dieta de uma população cristã dos séculos XIII e XIV d. C. foi realizado o estudo das razões isotópicas em carbono, azoto e enxofre em restos ósseos humanos recuperados de uma Necrópole escavada em Cacela-a-Velha (Algarve, Portugal). Estas populações, consideradas dos primeiros Cristãos do Reino de Portugal, instalaram-se nesta região após a conquista do Algarve durante a primeira metade do século XIII. Com este estudo pretende-se obter informação sobre os hábitos alimentares, utilização de recursos e práticas culturais desta população, com o objectivo de obter uma visão mais alargada da realidade vivida por esta comunidade, do seu contexto quotidiano e regional durante esse período. Foram observadas diferenças nas razões isotópicas no colagénio ósseo da fauna contemporânea aos restos humanos, permitindo reconhecer algumas diferenças nas práticas agrícolas e no comércio da região. Os resultados de $\delta^{13}C$, $\delta^{15}N$ e $\delta^{34}S$ do colagénio ósseo humano evidenciaram uma dieta heterogénea na população que poderia ser resultante de factores sociais e políticos.

O estudo permitiu obter dados isotópicos que poderão ser enquadrados em futuros estudos, mas também, permitiu obter uma perspectiva mais profunda das sociedades cristãs da Península Ibérica medieval, já que os dados foram comparados e complementados com informação histórica e antropológica. Esta informação poderá ser útil para proporcionar uma conceptualização mais complexa das culturas ibéricas medievais.

Palavras-chave: *Isótopos Estáveis, Dieta, Algarve, Cristãos, Idade Média*

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I am grateful with the Hercules Laboratory from Universidade de Evora for letting me perform the collagen extraction procedure and particularly to researcher PhD Nicasio Jiménez-Morillo and Vera Susana Correia Palma for performing the spectrometric analyses. Moreover, I would like to thank to all the Hercules Staff for their amazing kindness and availability and especially to Professor Pedro Miguel Cambeiro Barrulas and Rebbeca Anne MacRoberts for their advises, encouragement and truthness.

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List of Abbreviations

AD: Anno Domini

AIR: Ambient Inhalable Reservoir

BP: Before Present

C: Carbon

C/N: Carbon to nitrogen ratio

C/S: Carbon to sulfur ratio

CAM: Crassulacean Acid Metabolism

CVF: Cacela-a-Velha Fortaleza

EA-IRMS: Elemental Analyzer - Isotope Ratio Mass Spectrometry

H-CVPA: Human Cacela-a-Velha Poço Antigo

IAEA: International Atomic Energy Agency

N: Nitrogen

N/S: Nitrogen to sulfur ratio

S: Sulfur

VCDT: Vienna Canyon Diablo Troilite

VPDB: Vienna Pee Dee Belemnite

Chapter 1 Introduction

Between the subjects that the diverse disciplines that study the past address, the study of diet acquired a great importance, since food consumption is one of the determinants in our social, cultural and biological conformation (Harris 1987). Food is what led us to develop in a specific way. Our own body and our way to understand reality depend, or at some point depended, on what we eat. The evolution of humanity is strongly linked to it; nevertheless, food does not only depend on biological and subsistence terms; it also has clear social, historical and cultural components (Harris 1987).

The geography of a place determines what kind of plants is possible to grow and what animals are possible to breed. The birth of agriculture depended mainly in the latitude and the proximity to water resources. That is why in temperate or tropical areas is where most of the plants we consume today were domesticated (e. g. Indus Valley, Valley of Peru, China, Mesopotamia, Egypt, Mesoamerica). Coincidentally, it is in these same places that diverse civilizations were born (Wolf 2005).

Diet determines culture. It is not surprising that even in many religions the importance of certain foods was reflected in the form of diverse deities. Likewise, culture determines diet too. Examples of it are all over the world, in which the type of food is strongly linked to popular beliefs, religious ideas, age or sex (Harris 1987).

Human nutrition is also associated with temporality and social stratification. The consumption of certain products depends both on the epoch lived, as in the availability of these products and the possibility of individuals to afford them. Thus, the study of past diets can provide a large amount of information to understand in a more objective way the worldview of past societies, as well as our own.

This study comprehends the period between the 13th to the beginning of the 14th century in the town of Cacela-a-Velha, that is localized in the south of Portugal in the region of Algarve. During this period the kingdom of Portugal conquered the region, finishing in the year 1249 the Muslim occupation period of the nowadays Portuguese territory. The situation lived in that epoch is known partially and mainly through written sources. There are many historical studies dedicated to this period; however, many questions are still not answered. The study of past diets may reveal new perspectives relative to the way of life of population during medieval times and to understand how diet is crucial in the conformation of identities (Harris 1987). This study aims to supplement the existing information through a different methodology, since most of the studies have been done from ethnographic and documentary sources. For this, stable isotopes analysis of bone remains was employed.

Stable isotopes studies are based on the fact that the composition of the tissues of an organism has a direct relation with what it ingests. In other words, the consumer's tissues reflect the food that was ingested. In this way, osseous tissue become a repository and evidence of past diets.

The bone remains analyzed are part of the excavations that took place in the years 1998 and 2001, in a cemetery dated from the 13th Century AD (Tété Garcia 2015). The set of samples analysis within this study is composed by 42 human samples and 28 faunal samples. Faunal samples are required in the study to relate the information obtained from the human bones with the environment where the humans lived, and to infer what was the contribution of those animals to the human diet.

The specific objectives of this study are to analyze diet through three different isotopic systems: $^{15/14}N$, $^{13/12}C$ and $^{34/32}S$, and with that be able to understand if there were differences on diet that could be related with social status, migrations, ideology or beliefs. Finally, since faunal samples were analyzed, another objective is to find out if there were different husbandry practices and how these could be related with different agricultural practices.

The methodology employed consisted in recording and classifying the bone samples, after which their collagen was extracted for posterior analysis. Afterwards, the information was interpreted taking in consideration historical and anthropological information. In this way, through an interdisciplinary approach, a clearer picture of the population way of life was gained.

Chapter 2 Context

2.1 Geographical context

This section will discuss the geographical, geological and climatological characteristics of the immediate, local and regional context of Cacela-a-Velha, a town of the south coast of Portugal. Also, it will include the environmental changes throughout time, as well as the formation and territorial definition of the region, and its geomorphological differences with the rest of the Iberian Peninsula.

Portugal, it is worth to mention, is a land in which many of its characteristics are binary, and, the country's geography is not an exception. Generally speaking, Portugal, in contrast with other Mediterranean countries that are located on the boundaries of the Eurasian plate, does not present such a rough terrain. In fact, it is a country where areas with low altitudes predominate, since, more than the 70% of the territory is located at less than 400 meters above sea level, and only 12% is above 700 meters (Ribeiro, Portugal o Mediterrâneo e o Atlântico 1993). The lack of high mountainous terrains is particularly evident in the southern regions.

The climatological conditions of Portugal are reigned, to a large extent, by the unequal behavior in temperature between the masses of water from the Atlantic Ocean, and the Hispanic plateau. This is because during the summer, ocean waters are colder than the Iberian lands, while, during the winter, it occurs the opposite. Due to this alternating action between land and sea, the variation of meteorological elements has a clearly west-east component (De Pina Manique e Albuquerque 1954). In this sense, Portugal and Galicia act as a barrier that limits the actions of the Atlantic cyclones in the rest of the peninsula (Lautensach 1967).

Traditionally, Portugal is divided in two major regions: South and North, and this has its logic, not only due to historical reasons, but also as a result of orographic features. The divisor line that defines both regions is the Tagus river. South of Tagus, 97% of the land is located at less than 400 meters above sea level, and only 0.2% above 700 meters (Figure 1) (Ribeiro, Portugal o Mediterrâneo e o Atlântico 1993). This create a completely different landscape in the south from the one in the north. It is in the south, where is located the vast and monotonous land of Alentejo, that extends south until it is stopped by the mountains in the north Algarve, and in which its broad plains with cereal crops and groves from olive trees and cork oaks, with vineyards scattered on the landscape are characteristic.

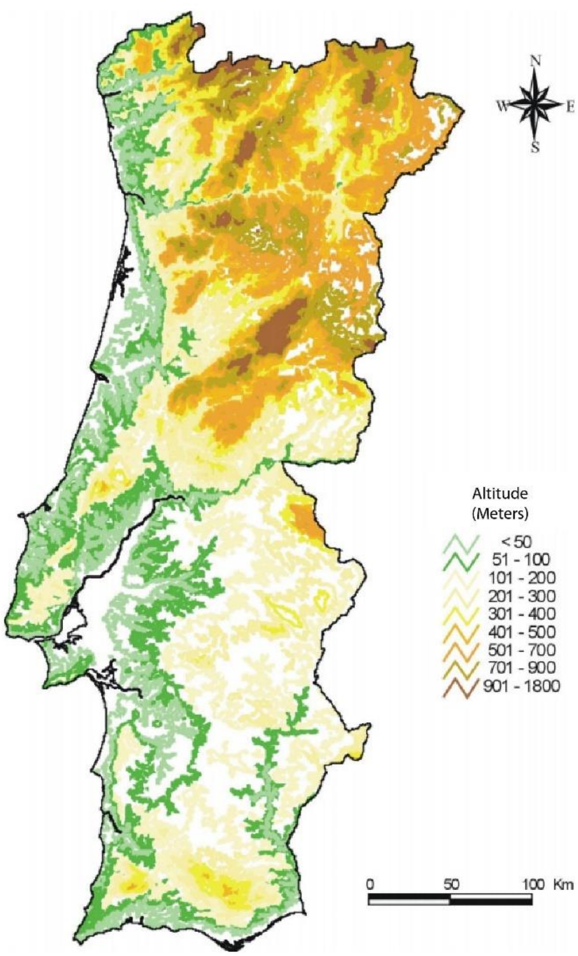

Figure 1 Hypsometric map of continental Portugal, in (Ferreira 2000)

The latitude and low altitude of these landscapes condition their hydrological features. In this way, Northern to Tagus region usually has a precipitation media of 1000 to 2000 mm per year, while the southern counterpart, unlike, is far much dry. Only in Monchique range and São Mamede range the precipitation has a media of 1000 mm. In Alentejo the rains do not arise further than 700 mm, while in the Guadiana basin it does not exceed 500 mm, having some years where the precipitations media is of 350 mm. Whereas in the north only two months per year are considered dry, because they present precipitations below 30 mm; by comparison, in the south there are three to six dry months (Ribeiro, Lautensach and Daveau, Geografia de Portugal. O Ritmo climático e a Paisagem 1999) (Ribeiro, Portugal o Mediterrâneo e o Atlântico 1993).

Cacela-a-Velha is a town located in the eastern part of the Algarve (see Figure 2), one of the regions of Portugal. This region is the most southern of the country and it extends from the coast of the Atlantic Ocean to the frontier with Spain, where the Guadiana river divides them. Nowadays, the zone that comprehends this region is the District of Faro; nevertheless, in the past, its area was larger.

The geographical area that the Algarve region comprehends was mentioned for the first time in history by Herodotus as a part of the Tartessian civilization. Afterwards, it would be mentioned by Polibio as Turdetania, in which the Turdetani and Cynetes people lived. It is until the Roman Empire when this region would be well defined as a Roman province, and it would be given the name of Lusitania. After the fall of the Western Roman Empire, the region passed to be controlled first by the Vandals, then by the Suebi, and after by the Visigoths, with a small period in between, in which the Eastern Roman Empire controlled the area, but the Visigoths could stablish again their rule (coord. de Oliveira Marques 1993). This region would not change during the Germanic invasions and the Visigoth kingdom (Stanislawski 1963). In the context of the Muslim invasion and their posterior settlement, the region would be redefined. The region would be named *al-Gharb*, that in Arabic means west, and its geographical limits would change with the course of time.

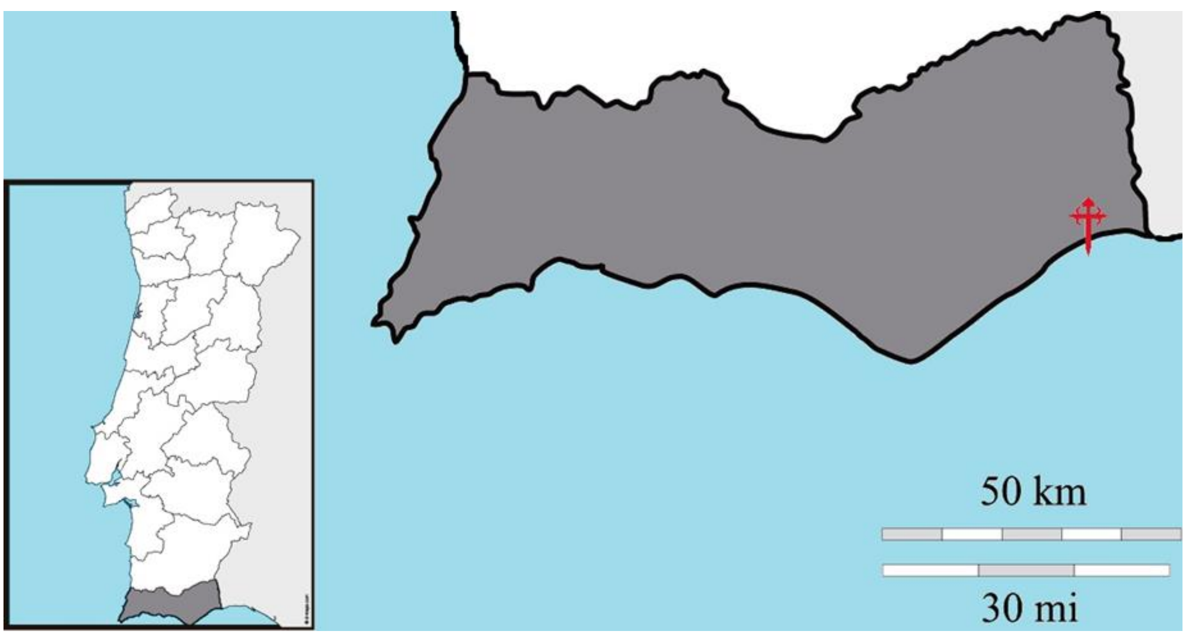

Figure 2 Map that depicts the location of Cacela-a-Velha (represented by a Santiago Cross) within Algarve, adapted from d-maps.com

It is worth to mention that with the Muslim conquest the region would see its blooming. While it is true that the area was developed during the Roman rule too, it is also true that the territory constituted a remote peripheral area, in which, it is plausible that the interests over this land were not a priority (Stanislawski 1963). In contrast, through the five centuries that Algarve was part of Al-Andalus, a vast quantity of developments was introduced, mainly in agriculture and irrigation practices. These improvements would lay the foundations for the present development aspects of the region.

Inside Algarve, the region is divided in two different ways that have an ecological reason. First, it is divided in two areas that have different climatological characteristics. These are: Sotavento and Barlavento. The latter extends from Cape São Vicente to Olhos de Água, and its weather conditions are subject to Atlantic influences; the former, Sotavento, extends from Olhos de Água to the delta of the Guadiana river and it is subject to climatic characteristics that are more similar to those of the Mediterranean, being more exposed to continental winds. Besides the differences in climate of these two regions, the contrast in geomorphological features is also quite significant. The coasts of Barlavento are characterized by a strong marine erosion with high calcareous cliffs, while Sotavento, in contrast, is constituted by a lower altitude coast with long sandspits of a more recent formation (Instituto de Conservação da Naturaleza e das Florestas 2007). To sum up, Barlavento is exposed to erosion processes and Sotavento to sedimentary processes.

Besides Sotavento and Barlavento divisions, Algarve is divided in three different regions that are defined by their sea level. These are Serra, Barrocal and Litoral and are constituted by three longitudinal strips that go from north to south. Serra is characterized by a rough relief that does not go above 500 meters above sea level with a singular exception that is the Monchique range, in Barlavento; an area that rises almost till 1000 meters. Barrocal is a territory that has been shaped by the erosion of the distinct rocks, creating a landscape of diverse shapes, and its maximal altitude is 410 meters in São Miguel hill. The Litoral region is characterized by the smoothness of the relief, and it covers an area of low altitudes, that do not exceed 60 meters, in which altitudes of 20-30 meters predominate (Instituto de Conservação da Naturaleza e das Florestas 2007).

The formation of the Algarve can be attributed to different geological processes that started in the Paleozoic period and that followed till the present. The northern part of the region, Serra, is composed by Paleozoic soils, where two reliefs of different formation appear: the Caldeirão range, of tectonic origin, is covered by schists and greywackes, and, the Monchique range of sub-volcanic formation from the superior Cretaceous period, is covered mainly by syenites (Instituto de Conservação da Naturaleza e das Florestas 2007).

Going south, in the Barrocal, the compact and marly limestones and dolomites dominate the region and are usually associated with the Jurassic and Cretaceous formations. This area presents formations of karstic type, with frequent depressions and vertical caves, since limestones are chemically rich in calcium carbonate which induces a process of alteration by dissolution. Thus, the reliefs are interspersed by floodplains and depressions, covered by very fertile clayey and loamy materials (Instituto de Conservação da Naturaleza e das Florestas 2007).

Towards the sea, in the Litoral, the age of the geological formations diminishes as one moves east. North from the Cape of S. Vicente, the coastal formations are essentially Paleozoic, constituted by schists and greywackes, whereas, from this Cape to the east, Jurassic, Cretaceous, Miocene, Pleistocene and present formations arise in an intercalated form. In the Sotavento, the Pleistocene deposits of sands are composed of micaceous silts and fine sands, which are followed by gravels with rounded quartz, quartzite or greywacke pebbles. The barrier islands of the Ria Formosa are formed by dune sands, which are usually accompanied by beach sands, which feed the dunes (Instituto de Conservação da Naturaleza e das Florestas 2007).

In particular, the formation base of Cacela and its stream contains Galvanas' conglomerates, which are composed by blocks of Jurassic calcareous rocks, Cretaceous sandstones and igneous rocks, together with sands and silts with some glauconites. The formation of Cacela dates from superior Tortonian to Messinian periods and it was dated by the Galvanas' conglomerates, ostracod fauna and calcareous nanoplankton (Oliveira 1992).

Coarse sands and pebbles from metapelites, sandstones and volcano-sedimentary rocks from the upper Triassic and lower Jurassic are deposited on schists and greywackes of the carboniferous period. Along the stream of Cacela, shallow levels of fossiliferous conglomerates settle with angular discordance in sandstones from the Triassic, followed by, silts and fine sands of greenish, orange and grayish hues, and, it also settles high amounts of fossils, specially malacological. All of these characteristics make the soils of Cacela to have a high content of soluble salts (Instituto de Conservação da Naturaleza e das Florestas 2007, Oliveira 1992).

Besides the physical conformation, one important feature that is necessary to address for understanding the reality of the region is its vegetation. For this, it is not enough to know the flora of present time, but to seek testimonies through micro and macro remains that are studied by Archaeobotany. Thanks to these studies, it is plausible to understand which were the plants that were introduced by the humans, in which period and the importance that those plants have in such a specific location.

The flora of the Algarve contrasts with its northern counterpart Alentejo due to anthropogenic factors. While in the latter, cereals and vines are abundant thanks to its flat landscape; in the former, the type of vegetation has characteristics not only of Mediterranean, but also from sub-tropical latitudes. Before human intervention, the vegetation of the region, as well as in many Mediterranean regions, was composed of plants with evergreen perennial leaves adapted to semi-arid weather. Some of the native flora would be holm oaks (*Quercus ilex*), carobs (*Ceratonia siliqua*), cork oaks (*Quercus suber*), strawberry tree (*Arbutus unedo*), mastic (*Pistacia lentiscus*), hackberry (*Celtis australis*) and wild olive trees (*Olea europaea var. sylvestris*) (Tété Garcia 2015). The area of the Serra preserves most of these features in the present.

The Barrocal and Litoral share a flora more similar with the one of the Maghreb and in this area were introduced more plants of sub-tropical environments. This is due to the fact that the Monchique range stops the cold winds of the north Atlantic. Between the plants that were introduced by the human populations are the domesticated olive tree (*Olea europaea*) that is believed that was introduced before the roman period, as well as the fig tree (*Ficus carica*) and the vines (*Vitis vinifera*). During Roman times many fruit species were brought into the Peninsula. Those would be peach (Prunus persica), plum (*P. domestica*), sweet cherry (*P. avium*), apple (*Malus domestica*), pomegranate (*Punica granatum*), melon (*Cucumis *melo*), cucumber (*Cucumis sativus*), and walnut (*Juglans regia*) (Peña-Chocarro, Pérez Jordá, et al. 2019).

In addition, the variety of fruits was enriched during the middle ages. Thanks to migrations, especially in the Muslim ruled territories, new products began to be commercialized. One of the first products introduced were citrus fruits, which fit perfectly in the Algarve thanks to its high soil fertility. Also, medlars (*Mespilus germanica*) and apricots (*Prunus armeniaca*) were introduced in this epoch. The latter appears for first time at Mértola during the 11th and 12th century AD (Peña-Chocarro, Pérez Jordá, et al. 2019). It is also during this time that the first remains of quinces (*Cydonia oblonga*) in the peninsula are confirmed (Peña-Chocarro and Pérez-Jordá, Los estudios carpológicos en la Peninsula Ibérica: un estado de la cuestión 2018).

Figure 3 Medieval scene that depicts two farmers plowing a field, in Add. Ms. 41230, British Library, London. © British Library

Aromatic plants cultivated in this region were oregano (*Origanum vulgare*), rosemary (*Rosmarinus officinalis*) mint (*Mentha spicata*), parsley (*Petroselinum crispum*), coriander (*Coriandrum sativum*) and fennel (*Foeniculum vulgare*), vegetables used as fodder for animals such as lucerne (*Medicago sativa*), and vegetables like celery (*Apium graveolens*) and carrots (*Daucus carota subsp. sativus*) (Peña-Chocarro and Pérez-Jordá, Los estudios carpológicos en la Peninsula Ibérica: un estado de la cuestión 2018). Another exotic introduction that were possible to cultivate in the Algarve thanks to irrigation technologies were cotton plants (*Gossypium* genus), bananas (*Musa paradisiaca*) and sugar cane (*Saccharum officinarum*) (Tété Garcia 2015, MacKinnon 2015).

Besides the study of botanical macro remains, micro remains can add information of other type. Between these, pollen is useful to reconstruct past landscapes, and, in this way, understand the evolution of a region, whether its climatic, vegetation or geomorphological attributes. Nowadays it is known that, on account of palynological studies, the region usually oscillates between large periods of time with drier weather, and other periods that present larger amounts of precipitation.

In the course between Mesolithic and Neolithic times, the area presented evergreen and deciduous forests of *Quercus* and *Pinus* types. Then, in the middle of the Neolithic period, the remains showed signs of an increase of anthropogenic land use with a high amount of pollen from *Ericaceae*, *Cistus*, *Arbutus*, *Pistacia*, *Cerealia* and *Olea* types. Besides, it is shown an increase of charcoal remains that could be evidence of a drier period. After, during the Copper age, there is a decrease in the presence of trees. This could be associated with the high demand of wood that was necessary on that epoque for the production of copper alloys. Afterwards, throughout the antiquity, there is an increase in *Olea* and *Vitis vinifera,* a characteristic that became more patent during the Roman period. Also, at the same time, there is evidence of a clear development of land use for animal husbandry and agriculture. Already in medieval times, along the Islamic period that comprehends the emirate of Cordoba there is a decrease of land use. In contrast, during the Caliphate period and after, there is a clear increase of deforestation due to agricultural practices (Schneider, et al. 2016). Taking all of this into consideration, we can understand certain features of the weather of Algarve during history. As stated by (Schneider, et al. 2016, 61):

> Drier periods along the Algarve coast existed prior to 8000 cal BP, around 7000 cal BP, between 6400 and 6200 cal BP, between 5000 and 3300 cal BP, between 2800 and 2500 cal BP, between 1300 and 1050 cal BP and between 700 and 500 cal BP.

During the time-lapse that this study focuses, the environment would be in the border between a normal precipitation period, and a dry period (700-500 BP), that, even with less rain, would not affect the agriculture of the region thanks to irrigation practices that do not depended on rainwater but on subsoil water. The evidences of land use are, besides deforestation, an increase of *macchia mediterranea*, ruderal and grassland that act as indicators (Schneider, et al. 2016). This argument is also supported by historical sources, in which agricultural production was not affected (Stanislawski 1963).

2.2 Historical context

After the decline of the Western Roman Empire as a political entity, multiple groups of Germanic origin settled in different provinces of the empire. Within the context of the Iberian Peninsula, the two Germanic peoples that settled were the Suebi and the Visigoth. These two kingdoms coexisted for a century, until the Visigoth Kingdom defeated the Suebi in 585 AD and consolidated as the only power in the Peninsula (coord. de Oliveira Marques 1993).

The Visigoth footprint left almost non kind of trace in the Algarve. Culturally speaking, the influence that Germanic peoples contributed was minimal, since, before entering the peninsula, the Visigoths had already been “Romanized” and were the ones that achieved hegemony in the territory (Quirós Castillo, Loza Uriarte and Niso Lorenzo 2013).

In the year 711 AD, The Umayyad Caliphate defeated the Visigoth forces in the Battle of Guadalete. The victory of Guadalete joined with the internal conflicts that the Visigoth State was passing through opened the doors of the Iberian Peninsula for the Umayyad Caliphate (coord. de Oliveira Marques 1993). With this event, the Muslim occupation period of the peninsula started.

The period known as “Reconquista” in the Iberian Peninsula was a very complex process influenced by factors of different kinds through its development. This geographical area experienced a unique dynamism, as it became the meeting place between the feudal European Christian society, and one of the most recent ideological political movements that had arisen in the Middle East, and that became a phenomenon in most of the world: Islam. The meeting of these two macro cultures complicated the reality of peninsular society in an ambivalent way. On one hand, it brought political and ideological conflicts, social changes and war. While on the other, it led to a cultural and biological miscegenation, new ways of understanding otherness, it also produced greater dynamism between social classes, introduced new technologies that increased productivity in the countryside and led to transformations in the ways society was organized (coord. da Cruz Coelho and de Carvalo Homem 1996, Stanislawski 1963).

At certain times, the Iberian Peninsula meant a constant battlefield, both militarily and ideologically, while at other times this period meant renaissance. Although it is such a long and full of nuances period, this study's temporality lies on posterior centuries (13th and 14th AD). In order to narrow and define both the period and the geographical space of this study, the facts prior the conquest of Algarve will be presented in the next timelines (see Figure 5 and Figure 6) and the territorial changes will be presented in the Figure 4.

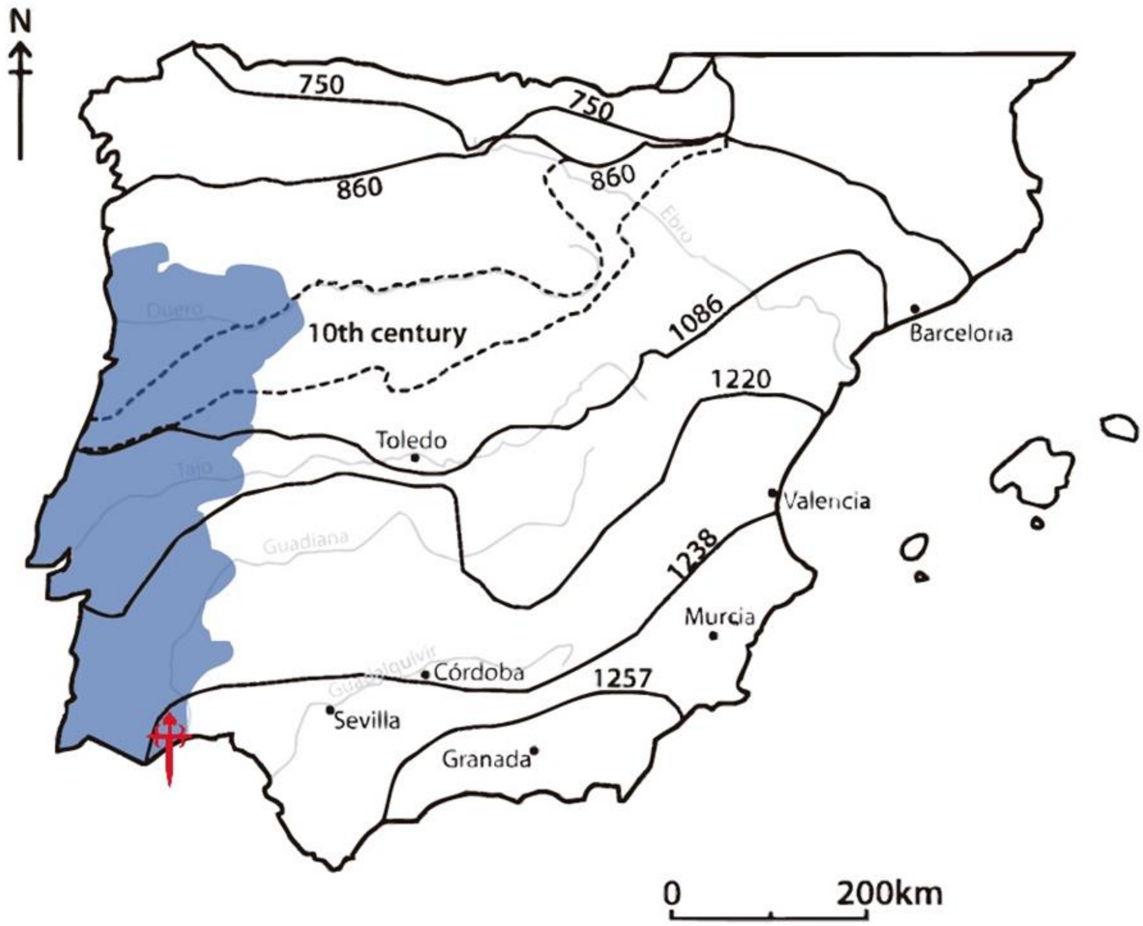

Figure 4 Map of Iberian Peninsula showing the territorial gains of the Christian Kingdoms against Al-Andalus. With a Santiago's cross is represented the location of Cacela. Portugal present territory is marked with a blue hue. This map was done through information obtained in (coord. de Oliveira Marques 1993).

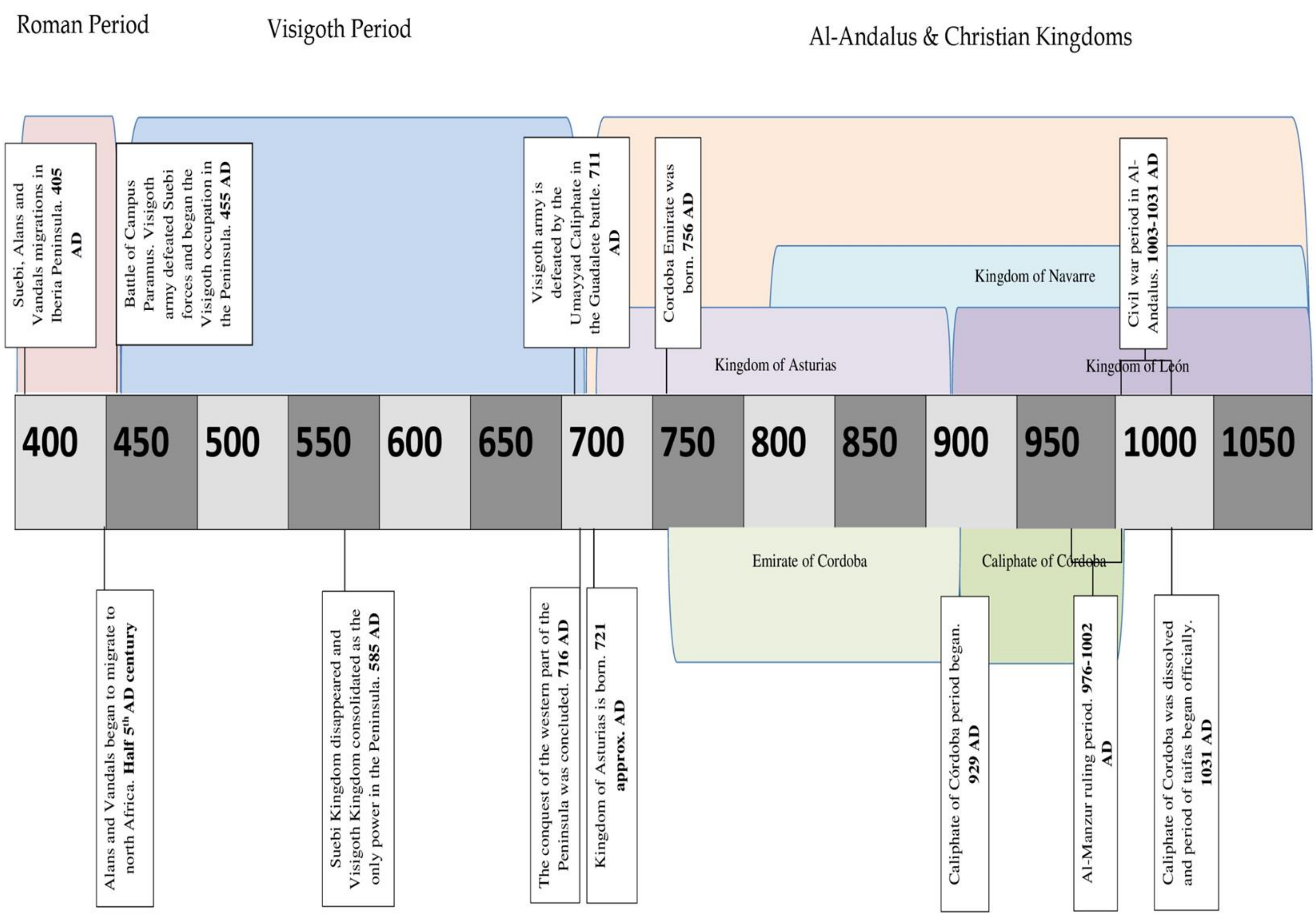

Figure 5 Timeline showing historical events from 400 AD to 1100 AD in the Iberian Peninsula. Based on (coord. de Oliveira Marques 1993)

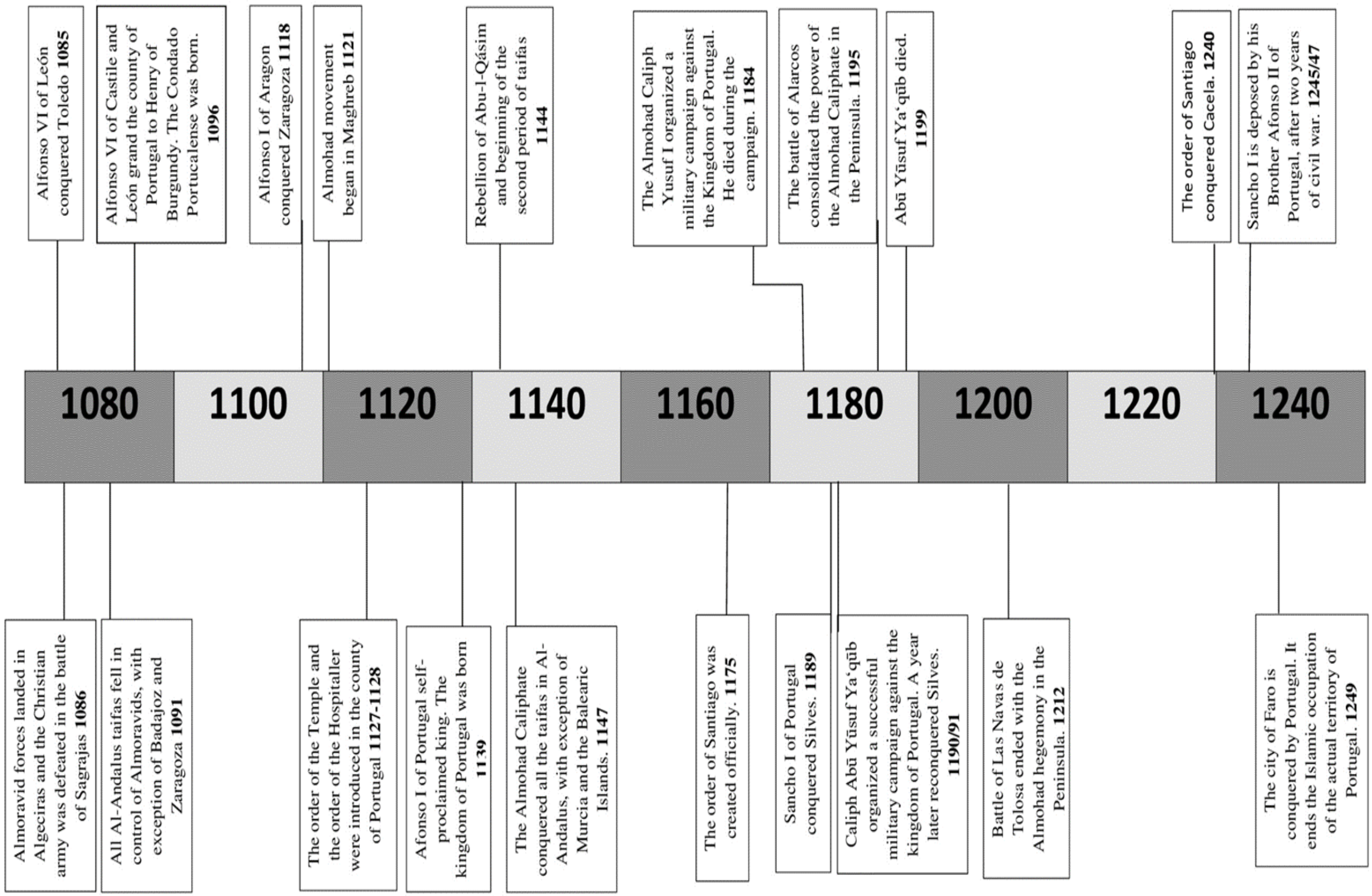

Figure 6 Timeline showing historical events from 1080 AD to 1260 AD in the Iberian Peninsula. Based on (coord. da Cruz Coelho and de Carvalo Homem 1996)

2.21 Brief history of Cacela

The first evidence of population in Cacela-a-Velha belongs to the last period of Roman Iberia (4th AD), in which a ceramic oven and some pools for preparation of garum, a fermented fish sauce, were found (Tété Garcia 2015). There are no evidences that could relate it to a settlement of a bigger scale, neither in this epoch nor in the following five centuries.

According to the historian of the ruling period of the Caliph al-Hakam II, Isa ibn Ahmad al-Razi, the first fortress of Cacela was founded in the 10th century, under the defensive construction policy of Abd al-Rahman III; nonetheless, there are no archaeological evidence to confirm al-Razi's reference. The name Cacela comes from this period, and it is an evolution of *Qastalla Darraj*, title of a noble arab family: the *Darraj Alcacetali*. The main objective of the fortress during this period was to protect the naval route that went to Tavira and Ossonoba. As a secondary purpose, the harbor of Cacela served as a refuge for ships that navigate through the Guadiana river, but due to meteorological reasons, they were not able to navigate upstream (Tété Garcia 2015).

After the Caliphate of Cordoba was dissolved in small kingdoms (taifas) and local rulers, the territory of present Algarve was distributed between Silves, Huelva and Santa Mariya. Cacela-a-Velha was part of the Taifa of Huelva in 1012, and then, it passed to be part of the Taifa of Santa Mariya (Faro), when an aristocratic family called the Banu Harun rebelled and created this latter Taifa in the year 1026. Years later, in 1051, the Taifa of Santa Mariya became part of the Taifa of Seville (coord. de Oliveira Marques 1993).

During the Almohad occupation of the Peninsula, the defenses of Cacela were improved as a policy of fortification of the whole *al-Gharb*, and most probably the silos were constructed at this time following this logic. Cacela became the most important base and harbor of military support from the west of the peninsula. To make this possible, a large number of people immigrated to the town to be part of the building force, to become a member of the military forces or to cover diverse services. Due to this demographical increase in a short period of time, it was necessary to build houses outside the walls, and the quartier of Poço Antigo was established (Tété Garcia 2015, Stanislawski 1963).

2.22 The conquest of Algarve

The kingdom of Portugal, through favoring politically the military religious orders – especially the order of Santiago–, consolidated its forces and advanced southward, and, by 1234, all the Alentejo region was conquered. From 1238 to 1240 Mértola fell and the entire border of the Guadiana was opened to the Christians. In 1240, Paio Perez Correia, member of the Order of Santiago, conquered Cacela and Aiamonte with naval support. Two years later, the Portuguese rule in eastern Algarve was consolidated with the fall of Tavira (Tété Garcia 2015).

In 1240, the headquarters of the order of Santiago remained for a while in Cacela. Around this period, the quartier of Poço Antigo was burned down and the space started to be used as a cemetery. Next to this, the church of *Nossa Senhora dos Mártires* was built, which became a center of devotion of all Algarve region (Tété Garcia 2015).

The participation of the Templars in the conquest of the Algarve was small, because its resources at that time were concentrated in the war against the Ayyubid Sultanate in Egypt. It is also possible that political instability inside the order had influenced their actions, since the Grand Master of the order had disappeared in 1244 during the Battle of La Forbie in Gaza.

After the conquest of Silves (1245) in the Barlavento, the military campaign stopped for Sancho II, because a civil war started. The conflict ended 2 years later, in 1247, and, as a result, Sancho II was substituted by his brother Afonso III on the throne. The civil war had its causes in the second half of the previous decade, in which the whole territory of Portugal, especially in the north, were passing through constant violence, crimes and pillage that the State was unable to control. The word of the king had weight in the cities, but in rural areas and in peripheric regions the absence of the State was evident. In addition to this, the king began to grant more political power and properties to the military orders, since the main objective of the ruling period of Sancho II was to conquer the Algarve. Therefore, the religious military orders were beneficiated, specially three of them: the Order of the Temple, the Order of Avis and the Order of Santiago (Fernandes 2011).

The benefits and power that these orders were gaining was so evident that it started to begin to bother the Portuguese nobility and secular clergy. The *Mestres* and the

Comendadores of the orders had such influence and power that they could even harass and perpetrate injustices against nobles and high figures of the clergy without any obvious consequence. Ultimately, it was the huge impunity and fear that the military orders generate what it took for the noblemen and high clergy to put on the Portuguese throne a king which was closer to the secular clergy (Fernandes 2011).

During the reign of Afonso III, the Muslim rule in the western part of the Peninsula vanished, when the city of Santa Mariya (Faro) was conquered in the year 1249. Some months later Loulé fell. The conquered territories in Algarve were given to the Order of Santiago, with exception of Albufeira and Porches. These were given to the Order of Avis and to the Chancellor-Master Estevão Eanes respectively (Tété Garcia 2015).

After the conquest had finished, the region stayed militarized, especially the Sotavento, where conflicts between Portuguese, Castilians and local populations where usual. In that time, the Guadiana surroundings became a focus of violence, in which the local population suffered many abuses and many Muslims were slaved. The ones that were not slaved were forced to pay taxes, and, after the Mudejar rebellion of 1264, they were relocated in *morerias* (neighborhoods in which Muslim communities were segregated) (Tété Garcia 2015).

To mitigate the abuses on the Muslim population and to make sure that they continued paying taxes to the Portuguese crown, the king made an agreement with the Order of Santiago to fix the Muslim population in the territory, avoiding migrations to other areas in the Peninsula still ruled by Islamic states. In this way many populations from Muslim origin stayed. Some years later, in 1286 during the reign of Dom Dinis, Cacela got a royal code of law, *foral*. In the *foral* document of Cacela, a numerous Muslim community is mentioned, and they should pay the *quinto real* (20% tax). The location of this population is uncertain but is believed that could be somewhere in the western part of the border of the term of Cacela (Tété Garcia 2015).

For the last years of the 13th century and the beginning of the 14th, the port of Cacela lost leadership in the region. One of the reasons was that the sand barriers of the lagoon started to complicate ship’s movements. Another reason was that Castro Marim started to become more important because of its location in the delta of the Guadiana river. At the same time, Tavira emerged as the port of the Sotavento of Algarve. In the following centuries Cacela started to decrease in population (Tété Garcia 2015).

2.23 The Order of Santiago

During the Almohad period, the military Order of Santiago was established in the kingdom of León, in order to take care of the pilgrims on the road to Santiago and safeguard the borders of the kingdom. The order was established by mandate of King Ferdinand II of León in conjunction with Celeberrimo (Cerebruno) archbishop of Toledo; João Peculiar, archbishop of Braga; Pedro Gundesteiz, archbishop of Santiago de Compostela; Ferdinand the Elder, bishop of Astorga and Esteban, bishop of Zamora, in the year 1170. However, the organization was recognized by Rome only in 1175, when Pope Alexander III granted them a papal bull. By this time the Order was already extended outside the borders of the kingdom of León.

The philosophy of the Order was extremely binary (faithful-unfaithful), which sought to bring nobles to their ranks, in order to increase the dominance of the Christian kingdoms. To

Figure 7 Illuminated image of Alfonso VIII of Castile giving the castle of Ucles in 1174 to the master of the order of Santiago, Pedro Fernández de Fuentencalada, in Tumbo menor de Castilla, Archivo Histórico Nacional, Madrid, Archival nr. 1046 B, f.15 © Archivo Histórico Nacional, licence CC BY-NC 4.0

attract them, they gave the conflicts a holy war character, where the enemy was the sin itself. They were ideologically based on preaching that it was the Holy Spirit who guided the faithful to reach divinity through defeating the Moorish heretics by the religious orders.

The Order of Santiago, unlike other religious organizations, was addressed for the upper class, so its rules and statutes were not so rigorous, and its vows differed from those of other religious orders, which were stricter. These vows were: obedience, living without own and conjugal chastity. Obedience was towards the Pope and the Master in the first instance and secondarily to other Christian authorities. Living without own meant that half of each knight's property belonged to the order. It is necessary to emphasize that it was not a vow of poverty, but that the use of the goods of each knight was under the permission of the *Mestre*. Conjugal chastity meant staying with only one woman until her death and honored her. The *freyres* could marry again after widowed. In addition to the vows, the *freyres* had a series of rules that they had to follow and that controlled elements of everyday life; however, it is documented that such rules used to be overlooked (Rodríguez Blanco 1985).

Regarding about the hierarchy of the order, the *Mestre* was the most important figure, since he was the one who had complete freedom in decision making. Only the Pope was a superior authority to the *Mestre*. At the regional level, the *Comendadores Mayores* were second in the hierarchical scale, and, after these, at the local level, the *Comendadores*. The regulatory and communication bodies were the *Visitadores*, whose function was to inform the *Capítulo* about irregularities in the administrations of the different *Comendadores*. The *Capítulo* was the executive and justice organ of the order, and, the elective body responsible for electing the *Mestres* was called *Los Treze*; which consisted of thirteen of the most important members of the order. At the end of the hierarchical scale were the *freyres*, who were the chivalrous military corps, who had multiple pawns at their service (Rodríguez Blanco 1985).

Between the years 1237 to 1277, which are the years of which the subjects of this study belong, the order was under the leadership of three *Mestres*. The first, Rodrigo Íñiguez, was at the head of the order during the conquest of the Sotavento, including Cacela. It is during his command that, for a brief period of time, the headquarters of the order was established in Cacela. It is also very likely, that he was the one who ordered the construction of the church *Nossa Senhora dos Mártires* in the area outside the town walls, and, therefore, who ordered that the quartier of Poco Antigo was burned and a graveyard was established in its place. The construction of the church would be one of the most important events for Christianity in the recently conquered region, because it was one of the five churches throughout the Algarve by the 1240s (Tété Garcia 2015).

The second *Mestre*, whose leadership is established in the years 1242 to 1275 is the famous conqueror of the Algarve Paio Perez Correia, who participated in the total conquest of the Algarve and in the surrender of Seville. Subsequent to the latter was Gonzalo Ruíz Girón, whose term would only last 2 years, as he would be killed in the Moclín Disaster, where most of the knights of Santiago perished because of an ambush commanded by Mohamed II, the emir of the Nasrid Kingdom of Granada. In fact, the battle was such a disaster that Alfonso X King of Castile and Leon, in order to avoid the extinction of the order, integrated all the members of another minor order named Saint Mary of Spain to that of Santiago and designated as new *Mestre* Pedro Nuñes, who was the *Mestre* of the minor order.

2.24 Medieval Diet

The pluricultural context that characterized the Peninsula in the middle ages led to an exchange of ideas, knowledge and, of course, products. On one hand, thanks to this, the diet

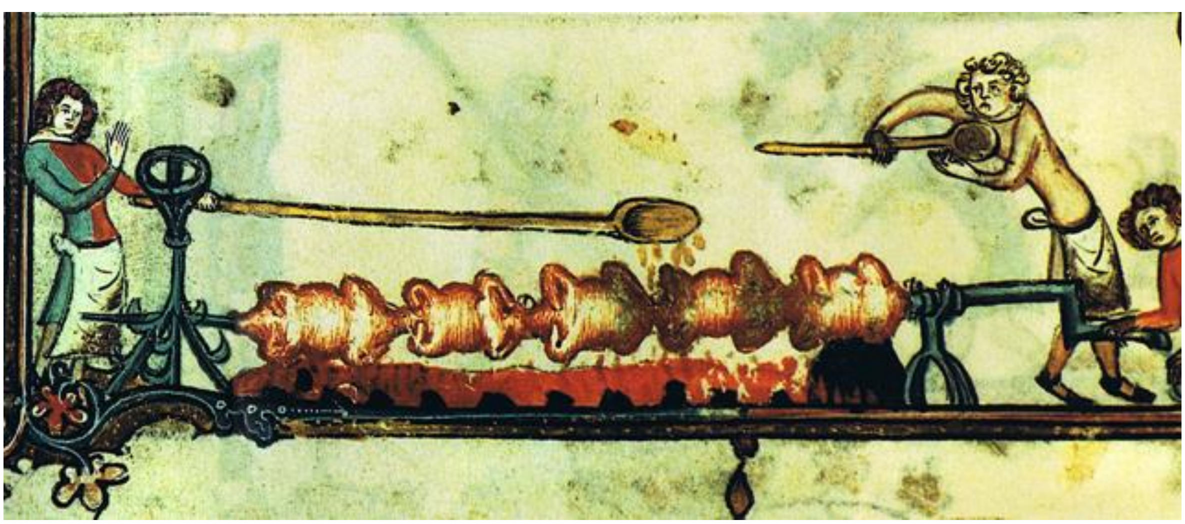

Figure 8 Illuminated image that depicts three persons grilling chickens, in MS Bodley 264, Bodleian Library, Oxford, Archival nr. 2464, f. 170v © Oxford University

was enriched with new food stuffs, but in contrast, so many political and social changes brought crisis and shortage.

The basis of the diet of Iberian Peninsula during the middle ages did not change from the one in ancient times, since the composition of the diet, as in the entire Mediterranean basin, had cereals from template climates as the main source of carbohydrates. Among these, wheat was the favorite and had a strong social class significance. The lower classes did not usually ate wheat (*Triticum spp.*), so they had to drew on other cereals such as sorghum (*Sorghum spp.*), barley (*Hordeum vulgare*), rye (*Secale cereale*) and millet (*Panicum miliaceum).* In southern Portugal, the consumption of rye was almost zero, since this cereal usually prefers colder and more humid environments. The subsistence of the common population in the Christian kingdoms used to be based on what was left over from what was not taxed by the feudal lord, therefore, food such as wheat –a cereal that requires a lot of work to process it and usually contributes less grains per plant compared to other cereals – was practically restricted for the majority. In contrast, millet was one of the few food stuffs that were not taxed by the lord, therefore it was very popular among the lower classes of the Christian kingdoms; while the evidence of millet carpological remains in Islamic medieval sites is very scarce (Peña-Chocarro, Pérez Jordá, et al. 2019). Besides this, millet has the characteristic of being a plant that resists well in more extreme climates, is easier to harvest and can be easier to store (MacKinnon 2015). Meanwhile, sorghum was more widespread among Islamic populations than among Christian ones. This may be due to the fact that sorghum in Al-Andalus was cultivated by tradition along with wheat and barley (García Sánchez 1983). Another cereal widely consumed in Andalusian society was rice, introduced to the peninsula during the emirate or caliphate period and that was adopted by Christians several centuries later (Stanislawski 1963, García Sánchez 1983).

One of the most popular foods, that its popularity even remains to this day, were pulses. They were consumed daily, being the main source of protein among the lower classes. Its abundance was, partly, through agricultural practices of crop rotation; pulses were planted in large quantities in order to fix nitrogen in the soil with the objective of balance its nutrients. The carpological remains evidence the consumption of peas (*Pisum sativum*), chickpeas (*Cicer arietinum*), broad beans (*Vicia faba*), lentils (*Lens culinaris*), and bitter vetch (*Vicia* *ervilia*) in all Portugal, both in Christian and in Muslim medieval populations (Peña-Chocarro, Pérez Jordá, et al. 2019).

Another source of protein that was common were nuts, which, thanks to irrigation systems, its cultivation was quite widespread. One nut, which its consumption shows precariousness in a population is acorn (*Quercus ilex*), because it was used, in times of prosperity, to feed the pigs to give their meat a good flavor; this practice is maintained nowadays in both Portugal and Spain through the production of Iberian ham. But, during times of famine the acorns were ground together with other roots to make bread flour (Curto, et al. 2019).

Fruits were perhaps one of the most contrasting aspects between Andalusian and Christian societies, since in Al-Andalus their consumption, variety and commercialization were extended geographically and socially. There is evidence of this in the archaeological and historical records. In contrast, populations ruled by the Christian kingdoms stigmatized their consumption. This stigmatization was based on faith, because fruit was associated with the primal sin of humanity, according to the myth of Adam and Eve (MacKinnon 2015).

The consumption of vegetables in Al-Andalus society was quite widespread in all social classes, while among Christians, vegetables were associated with the lower classes, since among the upper ones the consumption of meat was the core of their diet. The lower classes cultivated the lands of the lord, but the subsistence of the peasantry was not only based on what was produced on these lands, but their food was complemented by products grown in small plots or orchards that were outside each house. The existence of orchards dates from pre-medieval times; however, the importance of these increased, due to the aforementioned policies from part of the feudal lords. Also, this form of cultivation required a unique type of territorial organization that is mostly present in populations belonging to the Christian kingdoms (Peña-Chocarro and Pérez-Jordá, Los estudios carpológicos en la Peninsula Ibérica: un estado de la cuestión 2018).

Among the products grown in these spaces were fruit trees of different types such as apple trees (*Malus domestica*), peaches (*Prunus persica*) and plums (*Prunus* subg. *Prunus*); assorted vegetables such as celery (*Apium graveolens*), carrot (*Daucus carota*), escarole lettuce (*Lactuca sativa longifolia*); medicinal plants such as chamomile (*Chamaemelum* *nobile*); aromatic herbs such as oregano (*Origanum vulgare*), mustard (*Sinapis spp*.), coriander (*Coriandrum sativum*), and even, dye plants such as weld (*Reseda luteola*) and common madder (*Rubia cordifolia*) (Peña-Chocarro and Pérez-Jordá, Los estudios carpológicos en la Peninsula Ibérica: un estado de la cuestión 2018).

In contrast to this, the ruled populations, whether under the Emirate, Caliphate or any of the Muslim political entities that existed in the region, enjoyed a very different organization. Under these governments the territory was transformed, and trended to join in denser communities, thanks to the surplus food, and, for this reason, the importance of the orchards had a secondary role. This is due to the introduction of new agricultural irrigation technologies such as the Noria (a hydropowered machine used to lift water) and the Qanat (a gently sloping underground channel to transport water). These implementations caused agriculture to pass from extensive to intensive. According to Malpica Cuello (2012, 218): Thanks to the more or less permanent irrigation, we have a type of agriculture in which monoculture is not present, but a polyculture, a clear indication that it is managed by a peasantry that seeks its self-supply. But this is surpassed by its productive capacity.

Among the fatty sources that were consumed, the most popular, as in the entire Mediterranean basin, was olive oil. In the Algarve and Alentejo its production was regular and constant in both Christian and Islamic sites. Among Christians another fatty element used was pork lard. This culinary element was used even in regions with abundant olive oil production. This is possible to appreciate even today in all Iberian gastronomy.

As for protein sources, perhaps the most consumed were pulses as previously mentioned. Among the livestock animals, the most common and valuable were sheep (*Ovis aries*) mainly for their wool and after for its milk. The upper classes used to eat lamb meat, and unweaned lamb was considered a delicacy, while the lower classes only consumed mutton when the sheeps were old or their productivity had decreased (MacKinnon 2015). Even more common than sheep were chickens (*Gallus gallus dom.*), that were more affordable and were mainly raised for their eggs. Between the Christians the consumption of pig (*Sus scrofa dom.*) was quite extended and, in some areas, it was the second livestock animal that was eaten the most, while in Muslim ruled communities its consumption was lower. This changed dramatically when Muslim and Jewish communities were converted during the reconquest process, in which even inspectors visited homes to make sure that the new Christians had pork products and breed pigs (MacKinnon 2015). Another livestock animal that its consumption was quite widespread in Algarve were goats (*Capra hircus*) (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal) 2017), which both societies ate quite regularly and, on the other hand, cows were consumed far much less, since these animals were sometimes not even used for milk production, but for traction and as fertilizers (MacKinnon 2015). Among marine resources, the Christians were the ones that consume them the most. Fish was a symbol of Christianity and the clergy encourage its consumption, since they considered it as a pure meat because of its color, and because of the Christian tradition that said that Jesus Christ was a fisher. However, the consumption of fresh fish was affordable only for the upper classes, while the lower classes only consumed salt-cured fish. In the 11th century in the Basque Country, the cured cod (*Bacalhao* in Portuguese) market would be established, whose commercialization would spread throughout the Peninsula.

With the production of cured fish, the spice trade exploded, since spices were used to hide its strong taste. At that time the spices were introduced by the Muslims many centuries before. In fact, in Muslim archaeological contexts in comparison with the Christian ones, it is common to find evidence of spices such as cloves (*Syzygium aromaticum*), pepper (*Piper nigrum*), coriander seeds (*Coriandrum sativum*), cardamom (*Elettaria cardamomum*) and mustard (*Sinapis spp.*) among the carpological remains (Peña-Chocarro, Pérez Jordá, et al. 2019). The latter became very popular in the Christian community. Its seeds were ground together with salt and vinegar to form a paste which was used to decrease the taste of cured fish, while its leaves were used as fodder. “For the Medieval kitchen the mustard, with its cross-shaped flowers and symbolic seed, was culinarily, theologically, and medicinally important” (MacKinnon 2015, 72).

2.3 Archaeological Context

The fortification of Cacela was located in medieval times where the delta of the Guadiana river and where the river of Faro found each other; nonetheless, nowadays the river of Faro has become part of the lagoon of Ria Formosa. Cacela was a strategic port for navigation for the ships that wanted to access the city of Faro from east or for those that wanted to navigate through the Guadiana River. The fortification existed, at least, from the 10^{th} century, although it underwent alterations in the following centuries (Tété Garcia 2015).

The first archaeological intervention in Cacela-a-Velha was done in 1990 because of an emergency intervention. The call for this intervention was due to the fact that a roman oven was discovered when some people were doing trenches for apple tree cultivation. After, in 1998 it was discovered the old Islamic quartier of Poço Antigo. The archaeological intervention was sponsored by the municipality of Vila Real do Santo Antonio. In the process participated the associations of: “Archeological Field of Mertola” (CAM by its Portuguese acronym), the Commission for the Coordination of the region of Algarve (CCDRA by its Portuguese acronym) and the Natural Park of Ria Formosa (PNRF by its Portuguese acronym).

The direction of the archaeological excavation was in charge of Susana Goméz and Alicia Candón of the CAM. This intervention was carried out in two campaigns of 15 and 30 days, adding up a total of forty-five days of work. A medieval Christian sepulchral set was discovered on abandoned constructions that belong to the end of the Almohad period. The medieval necropolis of Cacela was located outside the fortification, near to a stream that passes through the eastern limits of the town, and it was located on an Islamic quartier. It is believed that the fact that the Christian burials were placed there could mean a sort of symbolic victory over the Al-Andalus. Situations like this one have been found in Mértola, Silves and Palmela (Tété Garcia 2015). The label of “Poço Antigo”, that in English means old well, was given because the local inhabitants of Cacela told the archaeologists that in the past, an old well for the supply of drinking water for the town was situated in that area.

In 2001, a new archaeological excavation was carried out at the site of Poço Antigo. The task was extended to the Institute of Anthropology of the University of Coimbra, with

Francisco Curate being responsible for the archaeological work. The archaeological excavation was carried out in two campaigns of 75 days each, with the total duration of four months and a half. The first campaign began on May 14 and ended on July 31; nevertheless, because of the Necropolis extended in all the area of the Islamic quartier the excavation was extended till the 9th of December of that same year.

Three years later (2004), the Cacela Heritage Information and Research Center (CIIPC from its acronym in portuguese), in the framework of a project financed by the European Union, promoted the archaeological excavation in the fortification of Cacela (Largo da Fortaleza). In 2007 the CIIPC promoted new archaeological works, reason why it was possible to expand the excavation in the Largo de Fortaleza (see Figure 9). The campaign was held between May and August. Silos were discovered (see Figure 10), some of reasonable dimensions, but it was not possible to reach the bottom of the structures, that were full of medieval rubble (Tété Garcia 2015).

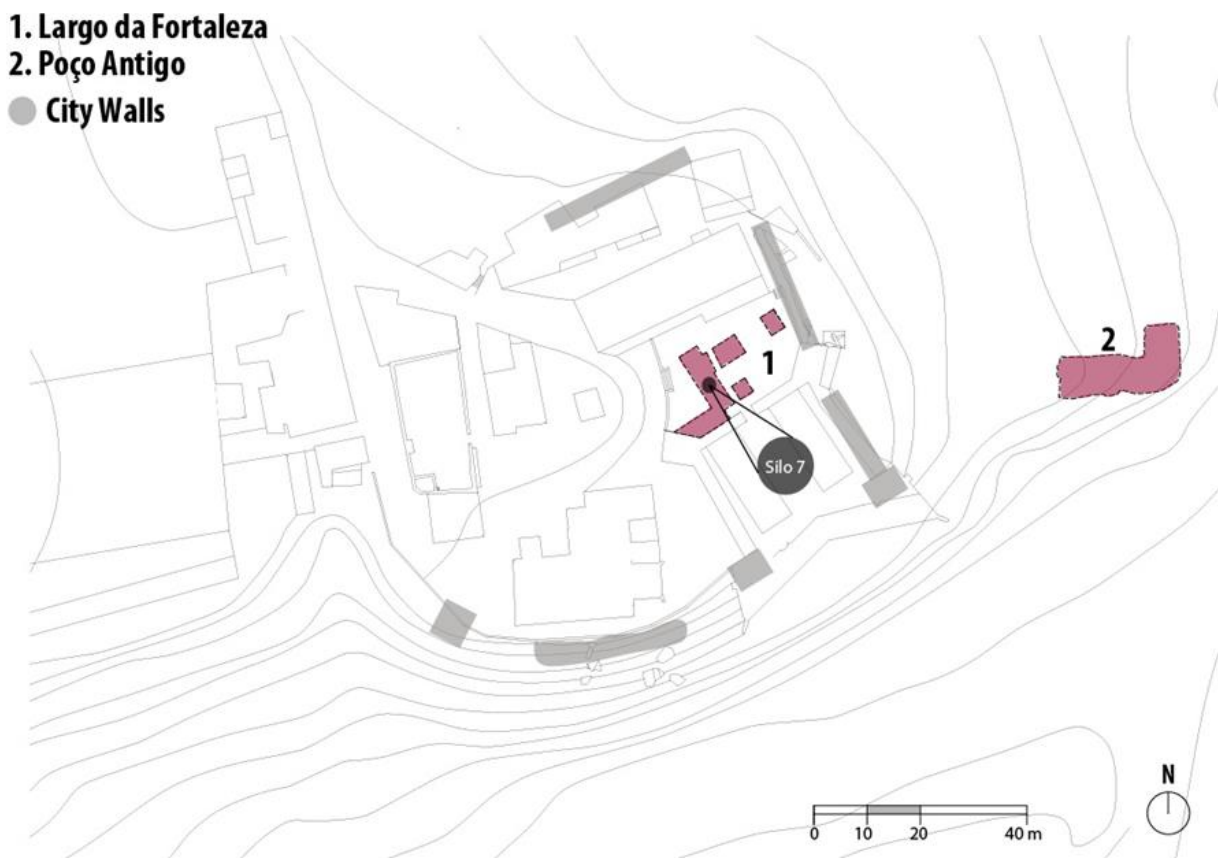

Figure 9 Map of Cacela-a-Velha showing the excavation areas in red. The old walls of the town are depicted in grey. Adapted from (Tété Garcia 2015).

In this campaign 81 stratigraphic units were registered and 20 bags (20x45 cm) collected with ceramics, fauna, malacology and glass. The malacofauna was classified in the Archeology laboratory of the University of Algarve, under the guidance of the professor specialized in Archaeozoology: Maria João Valente.

Silo 7 probably was built in the 12th century, during the Almohad period, with purpose of being used as a place to storage cereals in case of possible sieges. Afterwards, the Silo 7 was used as a garbage dump during the first years after the Christian conquest, period that this study concerns. It is possible that due to this use type, the content of the Silo was a mixture between materials from Islamic and from Christian occupation (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal) 2017).

Figure 10 Silos 3 and 7 during the excavations of 2007. Photo taken from (Tété Garcia 2015).

The most abundant faunal remains in Silo 7 were malacological. There were 2055 specimen of Mollusks, being the most abundant wedge clams (*Donax trunculus*), flat oysters (*Ostrea edulis*) and common cockle (*Cerastoderma edule*). Following in abundance were rabbit remains with 153 (*Oryctolagus cuniculus*), then sheep and goats with 140 (*Ovis aries/Capra hircus*), then chickens with 50 (*Gallus gallus dom*.), after pigs and boars with 34 (*Sus sp*.), following cattle with 32 (*Bos taurus*), and finally deer with 25 (*Cervus elaphus*). Another faunal remains in the silo included 4 black rats (*Rattus rattus*), 1 mouse (*Mus sp*.), 9 cats (*Felis sp*.), 5 equids (*Equus sp.*), 1 donkey (*Equus asinus*) and wild animals such as 2 turtles (*Mauremys leprosa*), 2 black bears (*Ursus arctos*), 3 foxes (*Vulpes vulpes*), 1 Granada hare (Lepus granatensis), 5 red legged patridges (*Alectoris cf. rufa*), 2 atlantic puffins (*Fratercula arctica*), 2 European turtle doves (*Streptopelia turtur*), and 1 Stint (*Calidris sp*.) (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal) 2017).

The age profile was done by the zooarchaeologist Maria João Valente. In general, among the swine, cattle, caprine and chickens remains the majority were mature specimens, with some exception of immature or in the case among swine with neonatal specimens (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal) 2017).

The discovery of the Christian necropolis during the campaigns of 1998 and 2001 covered the sectors, west, central and east. In these campaigns, the site of Poço Antigo was excavated with a total area of 200 m^2, 180 stratigraphic units were registered, 74 skeletons and reductions were collected, several other materials were collected, comprising about 9000 ceramic fragments, 1670 faunistic remains and 490 non-ceramic materials (Tété Garcia 2015).

The necropolis was opened in a sandy layer, that was part of the ruins of houses from the Almohad period (see Figure 11). The stratigraphic units where the graves were opened had the following characteristics: loose sand, consolidated sand, sandy soil with many blocks, fragments of roof tiles, and straw roof coverings, corresponding to the level of abandonment and destruction of previously existing rooms. The sandy soil, on which the necropolis was installed, provided an excellent preservation of the skeletal remains. The pH of this type of soil is alkaline, which, together with the optimal drainage conditions of the rainwater, made this place suitable for the protection of the human bones deposited there (Tété Garcia 2015).

The beginning of the use of the sepulchral space seems to match with the conquest timing of the fortification of Cacela-a-Velha, according to historical sources, since ^{14}C analysis were made (Tété Garcia 2015, 323):

> Two radiocarbon dates were made to the bones 13 and 53 by the Tamers & Hood laboratory. The radiocarbon dating applied to the right tibia of the individual exhumed from the grave 13, provided a calibrated date of approximately 1240: Intercept of radiocarbon age with calibration curve: Cal AD 1240 (Cal BP 710); 1 Sigma calibrated result (68% probability): Cal AD 1180 to 1270 (Cal BP 760 to 680). The radiocarbon dating, in this case applied to the right tibia of the male subject of grave 53, pointed to 1260: Intercept of radiocarbon age with calibration curve: Cal AD 1260 (Cal BP 690); 1 Sigma calibrated result (68% probability): Cal AD 1190 to 1280 (Cal BP 760 to 670).

The individuals 13 and 15 placed at the lowest level could be the oldest burials of the necropolis of Cacela. The individual 13 was a male adult that was deposited in a sandy layer with some coals and under a layer of fire. In contrast, north of a wall there were the most recent burials according to stratigraphy and contained several male adults, graves 53, 55 and 56.

All the exhumed individuals of the necropolis were oriented to the east, deposited in position of dorsal decubitus with the arms usually crossed over the chest or the abdominal area, with low variations between 240º and 270º. Their heads were delimitated by stones to make that they stayed looking at east (see Figure 12). This had its meaning and reason in the Christian philosophy, since it was believed that the second coming of Jesus Christ and the establishment of his Kingdom would have its origin in Jerusalem (Tété Garcia 2015).

The most common burial place was the churchyard. This was a sacred space that was considered the ideal place for the protection of the bodies after death. In the excavations of 2001, it was believed that five individuals of the whole set were positioned in place identified as probably a church, and, in this way, it was possible to theorized relations that were related to social status (Tété Garcia 2015, 324); however, this hypothesis was refuted in the excavations of 2018, when it was found that the possible church wall was in fact the remains of an Almohad period house. Nowadays, the location of the church is still unknown.

Figure 11 Excavation plan of the Necropolis Poço Antigo in Cacela-a-Velha. Numbers were given to the individuals analyzed. The only coffin burial is represented with a brown coffin. A red clock represents the individual that was dated by radiocarbon as the earliest. A blue clock represents the individual that was dated by radiocarbon as the latest. Adaptation from (Tété Garcia 2015).

All the burials of the necropolis presented a deposition of very simple characteristics. On one hand, this could reflect the poverty and precariousness of the community of Cacela-a-Velha. On the other hand, it could be related to the Christian philosophy itself, where all humans had to show solidarity and signs of humility through the use of modest graves, a philosophy that was quite spread during that century. The individuals would have probably been wrapped with linen or wool, that were common burial conditions of the epoch, although the traces of their existence are faint, because of the perishable character of the materials, but some metal pins were found, material that could be related to the existence of the wrapping fabric (Tété Garcia 2015).

Figure 12 Photo of the excavation of 1998 of the individual 1. Photo taken from (Tété Garcia 2015).

Of the exhumed set, only one coffin burial was identified. The male adult buried in grave 31 is this exception. The presence of short iron nails around the body, one of which is associated with a small fragment of wood, several iron fragments and decorative elements, are the things that induce the existence of an elaborate sepulchral container. In addition, it had on the chest a small metal pendant in the shape of a sea shell. It featured ribbed decoration and a perforation. This symbol was used by the pilgrims of Santiago de Compostela. This means that it is plausible that the individual 31 had a higher social status within the group, and it may correspond to a member of the militia of the Order of Santiago, who was installed in the fortification of Cacela (Tété Garcia 2015).

Among the individuals, there is a clear majority of males. Twenty-six individuals have been identified as male, ten as female, three as probably male, one as probably female, and two that were not possible to estimate their sex (Curate 2001). It is necessary to mention that the sexual disproportion may be the result of an error inherent to the fact that the excavation is just a portion of the whole necropolis and it cannot serve as a representative element of the total (Tété Garcia 2015).

Chapter 3 Scientific background

3.1 Using bone geochemical composition for reconstructing past diet

Several techniques have been developed to study past diets in both social and natural sciences. It is possible to study what was eaten by different documentary and ethnographic sources, as well as from various physical evidences. Archaeobotany studies the macroscopic (seeds, fruits) and microscopic remains (pollen, phytoliths) that were cultivated or consumed in the past, meanwhile zooarchaeology focuses on the faunal remains that were hunted or breed. It is also possible to study edible products from residues in ceramics or coprolites with chemical analytical techniques (Schneider, et al. 2016, Peña-Chocarro, Pérez Jordá, et al. 2019, Colombini, et al. 2005).

Besides the already mentioned remains, another source of information about past diets are osteological remains. It is plausible to find specific characteristics through the analysis of dental macrowear and microwear, as well as in dental caries and calculus e. g. (Gamza and Irish 2010). Also, the study of skeletal pathologies or morphological deformations can give general ideas that could refer to diet causes. Other osteological analysis used for diet reconstruction are chemical analysis such as trace elements and stable isotopes analysis, such as nitrogen, carbon, and sulfur.

While most of the other approaches give us the possibility to know which products were used or to understand how the diet was shaped, they are limited to very general features that do not make possible the study in detailed differences on diet between populations in specific areas or in reduced periods of time.

In contrast, the contribution that stable isotopes studies provide is the possibility of making more specific the understanding of past diets, since it focuses in more reduced populations, coming to focus even at an individual stage. In this way it is possible to understand characteristics that occur at cultural and social level, such as differences between sexes, status and ages. Furthermore, it is plausible to observe variations between diverse populations, even between nearby sites, and variations in short periods of time (Tykot 2004).

For studying the past, the stable isotope analysis that are used are carbon (^{12}C and ^{13}C), nitrogen (^{14}N and ^{15}N), sulfur (^{32}S and ^{34}S), hydrogen (^{1}H and ^{2}H), oxygen (^{16}O and ^{18}O) and strontium (^{86}Sr and ^{87}Sr); however, to study diet only the first three are used, while the latter can provide information about mobility. Carbon provides information on the foods that form the basis of the agricultural diet in general, since it differentiates between the intake of plants of type C_3 and C_4, whose characteristics will be explained below. Besides, carbon provides an idea of the intake of marine resources in contrast to terrestrial resources. Nitrogen, on the other hand, provides information about trophic level of the ingested food in the diet of a population or an individual. When these two analyses complement each other, they give a clearer vision of the diet, making possible to infer the source of protein consumed and the difference in contribution between marine and terrestrial resources (Ambrose and Norr, Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate 1993). The analysis of sulfur, on the other hand, provides the possibility of differentiating between aquatic resources, whether marine or freshwater, as well as understanding if a population belonged to a coastal area (Nehlich, The aplication of sulfur isotope analyses in archaeological research: a review 2015).

The analysis of stable isotopes of carbon (^{12}C, ^{13}C) and nitrogen (^{14}N, ^{15}N) recorded in bone collagen uses samples that range between 400 to 700 μg, while the analysis of sulfur (^{32}S, ^{34}S) uses samples that weight approximately 10 mg. The difference of this is due to the fact that carbon and nitrogen are more abundant in the osseous tissue, and in general in the human body, than sulfur. The samples are measured by isotope ratio mass spectrometry and the results are obtained using international standards and are written using delta notation ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) and the value is expressed in parts per mil (‰) (Ambrose and Norr, Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate 1993).

The studies of stable isotopes in bones can be done in the organic and inorganic part, since these two provide different information about the diet of an individual. Collagen is composed by amino acids, its biosynthesis is based on the protein intake of the individual's diet; meanwhile, hydroxyapatite records the three major macronutrients of the diet: proteins, carbohydrates and fats (Tykot 2004). The analysis is also carried on teeth, both in enamel and dentine. The use of these approaches together provides detailed information about the diet of an individual during lifetime. The study of the tooth enamel brings information about the childhood, since the formation of teeth happens from birth until 12 years approximately, and later in the case of the wisdom teeth. The study of the mineral part of the bone provides an average of the diet of the individual; meanwhile the study of the collagen gives an idea of the type of protein ingested on the diet. Besides, the temporality of diet can be established by the type of bone studied, since the process of renovation of bone depends on its size. In this way, it was believed that a bone like a clavicle or a rib could give information about the food intake of the last 5 years of an individual, meanwhile larger bones such as femurs could indicate longer periods; nevertheless, new experimental studies have indicated that the occipital bone has the longest turnover rate (Fahy, et al. 2017). Due to the possibility of observing these changes through the life of an individual, it is also possible to infer some of its causes. The study of different teeth of a person contribute to understanding shifts on diet related to the age (e. g. weaning), culture (allowance or forbiddance of consumption of a product) or migration (Tykot 2004).

In archaeological contexts the preservation of bones depends on many factors like the nature of the soil, humidity, temperature, time being buried, etc. Because of this, the most common stable isotopes analysis is done on bone collagen, since hydroxyapatite is more susceptible to diagenesis that can alter the original isotopic ratio. Usually when the study is done on the mineral part, teeth enamel is used, because it is harder and less porous than bones (Ambrose and Norr, Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate 1993).

3.2 The osseous tissue: the support of the dietary information

The osseous system has many functions in the body and one of its main purposes is to give structure to the body and to serve as anchor to ligaments, tendons and muscles. In addition, bones provide protection to the vital organs. They also contribute to produce some substances that are vital for the proper functioning of the whole body and, inside the bones, blood cells are produced, and fat and some important elements like calcium are stored.

Bone tissue is an ever-changing material, which is renewed thanks to certain specific cells within it. The shape and the size of bones change throughout life and may vary between individuals. Bone variation can occur in four ways. Ontogeny is the variation that occurs with the growth of the individual e. g. childhood and adult stage. The second variation is sexual dimorphism. The third type of variation is population-based, in which diverse human groups have distinctions in shape and size; e.g. commonly longer bones in individuals from north Europe in comparison with individuals from Mediterranean Europe. The fourth variation is idiosyncratic variation, which are individual disparities in people from the same population, age and sex (White, Black and A. 2012).

Bone is a composite material formed of protein (collagen) and mineral (hydroxyapatite). Collagen constitutes around 90% of the organic content and gives flexibility to the bone, while the hydroxyapatite $Ca_5(PO_4)_3(OH)$ hardens the skeleton. This mineral contains 99% of the calcium and 80% of the phosphorus reserves of the body. In general, all adult skeletons have two structural components: cortical bone (compact) and trabecular bone (spongy). The compact bone is denser, meanwhile the spongy bone is porous and lighter and is found where the tendons attach like in the vertebrae or in the extremities of the long bones. Unlike their differences of structure, both bones have identical molecular and cellular compositions (White, Black and A. 2012, 32).

The structure of the bone follows a logic, in which the main role of the compact bone is to provide a solid structure, while the spongy bone keeps in its interior red marrow, that it is a tissue that produces red and white blood cells as well as platelets. In the middle part of bone there is the medullary cavity where is found the yellow marrow, which constitutes a reserve of fat cells (see Figure 13) (White, Black and A. 2012).

The cells that conform bone tissue are from three types. Osteoblasts, whose purpose is to synthetize and deposit hydroxyapatite throughout the tissue, secrets a material called osteoid (unmineralized portion of the bone matrix that forms prior to the maturation of bone tissue) and other proteins. As the osteoid becomes mineralized it develops into new bone tissue. The second type of cells, the osteocytes, are the most common cells in mature bone tissue. Finally, the third type of cells that are called osteoclasts are responsible for the resorption of the bone tissue. These three different cells are part of a cycle in which is constantly reshaping and renewing the bone. This cycle, called ontogeny, plays a main role in the histological characteristics of bone, since it is possible to differentiate between osseous tissues of adults and subadults individuals.

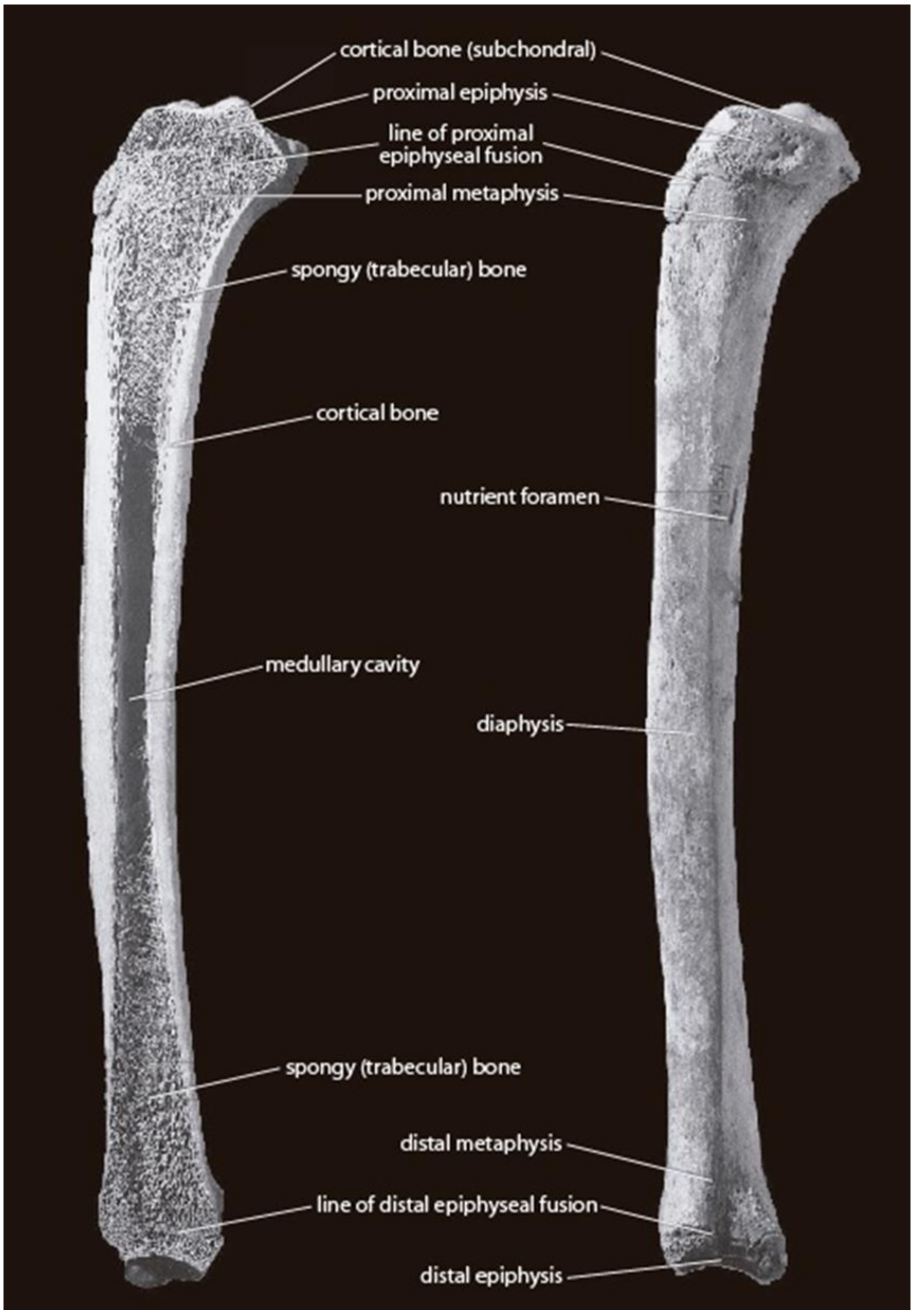

Figure 13 Image showing the structure of a bone. Image taken from (White, Black and A. 2012).

Immature bone (woven bone) is composed by a larger quantity of osteocytes and its collagen fibers are oriented randomly. As individuals grow, the immature bone is replaced by mature bone (lamellar bone), in which its proportions of osteocytes decrease and its collagen fibers are arranged and create an organized structure. Compact bone and spongy bone are lamellar (White, Black and A. 2012).

Because some of the individuals that this study analyzes have fractures and passed for a process of bone repair, it is necessary to mention it briefly. When the fracture occurs blood flows into the area and forms a hematoma. After, it creates a *Callus* that consists mainly of highly protein content connective tissue, that, after two days, the osteoblasts respond and start to mineralize the *callus* forming woven bone. This process can last until six weeks and if the fracture area is not properly immobilized can create a deformation. This woven bone eventually is converted in lamellar bone (White, Black and A. 2012).

3.3 Photosynthetic pathways: type of plant ingested via carbon isotopes

The photosynthesis is a vegetal metabolic process that uses sunlight as source of energy with the aim of transforming CO_2 into organic matter. Most of plants do photosynthesis; nevertheless, the way in which CO_2 is incorporated varies. There are three different pathways that diverse species of plants use to metabolize this compound: C_3, C_4 and CAM (Crassulacean acid metabolism) (see Figure 14). The reason that these three metabolic processes exist is due to climatological differences which the plant species have undergone, and they evolved diversely. The distinct pathways are observable in the isotopic ratio of the stable isotopes of carbon (^{12}C and ^{13}C) in the plants. When the ratio between $^{13}C/^{12}C$ change, it is called fractionation. The way fractionation occurs is what differentiates the distinct photosynthetic pathways (O'Leary 1988).

Atmospheric CO_2 is composed approximately by 98.9% of the stable isotope ^{12}C and 1.1% of ^{13}C; nevertheless, the ratio between these two isotopes ($^{13}C/^{12}C$) changes when the CO_2 enters the plant. When this gas enters through the stomata into the internal space of the plant, the first fractionation occurs. This happens because the lighter isotopes are absorbed more easily. The C_3 plants fix the CO_2 in their tissues with the enzyme ribulose bisphosphate carboxylase (RuBisCo). In this process a second fractionation occurs, where ^{13}C is discriminated because of the difference of mass, making the diffusion of $^{13}CO_2$ slower. In the process of diffusion of CO_2, RuBisCo also takes O_2, that produces a side reaction. This reaction is called photorespiration, that instead of fixing carbon produces losses of some already-fixed carbon, which translates in a waste of energy and water, and a decrease of sugar synthesis (Forseth 2010).

These losses of water and energy could be crucial for species that are found in environments with limited water resources. Therefore, C_4 plants carried out CO_2 by another enzyme that does not take O_2 and it is called PEP carboxylase. The CO_2 is transported in form of malate to the bundle-sheath and then is fixed by RuBisCo in the same way as in the C_3 pathway. This means that only one isotopic fractionation occurs and it makes more efficient the process by avoiding photorespiration, and this decreases any losses of water and energy (Forseth 2010).

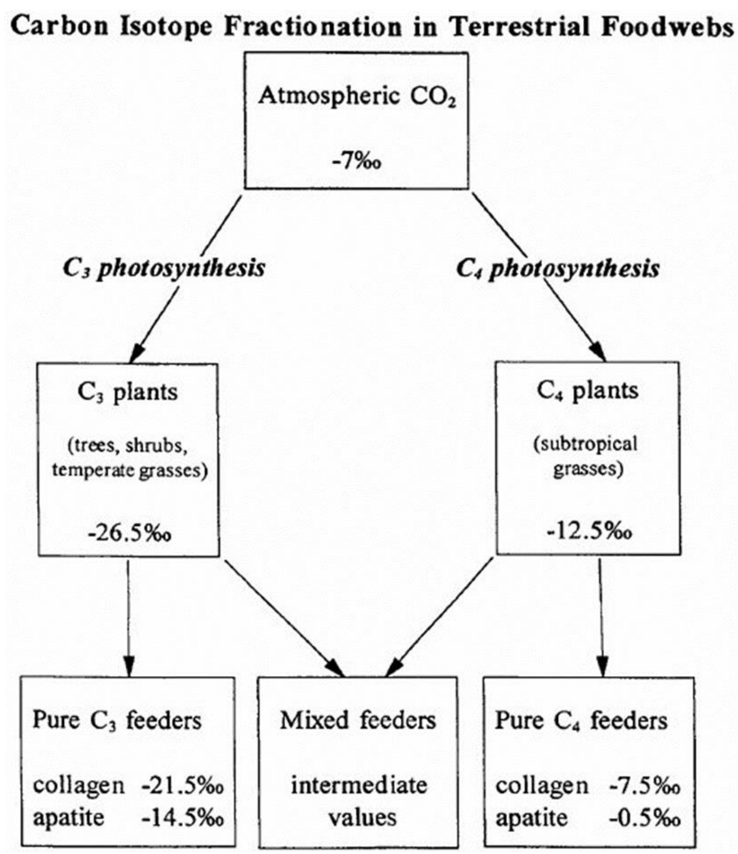

Figure 14 Carbon photosynthetic pathways, image from (Tykot 2004).

To measure the differences in ratio between stable isotopes $^{13}C/^{12}C$ of a sample a technique called isotopic ratio mass spectrometry is used. The measurement of the ratio is defined by:

$$R = {}^{13}CO_2/{}^{12}CO_2$$

The measurements are stated by the delta notation ($\delta^{13}C$) relative to international recognized standards and are expressed in parts per mil (‰) (Tykot 2004). The standard used is a carbon dioxide V-PDB, Vienna Pee Dee Belemnite (O'Leary 1988).

$$\delta^{13}C = \left[\left(\frac{R sample}{R standard}\right) - 1\right] \cdot 1000$$

The more negative a $\delta^{13}C$ value is, the less enriched in ^{13}C the sample will be. On the contrary, a more positive value means an increase of the heavy isotope (^{13}C) (O'Leary 1988).

The average of the $\delta^{13}C$ value of C_3 plants is -26‰, meanwhile the mean of the $\delta^{13}C$ value of C_4 plants is -12‰. The values of C_3 plants are also sensitive to weather conditions, while C_4 values are stable (Ambrose and Norr 1993). The variability of values increases in aquatic plants, due to the fact that the diffusion of CO_2 is less uniform and the source of it is soluble bicarbonate, which has a different isotopic ratio. This depends on the diffusion, therefore in a stream or in areas were water flows energetic and constant, the values are going to be more negative, even being similar to those in C_3 plants, meanwhile in places were CO_2 is less constant, the values are as positive as a C_4 plant (O'Leary 1988).

In general, all trees, weeds, shrubs and some grasses from the north hemisphere present a C_3 photosynthetic pathway, while, many plants and grasses from arid areas and subtropical environments present the C_4 photosynthetic pathway. CAM pathway is shown in plants where water resources are really limited. Due to the temporality and space that this study concerns, the plants that could be part of the diet of the humans of Cacela-a-Velha would be the following: C3 plants such as cereals, wheat and barley varieties, both naked and hulled, as well as rye, oats and the recently introduced rice. All fruit trees, vegetables of that epoch, tubers and pulses also belonged to C_3 plants. The only C_4 plants consumed were millet and sorghum; however, their consumption during middle ages was quite widespread and for some populations it was the most important source of carbohydrates (Peña-Chocarro, Pérez Jordá, et al. 2019). The use of these C_4 plants for animal feeding, as well as some marine plants was also quite widespread (Feio 1983). The consumption of CAM plants in the Algarve has not been documented.

3.4 Trophic levels information through study of nitrogen stable isotopes

Besides the information that the analysis of carbon isotopes provides to the study, the understanding of past diets is enriched when $\delta^{13}C$ is contrasted with nitrogen isotopic analysis. The stable isotopes of nitrogen are $^{15}N/^{14}N$. $\delta^{15}N$ give information about the trophic level, making possible in this way, to infer the source of proteins in the diet of the studied individuals (see Figure 15). To understand the protein source of a consumer, an experimental

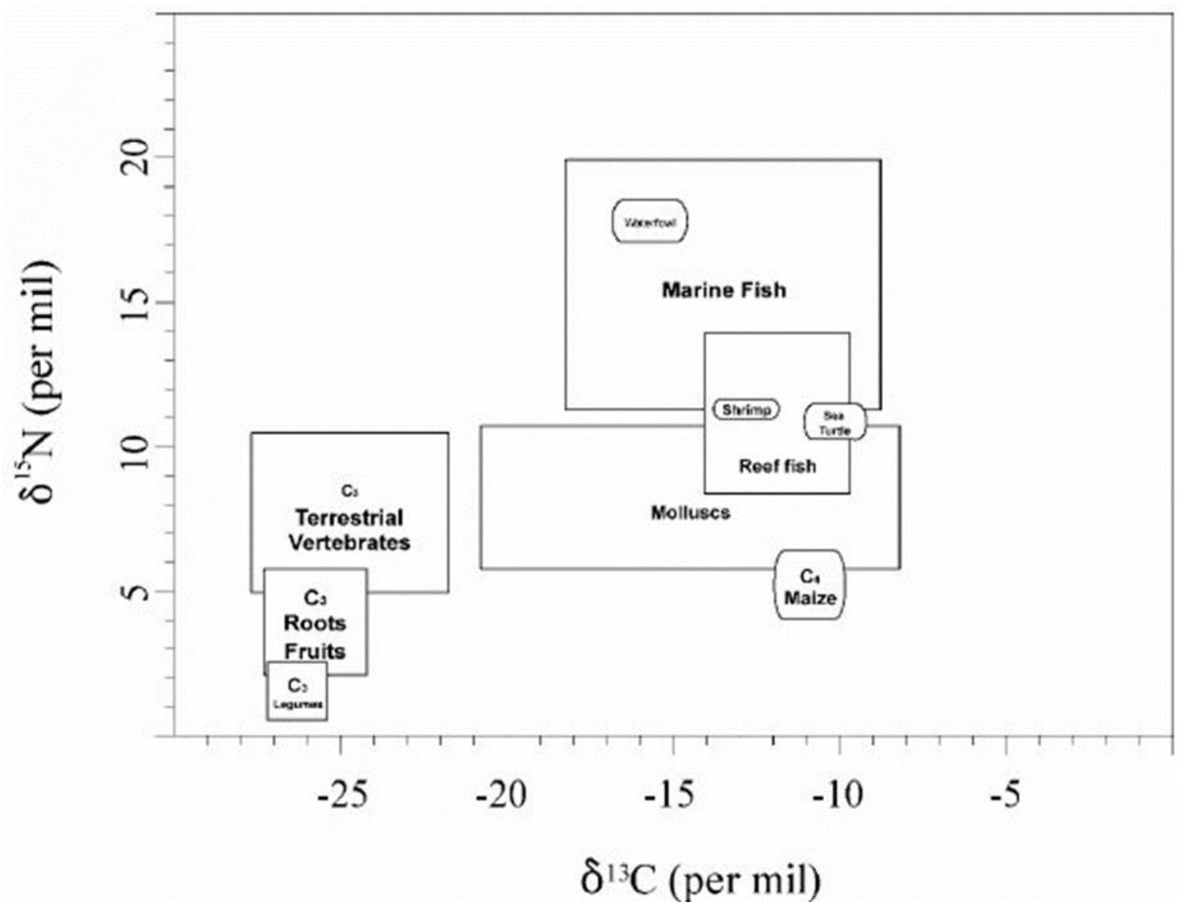

Figure 15 Graph depicting the hypothetic values of different animals' bone collagen according to their $\delta^{15}N$ and $\delta^{13}C$. Image by (Tykot 2004).

analysis study discovered that there is an enrichment in a range of 3 to 5‰ in $\delta^{15}N$ and 0 to 2‰ in $\delta^{13}C$ values between the consumer and the diet tissues (Bocherens and Drucker 2003). This isotopic change is called trophic offset. Also, the contrast of these two analyses give clues about marine resources, since the values, both $\delta^{15}N$ and $\delta^{13}C$, usually are more positive between animals and plants from the sea (Schoeninger y DeNiro 1984).

$\delta^{15}N$ values become more positive along the food chain. Subsequently, pulses (that fix nitrogen from the air into the soil) have the most negative values, then plants, after herbivores, then primary carnivores that feed from herbivores, and finally secondary carnivores that feed on primary carnivores (see Figure 15). In the case of marine flora and fauna the range of values is larger, since the food chain in the sea is longer and more complex.

The range of animals that feed exclusively from sea resources, including birds that live in the sea coast is 9.4 to 23.0‰ with a mean $\delta^{15}N$ value of +14.8 ± 2.5‰. Meanwhile, between terrestrial animals the maximum value is +10.0‰ and the average is +5.9 ± 2.2‰. The overlap between terrestrial and marine animals happens only in between the values 9.4‰, being the minimum of marine feeders, and 10‰ that is the maximum of land fauna. So, there is only 0.6‰ overlap (Schoeninger y DeNiro 1984).

To measure the differences in ratio between nitrogen stable isotopes $^{15}N/^{14}N$ of a sample a technique called isotopic ratio mass spectrometry is used. The measurement of the ratio is defined by:

$$R={}^{15}N_2/{}^{14}N_2$$

The measurements are stated by the delta notation ($\delta^{15}N$) relative to international recognized standards and are expressed in parts per mil (‰) (Tykot 2004). The standard use is atmospheric N_2 AIR,

$$\delta^{15}\mathrm{N} = \left[\left(\frac{\mathrm{R}sample}{\mathrm{Rstandard}}\right) - 1\right] \cdot 1000$$

3.5 Fish intake and mobility investigation using sulfur isotopes

Another isotopic system used in the field of paleodiets is sulfur. This proxy when combined with nitrogen and carbon can provide complementary information about protein intake that is linked to water resources, making possible to differentiate between sea and freshwater intake. In addition, it provides information about mobility, being able to differentiate between local and non-local individuals.

Sulfur is one of the most abundant elements on the earth, being distributed in three major reservoirs: in sulphates that are dissolved in all over the bodies of water, in evaporitic sulphates and in pyrite found in earth. Also, sulfur is the 7th element most abundant in the organic tissues of the human body and is found in the mineral part of the bone as calcium sulphate ($CaSO_4$) and in proteins, specifically in the amino acids methionine ($C_5H_{11}NO_2S$) and cysteine ($C_3H_7NO_2S$); however, from these amino acids, only methionine is found in the collagen of the bone tissue, with a frequency of 5/1000 residues; meanwhile in keratin – protein that constitutes soft tissues such as hair and nails– both amino acids are found (Richards, et al. 2003).

There are four stable isotopes of sulfur: ^{32}S, ^{33}S, ^{34}S and ^{35}S. The ones used in stable isotopes studies are ^{32}S, since it is the most abundant (95.02%), and ^{34}S, which is the one that follows in abundance (4.21%). The analysis of sulfur is also done using carbon and nitrogen. The standard used to scale against each sample is Canyon Diablo Troilite (V-CDT) and is reported by using the notation $\delta^{34}S$ and the values are expressed in per mil (‰) (Nehlich 2015).

Because sulfur is a minor component in human tissues, it cannot be taken as an indicator of diet by itself. The abundance of sulfur in tissues, as previously mentioned, is due to the presence of two amino acids. In bone tissue, the incidence of sulfur is much smaller than it is in muscle tissues or organs. However, when sulfur complements nitrogen and carbon isotopic analyses, it can provide tools that are necessary to understand whether protein consumption is constituted by marine animals or not. This is due to the fact that fish muscle tissue, and in general marine animal tissues, contains more of these two amino acids, since the concentration of sulfur diluted in the water is higher than that in most terrestrial areas

(Nehlich 2015). Nevertheless, it is necessary to be cautious in the interpretation of sulfur data, since "it should be noted that $\delta^{34}S$ values do not necessarily reflect consumption of marine protein, as they can also register the proximity of the dietary protein source to the sea" (Richards, et al. 2003).

This is because sulfur is deposited through rain over coastal regions. This effect is called spray effect and results in $\delta^{34}S$ values being greater than +20.3‰. On the other hand, in regions far from the coast (>50 km away from the sea) $\delta^{34}S$ values are less than +14‰, taking into account some exceptions, where the geological composition of the soil is rich in sulphates or by oxidation of sulfides and organic sulfur by microorganisms in the soils (see Figure 16) (Nehlich 2015). Sulfur analysis data can help to differentiate between local and non-local individuals in coastal areas.

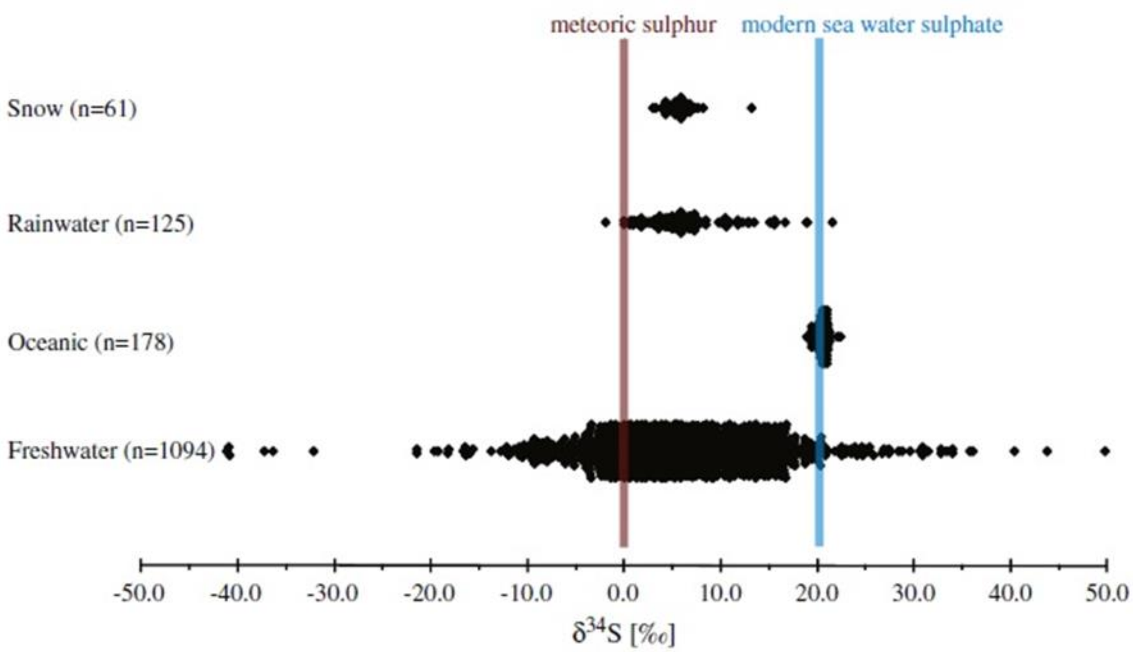

Figure 16 Plot of $\delta^{34}S$ from different aquatic environments. Plot from (Nehlich, The aplication of sulfur isotope analyses in archaeological research: a review 2015).

Chapter 4 Materials and Methods

4.1 Human samples

During the excavation campaigns of 1998 and 2001 in the Christian necropolis of Cacela-a-Velha, 74 individuals dated from the 13th century were identified. Of the 74 individuals recovered, 56 comprehended primary depositions and 14 were reductions and ossuaries, involving secondary depositions. A primary deposition is a burial that is found in the same context in which it was deposited, while a secondary deposition is the one in which the body is moved from its original burial deposition. Due to this change of context, ossuaries and reductions were not taken into account for this study.

Of the 56 burials, only 42 were analyzed. The burials 12, 16, 24, 42, 51 and 52 were not considered for analysis, because they belonged to skeletons of babies of only few months old, and in the case of grave 12, it belonged to a non-born child. In the burial 16 were found two individuals of approximately 6 months old. All of these were not used due to the fact that the information that they could provide implies a phenomenon called "nursing effect" that would skew the whole data. The nursing effect means that the composition of the bones of babies and children is still formed mostly or totally by the nutrients that the mother provided them when they were in the womb rather than by food of the surrounding environment (Fuller, et al. 2006). This provides higher $\delta^{15}N$ values that do not give any specific information about the diet of the mother. Because of this effect the burials 38 and 43 were not used either, since they belonged to skeletons of children under 3 years.

The burials 7 and 8 turned out to be from only one individual whose skeleton was fragmented, due to modern agricultural tools. It was not considered due to its poor state of preservation. The same happened with the burial 30, while burial 40 was not taken into account since only the feet bones were found.

For the analysis, long bones were used, especially femurs. This is because the renewal time of this type of bones is longer than others such as ribs or humerus (Fahy, et al. 2017). Femurs were used also because it is easier to extract the compact bone. Due to the absence of femurs in the burials 21 and 46 tibias were used. For the burial 11 the humerus was used, for 35 the fibula, and, in the case of burial 32, the clavicle was used.

The samples that were taken from the bones of each burial were catalogued in the next way: H-CVPA with the number of the burial e. g. H-CVPA 1. The H was added to avoid confusion between samples of humans and fauna. CVPA is an acronym of Cacela-a-Velha Poço Antigo.

From the set of individuals, there is an evident majority of masculine individuals. Twenty six out of the forty-two were identified as males, while three more were partially identified as males. On the other hand, only ten were identified as female with one more that was partially identified. Besides, two individuals were not sexual defined (see Figure 17).

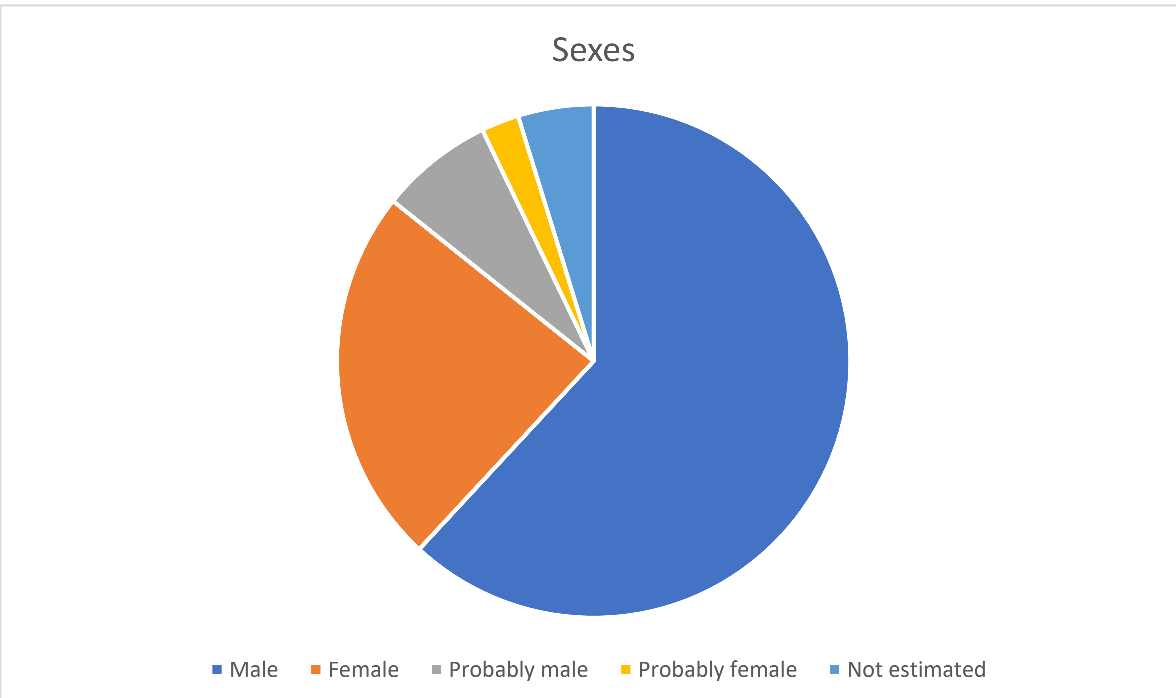

Figure 17 Sex distribution of the samples

The age of this group of people is quite disperse. The younger individual is a sub-adult of 14 years old, and the older individuals are elderly people that their age does not surpass the 60 years. For statistical purposes the individuals were divided in six ranges of ages (see Figure 18):

- Sub-adults, range in which were classified those individuals between 14 to 19 years old, and they represent the 10% of the whole set (4 individuals).
- 20-29 years, that represents the 29% (12 individuals).
- 30-39 years, that represents the 12% (5 individuals).
- 40-49 years, that represents 21% (9 individuals).
- 50-59 years, that represents 24% (10 individuals).
- Not estimated, that represents 5% (2 individuals).

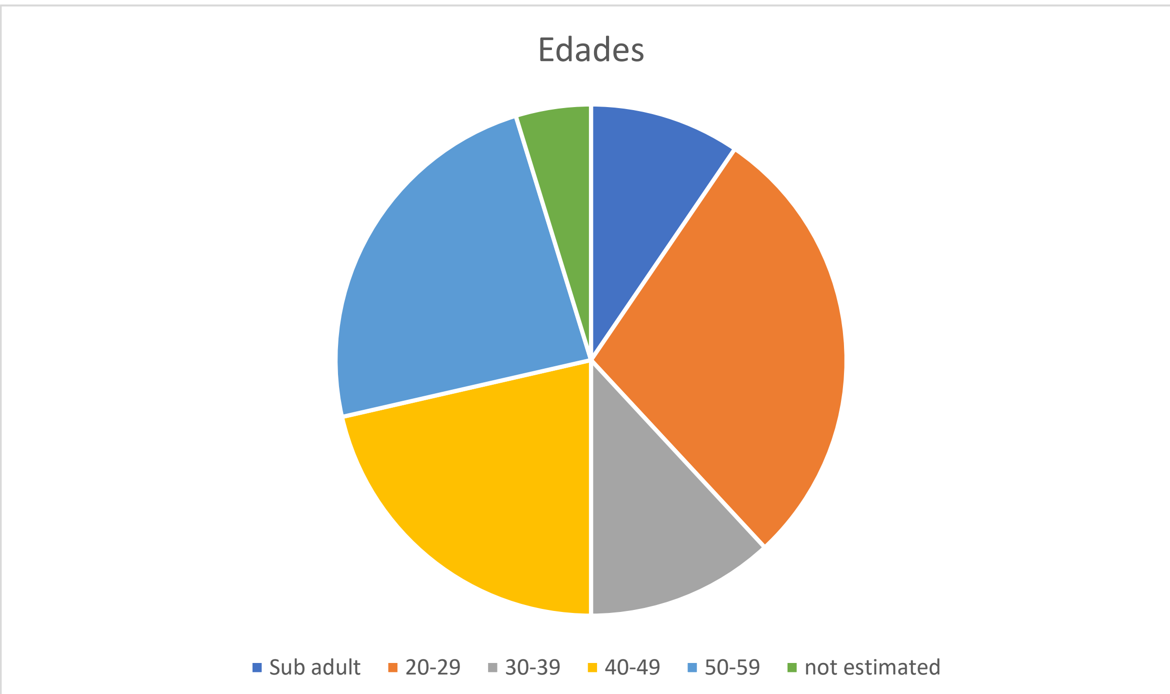

Figure 18 Age distribution of the samples

In general, the human remains belonging to Cacela-a-Velha show a population with a flimsy health. From this set of bones, most of them show signs of a hard-working life and a poor nutrition. Eighteen show signs of arthritis, nine have fractures that were not well consolidated; twelve show Schmorl's nodes, five individuals suffered *Spina bifida*, a congenital disease that is caused by the lack of folic acid during pregnancy; and one had *Cribra orbitalia*, an affection associated with signs of iron deficiency (anemia) (Brickley 2018). Also, thirteen presented signs of enamel hypoplasia, sixteen have at least one tooth that fell down before death, with some cases in which individuals that were not so old lost a big number of teeth before death e. g. H-CVPA 26 with 18 teeth lost *ante mortem* (see Table

5 in Appendix). Besides, the individual H-CVPA 29 shows signs of a severe brucellosis, meanwhile some other individuals from the same necropolis that were not chosen for analysis show some other nutritional deficiencies, such as, the child of the burial 16, baby of burial 24, and the baby of burial 52 had signs of anemia, as well as scurvy, a disease caused by absence of vitamin C. This is a quite curious disease in an area that since Al-Andalus period, as well as nowadays, is a big producer of *citrus* fruits.

4.2 Faunal Samples

Zooarchaeological samples were taken in order to create a baseline of the immediate context of the site. In this way the fauna provides information about the surrounding environment and makes possible to asses trophic levels and gives the possibility to understand human consumption of different protein sources. 28 samples were taken for analysis, of a total of 37 that were available. These samples were from bones excavated in the archaeological campaign that had place in "Largo da Fortaleza" of Cacela Velha in 2007. During the excavations many silos were found, and all the samples belonged to the Silo 7. Unfortunately, it was unknown from which layers the faunal samples corresponded to in the Silo; nevertheless, the upper layers were from post-almohad period, therefore the samples belong to the Almohad period or to the early Christian occupation of the town (12^{th}-13^{th} century).

From the 37 samples in total, 5 rabbits (*Oryctolagus cuniculus*), 2 chickens (*Gallus gallus dom.*) and 2 pigs/boars (*Sus sp.*) were excluded; because they did not have enough compact/trabecular bone. Therefore, only 28 samples were used (see Table 4). The Acronym CVF was used for the samples, and it means "Cacela Velha Fortaleza".

The pieces of the bones that were removed weighted in a range of 600 to 800 mg, and, in the case of the humans, were taken from the middle part of the bone, whether be femurs, humeri, tibias or the only clavicle considered. The middle part of the bone was chosen to remove a piece that would be use for analysis, based on two reasons. First, because in the middle, the medullary cavity is found; an area that contains a greater amount of trabecular bone (White, Black and A. 2012). Second, because in this way no specific features would be destroyed from the distal and proximal areas, that might be crucial for future bone characterization. In the case of the faunal samples, the pieces were removed from the parts of the bone that have more trabecular bone.

4.3 Samples for Sulfur analysis

Due to issues in the laboratory instrumentation, the sulfur isotope analysis was not done in Hercules Laboratory, therefore the samples were sent to the laboratory SIIAF from the Faculty of Sciences of the Universidade de Lisboa (Lisbon, Portugal). Due to the period established for delivering this study, it was decided that some samples should be analyzed urgently in order to have data on time. Of the 28 fauna samples, only 20 were analyzed (see Table 6 in Appendix). While, from the 42 human samples, 23 were analyzed (see Table 6 in Appendix). The way in which the samples were chosen was based on taking some of the most representative individuals that were closer to the mean from $\delta^{13}C$ and $\delta^{15}N$ values, as well as choosing the individuals that were outliers or had values that differed more from the average.

4.4 Method

4.41 Collagen extraction

First, the samples were documented with photographs of different angles of each bone, and notes were made about special features and colorations that the bones had. After that, a part of the bone was removed with a weight between 500 mg and 700 mg, from which the protein part of the bone would be extracted. In the case of the faunal samples, the bone pieces that were cut were the ones with higher quantity of compact bone and that did not present any type of unusual coloration. Meanwhile, for the human samples were used the femurs, with some exceptions when there were no available. From samples H-CVPA 21 and H-CVPA 46 the tibias were used, in the case of the sample H-CVPA 11 a piece from the humerus was extracted, and for sample H-CVPA 32, because of the absence of any bigger bone, the clavicle was used. The part that was cut from the femurs were from the middle part, avoiding the proximal areas for future identification. In the case of the samples that were from other bones rather than femur, they were cut as well avoiding proximal areas.

For this task a DREMEL ® 3000 with a diamond coated saw was used to cut the bone fragment. After removing the piece, a diamond polishing head was used to remove the outer layers of bone, soil contamination and the spongeous/trabecular bone that is more susceptible to diagenesis processes and may influence the result of the isotopic ratio of the tissue.

Once cleaned and being sure that its weight was higher than 500 mg, the portion of bone was broken into small pieces and the fragments were put inside 16 mm Ezee tube (Elkay Laboratory Products) with a perforated lid.

Collagen extraction was done following (Longin 1971) method with the modifications of (Brown, et al. 1988). First, 10 ml of 0.5 M of hydrochloric acid (HCl) were added until the demineralization process of the bone was completed. For this it was necessary to vortex the samples four times per day and subsequently change the acid when the acid finishes to react. After this, the samples were rinsed several times to reach a neutral pH, in order to add, in each of the samples, 10 ml of 0.125 M of sodium hydroxide (NaOH) for 20 hours. This step is necessary to remove any acidic contaminants from the soil that the bone may have and that may influence on the subsequent analysis (Sealy, et al. 2014). After that, the samples were rinsed again until a neutral pH was reached, to then continue to add 10 ml of 0.01 M of hydrochloric acid (HCl). The samples were taken into an oven with a constant temperature of 70 °C for 48 hours, time that was necessary for them to be digested for later filtration. During the process in which the samples were in the oven, the samples were vortexed after the first 24 hours and their digestion state was checked. For some samples 200 to 400 μl (and in some specific cases 500 or even 600 μl) of 0.5 M of HCl were added in order to ensure that the bigger bone pieces would entirely digest.

Once the digestion process was done, the samples were filtered with 9 ml Ezee-filter ™ (Elkay Laboratory products) and were placed in vials. After that, samples were frozen with liquid nitrogen to be subsequently taken to a Telstar LyoQuest freeze dryer. After 48 hours of lyophilization, collagen was finally obtained.

4.42 Carbon, nitrogen and sulfur isotope analysis

For the analysis of C and N stable isotopes, the collagen of each sample was placed in tin cups (IVA Analysentechnik GmbH & Co. KG, Meerbusch, Germany). The amount of collagen that was necessary was in a range between 400 to 600 µg per sample. While for S stable isotope analysis ~8mg of lyophilized collagen were placed in tin cups with additional V_2O_5.

The samples were analyzed using an Organic Elemental Analyzer (ThermoScientific FLASH 2000) with a Combustion (C, N and S) reactor. First, the tin cups containing collagen were flush-combusted and flush-reduced concurrently under a helium carrier steam and oxygen pulse at 1020 °C in a quartz reactor filled with chromium oxide (Cr_2O_3), silvered cobaltous-cobaltic oxide (Ag (Co_3O_4)) and reduced copper (Cu). After, the samples went through a 10 cm long glass column filled with anhydrous magnesium perchlorate ($Mg(ClO_4)_2$) that dried them; after, already dried samples passed through a 3 m long and 4 mm i.d. stainless steel gas chromatography column packed with Porapack stationary phase that is heated at a constant temperature of 40 °C. Then, the separated CO_2 and N_2 are carried in a helium stream at a flow rate of 95 mL/min to the mass spectrometer (ThermoScientific Delta V Advantage Isotope Ratio Mass Spectrometer) via a Conflo IV coupling (see Figure 19). For sulfur isotope analysis an IsoPrime mass spectrometer was used and was carried out in the laboratory SIIAF from the Faculty of Sciences of the Universidade de Lisboa (Lisbon, Portugal).

The isotopic ratios are expressed for carbon as $\delta^{13}C$ versus VPDB (Vienna Pee Dee Belemnite), for nitrogen as $\delta^{15}N$ versus atmospheric N_2 AIR, and for sulfur as $\delta^{34}S$ versus VCDT (Vienna Canyon Diablo Troilite):

$$x = \left[\left(\frac{\mathrm{R}sample - Rstandard}{\mathrm{Rstandard}}\right)\right] \cdot 1000$$

Where X is the $\delta^{13}C$, $\delta^{15}N$ or $\delta^{34}S$ value and R= $^{13}C/^{12}C$, $^{15}N/^{14}N$ and $^{34}S/^{32}S$ respectively. The standards and inhouse standards (L-alanine and caffeine) used are recognized by the International Atomic Energy Agency (IAEA). The standard deviation of bulk analysis of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ were ± 0.1‰, ±0.2‰ and ±0.08‰ respectively.

Figure 19. EA-IRMS equipment used for the analyses of carbon and nitrogen stable isotopes of this study in HECULES Laboratory.

Chapter 5 Results and Discussion

5.1 Results

5.11 Preservation indicators of bone collagen

After the extraction of collagen process is finished and before proceeding to analysis, the collagen yield is measured. This is measured by the following formula: x=(B/A) *100, in which x is the collagen yield percentage, B is the weight of the collagen extracted, and A is the weight of the raw bone. The collagen yield is one of the parameters used in stable isotope analysis to assess the collagen preservation of the samples in order to avoid the ones that could provide skew data caused by diagenetic processes. This is due to the context of the burials and can affect the real isotopic ratio of the bone tissue. According to (DeNiro and Weiner, Chemical, Enzymatic and Spectroscopic characterization of "Collagen" and other organic fractions from prehistoric bones 1988) the samples that had a value lower than 2% should be discarded. All the samples of Cacela, faunal and human, had a collagen yield superior to 2% and are reported in Table 1 and Table 2. Collagen yield of the faunal samples range from 2.7 to 19.8% with a mean value of 11.9 ± 4.6%; meanwhile human samples range between 3.4 to 14.0% with a mean value of 7.8 ± 2.6%.

Other parameters that are used to evaluate the preservation of collagen is the percentage of carbon (%C), the percentage of nitrogen (%N) and the C/N ratio. The Elemental Analyzer (EA) provides quantitative information about the elemental composition of each sample. Then, it is possible to calculate the C/N ratio in the following way:

$$C/N = \frac{(\%C*14)}{(\%N*12)}$$

The %C and %N should fall into a range established by (Ambrose, Preparation and characterization of bone and tooth collagen for isotopic analysis 1990) that is between 15.3 to 47.0% and between 5.5 to 17.3%, respectively. The faunal samples’ %C range between 40 to 47.33% (mean 42.97 ± 1.31%), and in %N from 14.34 to 16.78% (mean 15.3 ± 0.45%).

Meanwhile human samples range in %C from 37.95 to 43.45% (mean 40.64 ± 1.29%), and in %N between 13.22 to 15.46% (mean 14.49 ± 0.46%).

The C/N ratio provides information about contamination in the samples by humic acids or lipids. Samples that have values superior to 3.6 in C/N should be excluded since there is a possibility of lipid contamination, meanwhile the ones that have values inferior to 2.9 in C/N should be as well excluded because of possible humic acid contamination. The faunal samples reported C/N ratio values that go from 3.19 to 3.36 (mean 3.27 ± 0.04), meanwhile human samples range between 3.1 to 3.36 (mean 3.27 ± 0.05). Fresh bones have a C/N ratio around 3.2; nonetheless, according to (DeNiro, Postmortem alteration and preservation of in vivo bone collagen isotope ratios in relation o palaeodietary reconstruction 1985) in archaeological samples a range between 2.9 to 3.6 indicates good collagen preservation. In the case of the samples of Cacela, both faunal and human values are inside the allowed range.

To sum up, all samples fall into the ranges stablished in the literature for quality criteria of collagen with a singular exception. The sample CVF 21 had 0.33% more of %C from the range stablished by (Ambrose, Preparation and characterization of bone and tooth collagen for isotopic analysis 1990). Nonetheless, this sample accomplished with the other quality parameters (see Table 1), therefore, the sample was not discarded.

As for carbon and nitrogen, some quality criteria exist for sulfur measurements. The proper amount of sulfur should fall in a range between 0.15 and 0.35% (Nehlich and Richards, Establishing collagen quality criteria for sulphur isotope analysis of archaeological bone collagen 2009). Faunal samples range from 0.16 to 0.24% with a mean value of 0.2 ± 0.02%; meanwhile human samples range between 0.18 to 0.25% with a mean value of 0.21 ± 0.02%.

As with C/N ratio, in sulfur analysis C/S and N/S ratios are used as measurements of quality boner preservation. The formula used to measure C/S and N/S ratios are the following:

$$\mathrm{C/S} = \frac{(\%C*34)}{(\%S*12)} \qquad \mathrm{N/S}= \frac{(\%N*34)}{(\%S*14)}$$

The acceptable range of C/S is between 300 to 900, and for N/S is between 100 to 300 (Nehlich and Richards, Establishing collagen quality criteria for sulphur isotope analysis of archaeological bone collagen 2009). The faunal samples reported C/S ratio values that go from 623 to 767 (mean 613 ± 74.1), and N/S ratio values from 191 to 233 (mean 187 ± 23.5). Human samples reported C/S values from 465 to 657 (mean 561 ± 61.2), and N/S ratio values from 140 to 202 (mean 171 ± 18.5).

5.12 Stable isotopic composition of human and faunal bones

In Table 1, the $\delta^{13}C$ and $\delta^{15}N$ values from bone collagen of faunal samples are reported. Stable isotope analysis of the twenty-eight faunal samples show $\delta^{13}C$ values that range from -22.3‰ to -18‰ with a mean value of -20.2 ± 0.93‰, and $\delta^{15}N$ values that range from 2.5‰ to 12.1‰ with a mean value of 7.9 ± 2.49‰.

In Table 2, the $\delta^{13}C$ and $\delta^{15}N$ values from bone collagen of the human samples, are reported. Stable isotope analysis of 42 human samples had $\delta^{13}C$ values in a range between -19.2‰ to -15.1‰ (mean -17.9 ± 0.93‰), and $\delta^{15}N$ values that ranges between 7.6 to 13.5‰ (mean 10.9 ± 1.47‰).

In Table 1, the $\delta^{34}S$ values from faunal bone collagen are reported. Stable isotope analysis of 20 faunal samples gave $\delta^{34}S$ values that range from 7.5 to 17.7‰ (mean 13.5 ± 2.6‰). In Table 2, the $\delta^{34}S$ values from bone collagen of the human samples are reported. Stable isotope analysis of 23 human samples had $\delta^{34}S$ values in a range between 9.8‰ to 14.5‰ (mean 12.1 ± 1.4‰).

Table 1 Carbon, nitrogen and sulfur stable isotopes from faunal bone collagen with indicators of quality.

Sample	Taxonomy	$\delta^{15}N$ (‰)	$\delta^{13}C$ (‰)	$\delta^{34}S$ (‰)	Collagen yield (%)	%N	%C	%S	C/N	C/S	N/S
CVF 2	*Bos Taurus*	8.1	-20.1	10.4	18.89	14.84	41.47	0.19	3.26	623	191
CVF 3	*cervus elaphus*	4.9	-20.0		16.60	15.63	43.47		3.24		

Table 1 (continuation)

CVF 4	*Ovis aries/ Capra hircus*	8.8	-20.7	7.5	17.53	15.35	42.8	0.16	3.25	747	230
CVF 5	*Sus sp.*	10.0	-20.7		5.71	14.63	41.44		3.30		
CVF 8	*Ovis aries/ Capra hircus*	10.9	-20.8	14.5	19.76	15.38	42.57	0.18	3.22	680	211
CVF 9	*cervus elaphus*	5.0	-20.4	16.1	14.21	15.57	43.6	0.18	3.26	675	207
CVF 10	*Oryctolagus cuniculus*	6.3	-21.5		13.35	15.34	42.86		3.25		
CVF 11	*Bos Taurus*	11.7	-20.2	9.9	17.65	15.57	42.93	0.18	3.21	664	206
CVF 13	*Ovis aries/ Capra hircus*	9.6	-19.1	13.8	10.29	15.06	42.3	0.21	3.27	578	176
CVF 14	*Bos Taurus*	7.5	-21.4		3.17	14.86	42.86		3.36		
CVF 16	*cervus elaphus*	6.3	-20.2	16.4	6.46	15.35	42.77	0.19	3.25	652	201
CVF 19	*Ovis aries/ Capra hircus*	12.1	-20.8	9.6	8.03	15.04	41.61	0.20	3.22	605	187
CVF 20	*Bos Taurus*	7.3	-20.1	13.8	11.11	15.28	41.86	0.19	3.19	615	192
CVF 21	*Ovis aries/ Capra hircus*	6.3	-20.0	15.8	12.15	16.78	47.33	0.17	3.29	767	233
CVF 23	*Gallus gallus dom.*	6.7	-19.5	12.6	12.65	14.34	40.00	0.21	3.25	534	164
CVF 24	*Ovis aries/ Capra hircus*	6.8	-19.7	14.6	10.76	15.76	44.38	0.18	3.28	686	209
CVF 25	*Bos Taurus*	9.9	-20.0	11.3	2.67	14.91	42.54	0.21	3.32	585	176
CVF 26	*Sus sp.*	9.2	-19.0		16.16	15.38	42.99		3.26		
CVF 27	*Bos Taurus*	9.9	-20.6	14.5	5.95	14.92	42.06	0.19	3.28	623	190
CVF 29	*Vulpes vulpes*	9.5	-19.7	13.2	7.78	14.86	41.81	0.22	3.28	537	164
CVF 30	*Sus sp.*	6.6	-21.2		13.74	15.23	42.87		3.28		
CVF 31	*Oryctolagus cuniculus*	2.5	-22.3	17.7	12.92	15.39	43.66	0.23	3.30	548	165
CVF 32	*Oryctolagus cuniculus*	4.9	-21.0	14.9	7.75	15.55	43.71	0.24	3.28	517	158
CVF 33	*Oryctolagus cuniculus*	6.3	-20.4	15.1	12.73	15.21	43.72	0.24	3.35	522	156
CVF 34	*Oryctolagus cuniculus*	3.9	-21.0		14.26	16.00	44.27		3.22		

Table 1 (continuation)

CVF 35	*Gallus gallus dom.*	10.1	-18.0	16.3	12.09	15.53	44.07	0.23	3.31	555	168
CVF 36	*Gallus gallus dom.*	10.0	-18.5		14.08	15.38	44.00		3.33		
CVF 37	*Gallus gallus dom.*	11.0	-19.2	12.8	14.12	15.33	43.42	0.23	3.30	543	164

Summary

Fauna Samples	**δ^{13}C Range and (mean*) (‰)**	**δ^{15}N Range and (mean*) (‰)**	**δ^{34}S Range and (mean*) (‰)**
Oryctolagus cuniculus	-22.3 to -20.4 (-19.67 ± 0.7)	2.5 to 6.3 (4.77 ± 1.61)	14.9 to 17.7 (15.9 ± 1.5)
Cervus elaphus	-20.4 to -20 (-20.2 ± 0.2)	4.9 to 6.3 (5.40 ± 0.78)	16.1 to 16.4 (16.3 ± 0.2)
Ovis aries/Capra hircus	-20.8 to -19.1 (-20.18 ± 0.7)	6.3 to 12.1 (9.08 ± 2.27)	7.5 to 15.8 (12.6 ± 3.3)
Bos Taurus	-21.4 to -20 (-20.4 ± 0.53)	7.3 to 11.7 (9.07 ± 1.72)	9.9 to 14.5 (12.0 ± 2.0)
Sus sp.	-20.7 to -19 (-20.3 ± 1.15)	6.6 to 10 (8.6 ± 1.78)	
Gallus gallus	-19.5 to -18 (18.8 ± 0.66)	6.7 to 11 (9.48 ± 1.88)	12.6 to 16.3 (13.9 ± 2.1)
Vulpes Vulpes	-19.7	9.5	13.2

*Error (1σ)

Table 2 Carbon, nitrogen and sulfur stable isotopes from human bone collagen with indicators of quality.

Sample	**δ^{15}N (‰)**	**δ^{13}C (‰)**	**δ^{34}S (‰)**	**Collagen yield (%)**	**%N**	**%C**	**%S**	**C/N**	**C/S**	**N/S**
H-CVPA 1	9.3	-16.3	12.2	6.40	14.51	40.52	0.20	3.25	580	178
H-CVPA 2	8.4	-18.8	14.2	7.41	14.94	42.06	0.23	3.28	511	155
H-CVPA 3	10.7	-16.7		5.36	13.92	39.02		3.27		
H-CVPA 4	12.2	-16.8		7.24	14.41	40.97		3.31		
H-CVPA 5	13.2	-16.6	13.5	6.40	14.72	41.89	0.18	3.32	644	194
H-CVPA 6	10.0	-19.2	9.8	6.79	14.89	42.08	0.19	3.29	626	190
H-CVPA 9	11.8	-17.5	10.7	9.18	15.23	43.20	0.23	3.30	528	159
H-CVPA 10	11.9	-18.3	10.1	7.34	14.01	40.36	0.18	3.36	634	189
H-CVPA 11	8.6	-17.8		10.61	14.84	41.42		3.25		
H-CVPA 13	12.5	-17.4	13.6	6.52	14.62	41.40	0.23	3.30	518	157
H-CVPA 14	11.8	-17.9	11.7	3.41	14.35	40.97	0.25	3.33	465	140
H-CVPA 15	9.3	-18.5		5.11	13.65	38.63		3.30		
H-CVPA 17	11.9	-18.2		6.29	14.02	39.37		3.27		
H-CVPA 18	11.9	-18.7		9.78	13.98	39.35		3.28		
H-CVPA 20	10.5	-18.7		3.58	14.68	41.90		3.33		
H-CVPA 21	11.0	-17.9	13.3	5.80	14.38	39.67	0.20	3.21	567	176
H-CVPA 22	11.3	-18.8	12.2	11.75	14.77	42.29	0.21	3.34	562	168
H-CVPA 23	9.9	-19.0		14.01	14.65	39.33		3.13		
H-CVPA 25	10.1	-17.1	12.6	13.98	15.46	43.45	0.21	3.27	574	175

Table 2 (continuation)

H-CVPA 26	11.9	-18.5	10.9	7.13	14.87	42.00	0.19	3.29	623	189
H-CVPA 27	12.0	-17.8		10.42	14.47	39.91		3.21		
H-CVPA 28	12.0	-17.6		4.88	14.10	39.11		3.23		
H-CVPA 29	11.2	-18.2		6.31	13.95	39.70		3.31		
H-CVPA 31	11.2	-18.1		4.00	14.63	40.14		3.20		
H-CVPA 32	10.5	-18.4	11.4	9.02	14.92	39.69	0.21	3.10	524	169
H-CVPA 33	10.6	-17.7	11.7	10.74	14.67	40.64	0.18	3.23	652	202
H-CVPA 34	9.9	-18.5	13.4	9.13	14.68	41.70	0.23	3.31	520	157
H-CVPA 35	11.4	-18.6		5.00	14.74	41.77		3.30		
H-CVPA 36	11.8	-17.5	11.0	9.66	14.29	39.44	0.18	3.21	622	193
H-CVPA 37	11.6	-15.1	13.5	8.26	14.53	40.92	0.19	3.28	608	185
H-CVPA 39	10.4	-18.7	10.1	10.63	15.00	42.03	0.18	3.26	657	201
H-CVPA 41	8.8	-18.1		6.99	14.12	39.66		3.27		
H-CVPA 44	10.9	-18.9		6.65	14.21	40.30		3.30		
H-CVPA 45	9.6	-18.2		9.86	15.09	41.08		3.17		
H-CVPA 46	12.1	-16.9		6.53	14.11	39.94		3.30		
H-CVPA 47	13.0	-17.9		3.60	13.22	37.95		3.34		
H-CVPA 48	9.0	-18.2	13.3	7.09	14.55	40.21	0.23	3.22	498	154
H-CVPA 49	13.5	-15.4	14.5	9.96	13.77	38.33	0.23	3.24	475	146
H-CVPA 50	9.3	-19.2	9.8	7.08	14.87	40.61	0.23	3.18	503	158
H-CVPA 53	7.6	-18.8	12.5	9.23	14.70	41.83	0.23	3.32	507	153
H-CVPA 55	13.3	-17.7		8.19	14.07	40.10		3.32		
H-CVPA 56	8.4	-18.1	11.6	8.95	15.03	41.96	0.23	3.25	509	156

Summary

Data of human groups	***n*=**	**$\delta^{13}C$ Range and (mean*) (‰)**	**$\delta^{15}N$ Range and (mean*) (‰)**
By Sex			
Female	11	-19.2 to -15.1 (-17.8 ± 1.18)	9 to 12 (10.4 ± 1.14)
Male	29	-19.2 to -15.4 (-18 ± 0.87)	7.6 to 13.5 (11.1 ± 1.5)
By Age			
Sub-adult	4	-18.5 to -16.8 (-17.8 ± 0.7)	8.8 to 12.2 (10.5 ± 1.6)
20-29	12	-19.2 to -15.4 (-17.7 ± 1.2)	9 to 13.5 (11 ± 1.4)
30-39	5	-18.8 to -15.1 (-17.5 ± 1.4)	9.6 to 12 (11.3 ± 1)
40-49	9	-19.2 to -17.1 (-18.1 ± 0.6)	11.4 to 12 (10.6 ± 1.5)
50-59	10	-18.9 to -17.4 (18.2 ± 0.5)	8.4 to 13.3 (11.3 ± 1.4)

*Error (1σ)

5.2 Discussion

5.21 Fauna interpretation

Rabbit (*Oryctolagus cuniculus*) samples were the faunal group that had more negative $\delta^{13}C$ values in this study (see Table 1), because their diet was possibly based on wild resources, where majority of plants have a C_3 photosynthetic pathway in this environment. Rabbit bone samples had $\delta^{13}C$ values that range from -22.3‰ to -20.4‰ with a mean value of -19.67 ± 0.7‰ and a range of $\delta^{15}N$ values of 2.5‰ to 6.3‰ with a mean value of 4.77 ± 1.61‰. The variation in $\delta^{13}C$ values in rabbit samples could be explained by environmental differences. Some rabbits –as sample CVF 31 that has the lowest values of all samples ($\delta^{13}C$ of -22.3‰ and $\delta^{15}N$ of 2.5‰) –could have fed closer to a wooded area, susceptible to canopy effects. The canopy effect means that $\delta^{13}C$ values of plant tissue are influenced by the amount

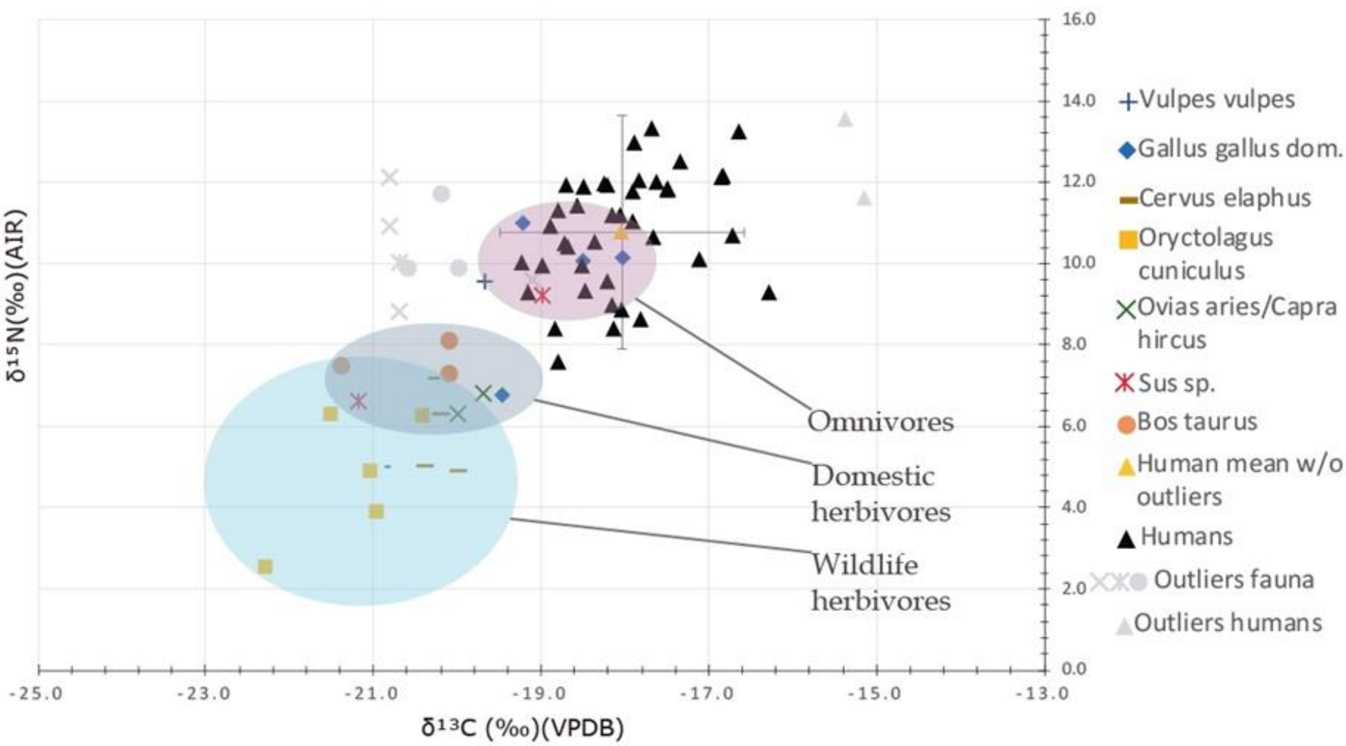

Figure 20 Plot showing the $\delta^{13}C$ and $\delta^{15}N$ values of humans and animal bone collagen. Omnivore, domestic herbivore and wildlife herbivore areas are represented with ovals. These areas were defined by the average+2σ of representative animal species: Wild (rabbits and deer), domestic (sheep, goats and cows), omnivores (pigs and chickens). In a gray hue the faunal and human outliers are presented.

of sunlight they receive. Plants that are less exposed to sunlight on a daily basis have more negative $\delta^{13}C$ values (Bonafini, et al. 2013).

This does not necessarily mean that there was a forest in the immediate vicinity of Cacela, but that it is likely that the plants, which were eaten by the wild animals whose $\delta^{13}C$ values are more negative, were less exposed to sunlight. Meanwhile, rabbits with higher values in both $\delta^{13}C$ and $\delta^{15}N$ could have fed in a wider environment, or, closer to the seacoast, where two native C_4 plants called cordgrass (*Spartina maritima*) and "collejón" (*Moricandia arvensis*) grow, or, closer to human settlements, where soils were more enriched in ^{15}N due to agricultural practices.

In order to be able to define the range of values of wild animals, deer were used in complement to rabbits as a baseline. Deer values provide information of a wider geographic area compare to rabbits. Their $\delta^{13}C$ values turned out to be more positive than those of the rabbits and with low variability among them (see Table 1). The three deer samples used in this study presented $\delta^{13}C$ values in a range of -20.4 to -20.0‰ (mean -20.2 ± 0.2‰), and $\delta^{15}N$ ranging from 4.9 to 6.3‰ (mean 5.40 ± 0.78‰). Close to the isotopic values of rabbits and deer was the sample CVF 30 that belongs to the Genus *Sus sp*., with a $\delta^{13}C$ value of -21.2‰ and a $\delta^{15}N$ value of 6.6‰ (see Table 1 and Figure 20). Taxonomic identification of the Sus sample, made by the zooarchaeologist Maria João Valente, was only possible at the Genus level, not being able to differentiate between wild boar (*Sus scrofa*) and domestic pig (*Sus domesticus*) (Valente, Report on the zooarchaeological identifications of fauna samples from Largo da Fortaleza de Cacela-a-Velha (Vila Real de Santo António) 2019); however, the CVF 30 stable isotopic values indicate that it was, more likely, a wild boar.

To understand the trophic levels expressed on the figure 20, only a sample of a primary predator was used. Sample CVF 29 belongs to a fox, whose $\delta^{13}C$ value is -19.7‰ and $\delta^{15}N$ value is 9.5‰. The difference between the fox values and the average value of the rabbits (1.56‰ $\delta^{13}C$, 4.76‰ $\delta^{15}N$) show a trophic offset according to Bocherens and Drucker (2003) of 0-2‰ in $\delta^{13}C$, and 3-5‰ in $\delta^{15}N$, that would correspond to a primary carnivore to prey spacing.

As in the case between domestic pigs and wild boars, taxonomic differentiation between sheep and goats was not possible; therefore, they were grouped with the tag *Ovis* *aries/Capra hircus*. Six samples belonged to bone remains of *Ovis aries/Capra hircus*, whose $\delta^{15}N$ values were very variable: 6.3 to 12.1‰ (mean 9.08 ± 2.27‰, see Table 1). With less variability, their $\delta^{13}C$ values range from -20.8 to -19.1‰ (mean -20.18 ± 0.7‰). Two of the samples (CVF 21, CVF 24) present values that are in the area associated with typical domestic animal values (see Figure 20), since there are not so much spacing between their values and the ones of wild animals. Meanwhile the other four samples (CVF 4, 8, 13 and 19) have an unusual enrichment of ^{15}N. Like the latter, the isotopic values of cattle bone remains have a great variability in $\delta^{15}N$ values, in which some samples (CVF 2, 14, 20) present common values according to domestic animals, and others (CVF 11, 25 and 27) present the same phenomenon mentioned above (unusual enrichment of ^{15}N). $\delta^{13}C$ values of *Bos taurus* samples ranged from -20 to -21.4‰ (mean 20.4 ± 0.53‰), while $\delta^{15}N$ values ranged from 7.3 to 11.7‰ (mean 9.07 ± 1.72‰). Besides these ^{15}N enriched samples, two other samples of *Sus sp*., presented the same phenomenon mentioned. $\delta^{15}N$ values were 10‰ and 9.2‰ from the samples CVF 5 and CVF 26, respectively; meanwhile their $\delta^{13}C$ values were -20.7‰ and 19‰. These values are not as rare in pigs as in cattle, since pigs sometimes are fed with human waste and their diet is omnivorous.

Such high values in $\delta^{15}N$ in bovine, sheep and goat livestock could be explained because of agricultural practices such as manuring and bedding (Bogaard, et al. 2007). The fact that there are animals among the same species that contrast so much in their values, may be because some of them were in confined spaces, perhaps some kind of fence to delimit property. This would cause the land to be much more enriched in ^{15}N, due to the constant manure of animal dung. Besides, it is possible that the owners or the peasants, on charge of this livestock group, manured the soils, intentionally or not, with "night soil" (human waste), practice that would explain such high $\delta^{15}N$ values in domestic animals (MacKinnon 2015). Another common practice that is carried out in the region, even today, is to fertilize the land with seaweed, "sapeira" (a succulent native plant of the genus *Salicornia*) and cordgrass (*Spartina maritima*). Seaweed increases $\delta^{15}N$ values in the food web. These algae and coastal plants may also have been used as fodder for livestock, which would increase $\delta^{15}N$; however, this is less probable, since their direct consumption would also produce an increase of $\delta^{13}C$. In contrast, this would not be the case if they were used as manure. Even though plants absorb part of the carbon they need from their roots, the vast majority is taken from the CO_2 of the air through photosynthesis (Blanz, et al. 2019).

Animals less enriched in ^{15}N have lived in a wider space to graze, or because the cattle were taken to graze for seasons in diverse areas with different elevations (MacKinnon 2015). Nevertheless, the role of trade in this region cannot be overlooked, as there is historical evidence of complex commercial networks, in which even bread from Mértola (not flour) was sold in different areas of the Sotavento (Catarino 1997/1998).

Besides cattle, bone collagen of chicken *(Gallus gallus dom.)* was analyzed. Chicken was consumed by both peasants and high classes in that time, and it is found often in archaeological contexts. The consumption of chicken was encouraged by the church, since its lighter color flesh was associated with purity (MacKinnon 2015). The chickens of the set of samples presented few variabilities, except for one that had values that fitted more in the domestic herbivores area (CVF 23). This contrasting result could be explained because of a different way of feeding compare to the other chickens, having an enriched diet in C_3 plants; nevertheless, the fact that a singular chicken was fed differently is quite improbable, therefore, it is more plausible that it was bred in another environment and it was brought for later consumption to Cacela through commerce. Chickens' $\delta^{13}C$ values ranged between -19.5 to -18‰ (mean -18.8 ± 0.66‰), meanwhile $\delta^{15}N$ values ranged from 6.7 to 11‰ (mean 9.48 ± 1.88‰).

With the purpose of a better understanding of the distinctive diets from the set of samples, it was necessary to define the areas that were equivalent to wild animals, domestic herbivores and omnivores. For wild animals an average was made by using the samples of rabbits and deer, and then, to define an area, two standard deviations (2σ) were used with aim of representing a wide portion of the samples. The wild animals average $\delta^{13}C$ value was -20.8 ± 1.05‰, and $\delta^{15}N$ was 5 ± 2.65‰. Subsequently, the average of domestic herbivores was established by using only the cattle and sheep/goat samples that did not have an atypical increase in ^{15}N. To calculate this, the samples of *Bos Taurus* (CVF 2, 14, 20) and *Ovis aries/Capra hircus* (CVF 21, 24) were used. The average of $\delta^{13}C$ was -20.3 ± 1.31‰, and of $\delta^{15}N$ was 7.2 ± 1.37‰. Finally, to delimit the omnivore area, a pig sample (CVF 26) and the chicken samples were used, with exception of the sample CVF 23 that had a low $\delta^{15}N$ value.

The omnivore average of $\delta^{13}C$ was -18.7 ± 1.05‰, and of $\delta^{15}N$ was 10.1 ± 1.46‰. The fact that some animals were necessary to exclude could mean that the remains found in Silo 7 were not representative of the consumption of the entire population, but only partially. This hypothesis would make sense, since the "silo 7" was part of another excavation in the fortress of Cacela, where the local ruling class lived, therefore, it is possible that social class factors influenced in the content of that silo or that part of the materials in that Silo did not correspond to the same period of time, since silo 7 content was not dated by radiocarbon (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal) 2017).

5.22 Humans

As it is possible to see in Figure 20 the isotopic values of human bone collagen are dispersed. To understand what was the main source of protein of the different individuals and to know how much it was based on domestic animal consumption, human outliers' values were set aside. To comprehend which human values were outliers, boxplots were used (see

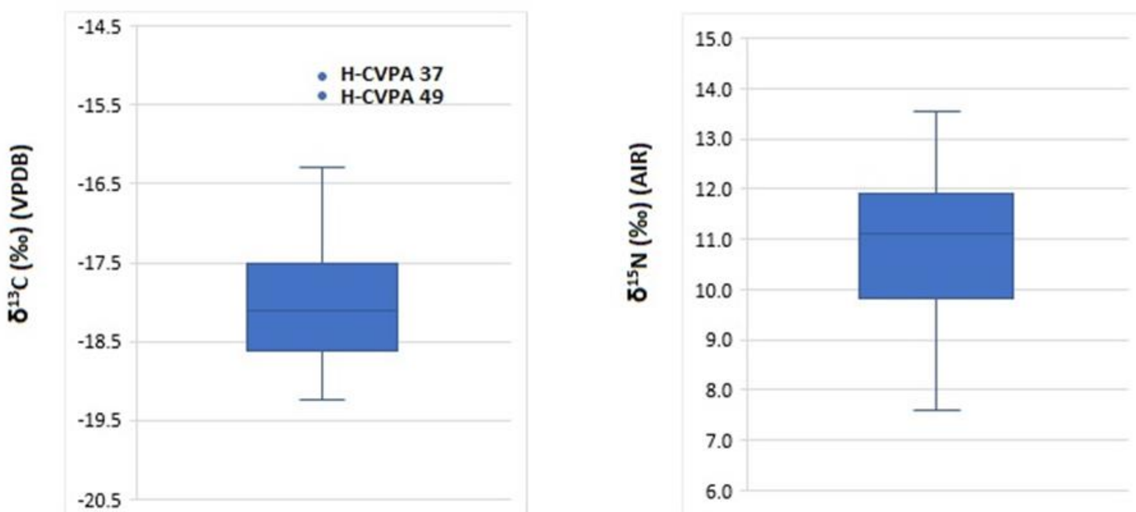

Figure 21 Boxplots of $\delta^{13}C$ and $\delta^{15}N$ values of human bone collagen. In the plot of the left is possible to appreciate two outliers.

Figure 21). By using this tool, it was possible to identify samples H-CVPA 49 and 37 as $\delta^{13}C$ outliers. Afterwards, an average without the latter was done.

The difference between the mean values of humans and the one of domestic animals were 2.2‰ in $\delta^{13}C$, and 3.6‰ in $\delta^{15}N$. As a result, in Figure 22 it is plausible to identify a trophic shift; nonetheless, the δ13C difference contrasts with the range established by (Bocherens and Drucker 2003), in which there should be an increase of 0-2‰ in δ13C and 3-5‰ of δ15N between diet and consumer.

The human values suggest a diet that varies among individuals. From the δ13C and δ15N values of the individuals that are inside the mean+1σ (see Figure 22) (-18 ± 0.72‰, 10.8 ± 1.43‰ respectively), it is possible to infer that they had a diet based on C_3 resources; nevertheless, due to the fact that the δ13C trophic value (2.2‰) is outside the range established on the literature, it could mean that their diet was enriched with a little input of C_4 plants, or by marine resources. Meanwhile, the enrichment of δ15N of the trophic offset is inside the quoted range, so it is plausible that the enrichment of ^{13}C is due to C_4 plants (sorghum, millet) or marine animals from lower trophic levels, such as shellfish (Mays 1998). This is because marine animals from higher trophic levels would increase both ^{13}C and ^{15}N (Schoeninger y DeNiro 1984).

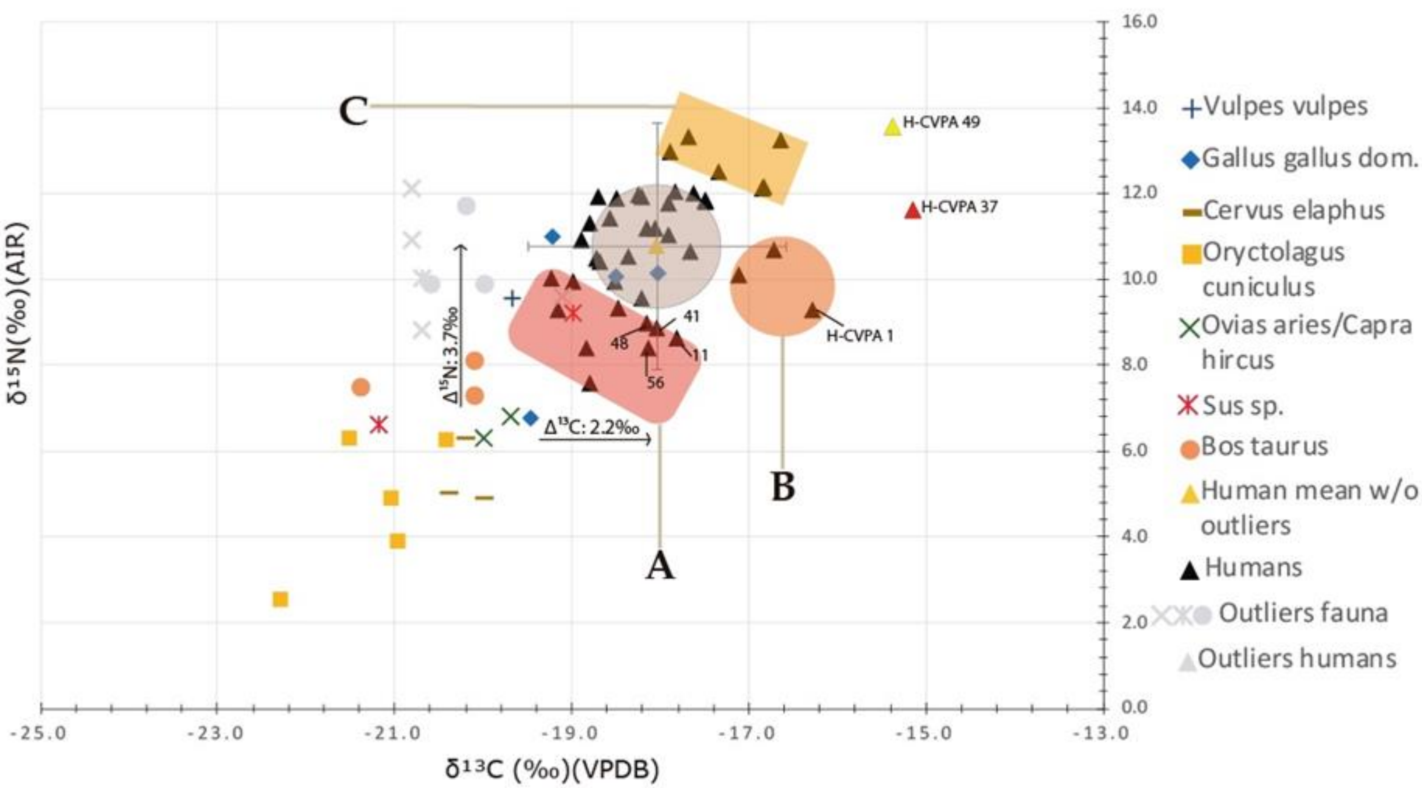

Figure 22 Plot showing δ13C and δ15N values of human and faunal bone collagen. Areas A, B, C and human outliers are shown. The human mean+1σ area is shown by a shaded circle. A cross represent two standard deviations. A trophic offset between domestic herbivores and humans mean is represented by arrows.

The individuals' values outside the mean+1σ vary a lot between them, so, in order to have a clearer picture of their diets, they were put together arbitrarily in three different groups, as it is shown in Figure 22. Group A ($\delta^{13}C$ mean -18.6 ± 0.5‰, $\delta^{15}N$ mean 8.9 ± 0.74‰) has more negative values of carbon and nitrogen than the individuals inside the mean+1σ range, therefore it could be inferred that their consumption of C_3 plants was higher. The trophic offset within domestic herbivores does not fit into the mentioned range of $\delta^{15}N$ (1.7‰). This could mean that they have a lower intake of animal products, being the individual H-CVPA 53, the one that would have less animal consumption. It is plausible that the main protein source of the group A would be legumes. Consumption of pulses in the area, such as broad beans, chickpeas, vetch, bitter vetch and peas, is well documented by written sources and by carpological remains (Peña-Chocarro, Pérez Jordá, et al. 2019). On the other hand, the trophic offset between this group and wild animal values is inside the expected trophic shift, therefore, it is possible that the main protein source of these individuals were wild resources, specially deer meat. This is conceivable in some individuals of the group; nonetheless, it is more probable that their main source of protein was vegetables with an occasionally intake of animal products, including wild ones. In the case of individuals H-CVPA 11, 41, 48 and 56 (see Figure 22), they could have had a higher consumption of C_4 plants in comparison with the others.

Group B values ($\delta^{13}C$ -16.7 ± 0.41‰, $\delta^{15}N$ 10 ± 0.7‰) showed even greater difference to domestic herbivores than group A. The $\delta^{15}N$ values are lower than the humans that fall inside the mean+1σ range, and a little higher than the individuals of group A. The contrast of this group is even wider in its $\delta^{13}C$ values. Group B shows ^{13}C enrichment, by opposition to ^{15}N enrichment, which makes possible to assume that the individuals of this group had a diet with a higher consumption of C_4 plants and a moderate protein intake. It is also likely that their main protein source were bivalves, which usually have $\delta^{15}N$ values between 7‰ and 8‰ and $\delta^{13}C$ values close to -12‰ (Mays 1998, Renfrew and Bahn 2012). South from Cacela, a barrier island that is part of the Ria Formosa ecosystem is found, which is an ideal environment for bivalves' production. It is also important to mention, that during the excavations of the fortress of Cacela, 2055 specimens of bivalves were found in Silo 7 (Valente and Garcia, Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in

Medieval Cacela-a-Velha (Algarve, Portugal) 2017). This evidenced a large-scale consumption of these animals. The diet of these individuals could be strongly enriched by these marine resources, with exception of individual H-CVPA 1 (see Figure 22), whose lower $\delta^{15}N$ values matched more with the first hypothesis.

Group C showed higher values of both isotopic systems ($\delta^{13}C$ -17.2 ± 0.51‰, $\delta^{15}N$ 12.7 ± 0.53‰); therefore, it is likely that the food base of this group was C_3 plants and its main source of protein was marine resources. This inference is based on the individuals of the group C which are enriched in both ^{13}C and ^{15}N. It is possible that the intake of marine products was supplemented by an important intake of omnivorous animals and their derivatives, such as pork meat, lard, chicken meat and eggs.

Having already mentioned the diet of the three groups, it is necessary to mention that of the individuals labeled as outliers, the individual H-CVPA 49 had the highest $\delta^{15}N$ value of the whole set (see Figure 22). It is possible that his diet was based on marine resources and C_4 plants with sporadic intake of C_3 plants and land animals. Meanwhile, the individual H-CVPA 37 had the highest $\delta^{13}C$ value, therefore, it could be that her diet was based on C_4 plants. Her $\delta^{15}N$ values are lower compared to individual 49 and it could be due to consumption of terrestrial animals that foddered C_4 plants. Another explanation for the resultant isotopic values could be consumption of bivalves and low trophic level fish.

5.23 Sulfur information

In order to understand more about these dietary differences, sulfur stable isotope analysis was performed in some samples (see table Table 6). As it is possible to appreciate in Figure 23, Rabbit samples differed in $\delta^{34}S$ values. Sample CVF 31 displayed the highest $\delta^{34}S$ values (17.7‰) of all analyzed samples. Due to such a high value, joint with its low $\delta^{15}N$ and $\delta^{13}C$ values is possible to infer that this rabbit could be from another area. Probably it was brought to Cacela through commerce or hunting. Concerning to the other faunal $\delta^{34}S$ values, it is possible to identify two different groups. The group that in Figure 23 is represented in a blue area have $\delta^{34}S$ values that could be related to sea spray effect, in which the sulfur ratio is influenced by sea spray sulphates, giving $\delta^{34}S$ values up to 18‰ (Nehlich, The aplication of sulfur isotope analyses in archaeological research: a review 2015). In this case, the range of values of this group ($\delta^{34}S$=12.6 to 17.7‰) could represent fauna that fed in the immediate environment of Cacela.

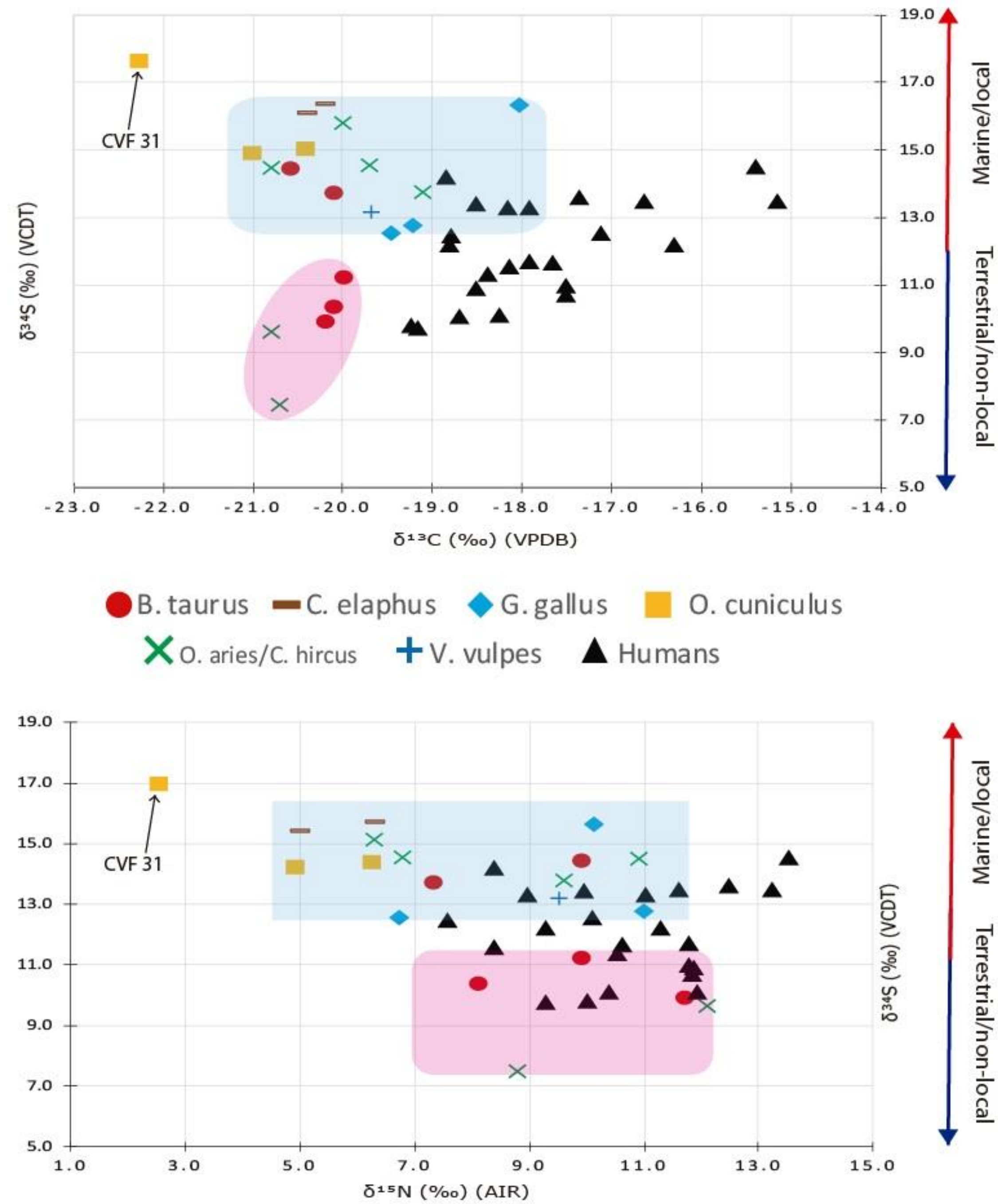

Figure 23 Dispersion plot of $\delta^{13}C$ values contrasted with $\delta^{34}S$ values, and $\delta^{15}N$ values with $\delta^{34}S$ values. Two different areas are shown to differentiate $\delta^{34}S$ values in faunal samples.

In contrast, the faunal samples that are represented in light red in Figure 23 present lower values ($\delta^{34}S$=7.5 to 11.3‰). Since Cacela-a-Velha is a coastal site and the values of this group of animals present values associated with a terrestrial environment (see Figure 16) (Nehlich, The aplication of sulfur isotope analyses in archaeological research: a review 2015), joined with the fact that is less probable that fodder from other region was brought to Cacela only to fed a determinate group of animals, it is plausible to hypothesize that these animals were not bred in Cacela.

The $\delta^{34}S$ values of the humans ($\delta^{34}S$=12.1 ± 1.4‰) are variable and not so high despite being a coastal population. Thus, there is the possibility that part of the diet of these individuals came from non-local foods, where the $\delta^{34}S$ was lower in their foodwebs, and in which the consumption ratio of non-local and local products, as well as terrestrial and marine products, was different among the community. It is documented that in areas of the Algarve very close to Cacela-a-Velha, as it is Tavira, wheat was brought from Alcoutim and Martim Longo (Catarino 1997/1998), towns that are not susceptible to spray effect, as they are more than 50km inland. Besides, in medieval times, occasional markets were traditional in Algarve and used to trade products from other regions (Catarino 1997/1998). Posterior $^{87/86}Sr$ and $\delta^{18}O$ analysis would be required to understand if the causes of these differences lie on diet and commerce, or on migration.

5.24 Social and cultural variables

In order to understand if social factors influenced the diet of the individuals of this study, the data was analyzed based on different variables. First, the values were analyzed based on sex (male and female), with purpose of understanding if the values were influenced by gender related issues. Table 2 shows the range of values between different sex, in which for interpretation reasons, the samples cataloged by (Curate 2001) as “probably men” were taken as “Men”, and “probably women” as “Women”. Individuals that were not possible to identify by sex were labeled as “not determined” (H-CVPA 14, 47) and were not taken into account for this interpretation, since they did not provide relevant information.

Among the data set, the only significant difference between male and female was that the female population had a greater dispersion in the $\delta^{13}C$ values than males, while the male population had a greater dispersion in the $\delta^{15}N$ values (see Figure 24). Alexander, *et al.* (2015) points to the possibility that the dispersion in $\delta^{13}C$ values could be due to religious based differences (Mudejar, Christian) in diet, where a higher consumption of C_4 plants in Muslim population was found in their study. Although, all the samples from this study belonged to Christians, it is possible that part of the population studied were converts or New Christians, since human samples dated to the first years of the conquest of the Algarve. In this region, there are historical evidences of conversions and permanence of local populations (Stanislawski 1963). In this same study, Alexander et al. (2015) found differences in $\delta^{13}C$ values between the Christian and Mudejar female population. It is possible that the high variability of $\delta^{13}C$ between female individuals in Cacela is due to the same cause. Meanwhile, statistical analyses indicate that there is no significant difference in $\delta^{13}C$ and $\delta^{15}N$ values

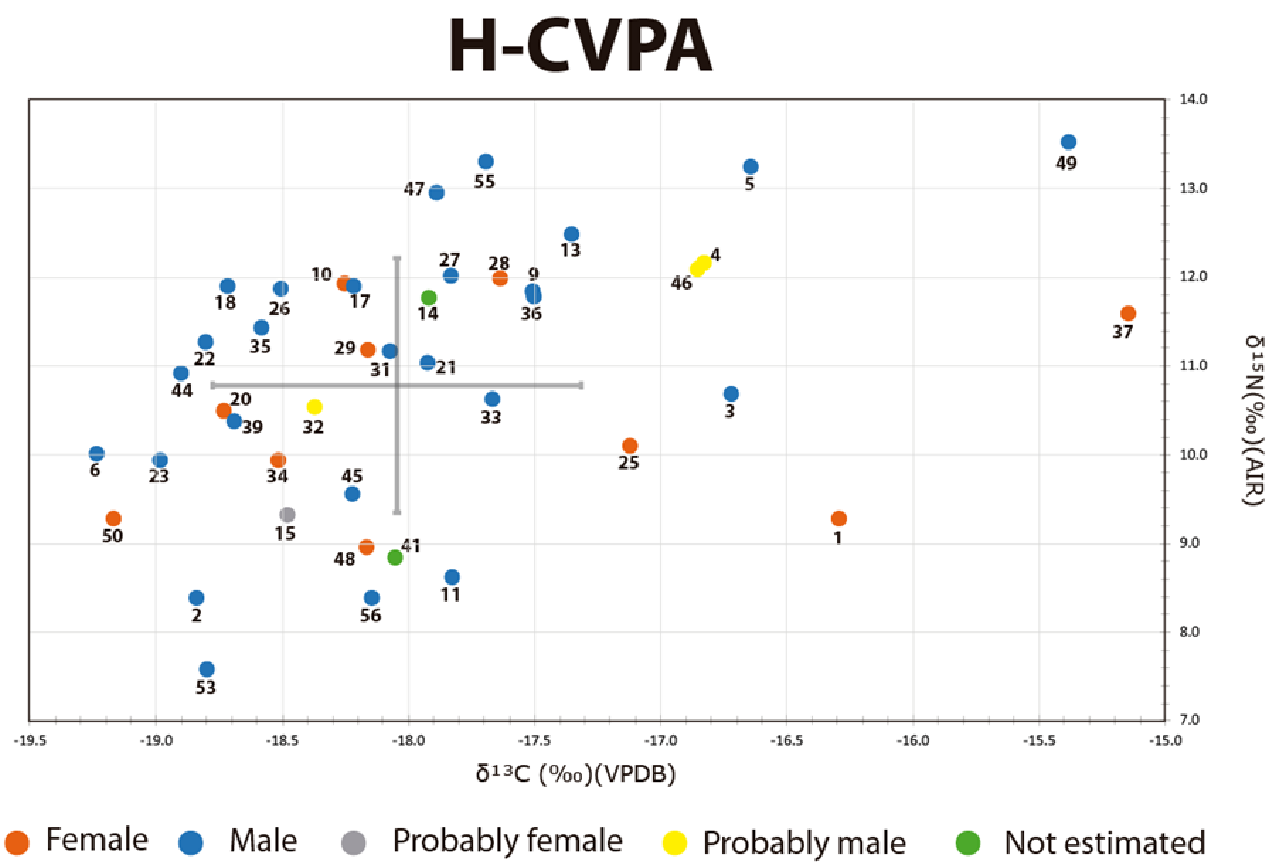

Figure 24 Dispersion plot showing human bone collagen values differentiated by sex. The numbers correspond the sample number without the acronym H-CVPA.

between men (n=29) and women (n=11) (Mann-Whitney U = 155.5 P = 0.903 $\delta^{13}C$; U = 107.5 P= 0.115 $\delta^{15}N$), therefore, it is not possible to reach any inference. It is necessary to mention that the number of samples and the sexual disproportion in the set of samples are insufficient to reach any conclusion about whether gender was a factor that affected the diet of this population.

Another variable by which the data was analyzed was age. Samples 20 and 53 were not consider because their age was not estimated. The variability among the sub-adult population is high (see Table 2 and Figure 25), especially in $\delta^{15}N$ values. This may be because in periods of growth and hormonal change, such as adolescence, there is a higher consumption of food, which produces nutritional surpluses. Of these surpluses, light isotopes (^{14}N) are more easily absorbed due to their physical-chemical characteristics, thus producing lower $\delta^{15}N$. On the other hand, when growth is accelerated, the body uses part of the amino acids found in muscle tissue for the production of other tissues, like enzymes or other substances that the body requires. In this process, there is an enrichment of ^{15}N (Fuller, et al. 2005, Hobson, Alisauskas and Clark 1993). Besides, individuals around 16 years old are still prone to a remnant nursing effect (Fuller, et al. 2006).

In the 20 to 29 years group data (see Table 2 and Figure 25) it is possible to differentiate two distinct groups with different values. The first group is constituted by samples H-CVPA 6, 17, 23, 32, 34, 35 and 48 ($\delta^{13}C$: -18.6 ± 0.39‰; $\delta^{15}N$: 10.4 ± 1‰) and it had a trophic offset of 3.2‰ in $\delta^{15}N$ and 1.7‰ in $\delta^{13}C$ compared to domestic herbivores, inside the quoted range mentioned by Bocherens and Drucker (2003). This group would therefore have a diet which the main protein source was based on domestic terrestrial animals. The $\delta^{13}C$ values from this group indicate a consumption based on C_3 plants with a small intake of C_4 plants. In contrast, the other group (H-CVPA 1, 3, 5, 46) ($\delta^{13}C$: -16.6 ± 0.23‰; $\delta^{15}N$: 11.3 ± 1.7‰) could have a diet more enriched in marine products and with a higher intake of C_4 plants. Individuals of this group practically do not differ in their values while in $\delta^{15}N$ they do. This may be due to different sources of marine protein, in which some of them may have consumed fish and the other consumed more shellfish or low trophic level fish and other sources of protein such as omnivorous animals and their derivatives. Also, diet difference among these groups could be due to the fact that one of the groups was local and the other was not.

The $\delta^{15}N$ and $\delta^{13}C$ values of the population of 30-39 years had variable values. Due to the small size of the sample (*n*=5) representing this age range, no conclusions could be reached. Individuals from the 40-49 age group have less variability and all fall within the mean+2σ range. The same happened, with less variability, with the age group of 50-59 years, that fell inside the mean+2σ range. This could mean that as the population advanced in age their diet became more homogeneous (see Figure 25). The causes of this phenomenon are uncertain but it could have something to do with appetite changes, medical beliefs, or physical disabilities *e. g*. teeth loss. This last example would not be the case in these two groups, since the individuals that had *ante mortem* teeth loss had very variable values between them. It may also be due to the possibility that older populations were mostly local,

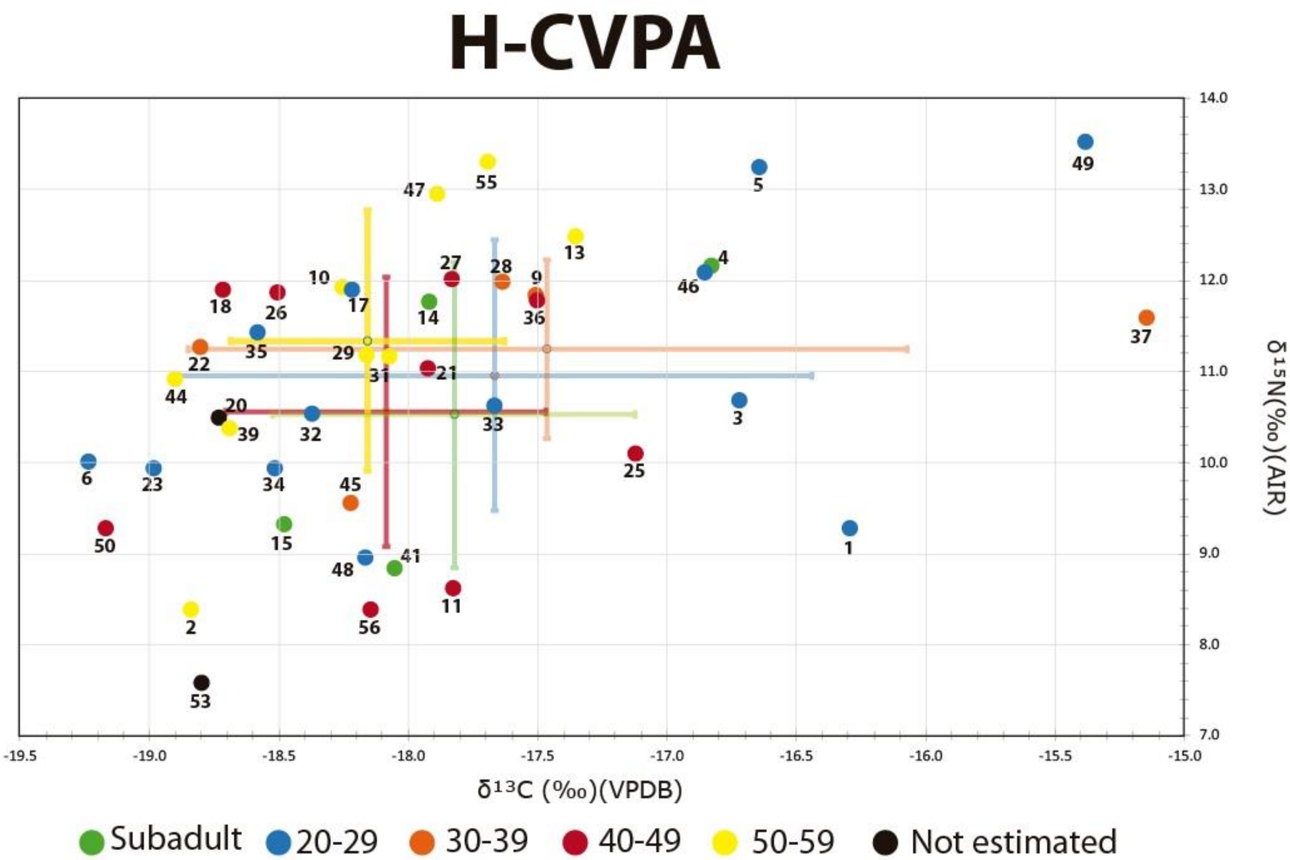

Figure 25 Dispersion plot showing human bone collagen values differentiated by age. The numbers correspond the sample number without the acronym H-CVPA. One standard deviation is represented of each age group.

since it was usual that armies and groups of colonizers were usually made up of younger individuals, instead of old.

In addition to the variables of sex and age, there was also the hypothesis that burial location in the Necropolis had a hierarchical sense, in which the most important individuals or with more resources would be located in a specific sector. This type of practice was common in Christianity *e.g.* the practice of *ad sanctos,* in which the most important individuals of a community were buried closer to the church altar (MacKinnon 2015). Although in the necropolis of Poço Antigo all the burials had very sober characteristics –with the exception of the individual H-CVPA 31 which represented the only burial with a coffin– it does not necessarily mean that the population was poor, but that it could be due to the Christian philosophy of the period that sought to represent humbleness (Tété Garcia 2015). To know if the location of the tomb was related to status, and also reflected through diet, different groups were made according to the sections of the necropolis; however, it was not possible to establish any relationship between diet and burial location.

In order to understand which social and cultural practices could have some influence on the diet of the population of Cacela during the 13^{th} century, it was necessary to compare the values to other population that shared similar characteristics. The data was compared with other studies of populations that were also ruled by the Christian kingdoms of the Iberian Peninsula, and that belong to a similar time period. The data used to compare belongs to diverse stables isotopes studies that are mentioned in Table 3. Their location is shown in Figure 26. The expressed error that is shown corresponds to 1σ.

First, to know if the human groups were comparable, it was necessary to comprehend the baseline that those studies used. For this reason, an average of the bovine, sheep and goat livestock values used in those studies was calculated, and it is reported in Table 3. Sheep and goats were employed because it is the most common livestock in archaeological medieval contexts (Grau-Sologestoa 2017), and bovine cattle values were used since they were available in all the chosen studies. In the case of Evora, there was no faunal baseline reported.

Table 3 listing different stable isotopes studies on Christian medieval populations. Location, period of time and $\delta^{13}C$ and $\delta^{15}N$ averages with a standard deviation of the sites are presented. The trophic offset between the populations and the domestic baselines used on those studies are also shown.

N°	Location	*n*=	Period	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
1	Necropolis of Santa Maria do Olival, Tomar, Portugal	32	11th – 17th	-18.6 ± 0.5	10.9 ± 1.46	(Curto, et al. 2019)
2	Necropolis and church of San Salvador de Valdedios, Asturias	12	10th – 13th	-19 ± 0.4	9.7 ± 0.9	(MacKinnon 2015)
3	Necropolis of Castro de Chao Samartín, Asturias	6	7th – 15th	-18.8 ± 0.5	10.2 ± 0.6	(MacKinnon 2015)
4	Cemetery of San Pedro de Nora, Asturias	12	12th – 15th	-18.3 ± 1.8	10.3 ± 1	(MacKinnon 2015)
5	Church of San Miguel de Lillo, Asturias	16	11th – 14th	-17.5 ± 2.5	10.4 ± 1.1	(MacKinnon 2015)
6	Cathedral of San Salvador, Asturias	4	Medieval	-18.6 ± 0.2	12 ± 1.2	(MacKinnon 2015)
7	San Pedro de Plecín, Asturias	3	Medieval	-18.8 ± 0.9	12 ± 0.9	(MacKinnon 2015)
8	Dutantzi, Basque Country	61	6th – 14th	-18.8 ± 1.4	9.1 ± 1.2	(Lubritto, et al. 2017)
9	Aistra, Basque Country	44	6th – 14th	-18.9 ± 1	8 ± 1	(Lubritto, et al. 2017)
10	Zaballa, Basque Country	14	6th – 15th	-19.9 ± 0.9	9.4 ± 1.3	(Lubritto, et al. 2017)
11	Treviño, Basque Country	19	12th	-19.5 ± 0.7	9.7 ± 1.1	(Lubritto, et al. 2017)
12	Zornoztegi, Basque Country	9	12th	-18.2 ± 0.8	8 ± 0.6	(Lubritto, et al. 2017)
13	Santa María, Galicia	47	13th – 17th	-16.2 ± 2	12.9 ± 1.1	(López-Costas and Müldner 2019)
14	San Bartolome, Galicia	16	13th – 15th	-16.9 ± 1	11.7 ± 1	(López-Costas and Müldner 2019)
15	Palacio de la Sierra, Castile	5	11th – 13th	-18.8 ± 0.8	9.4 ± 1.5	(Jiménez-Brobeil, et al. 2016)
16	Las Gobas, Castile		10th – 11th	-19.1 ± 0.6	8.6 ± 0.4	(Guede, et al. 2018)
17	Valencia	19	14th – 15th	-18.4 ± 0.6	10.9 ± 1.9	(Alexander, Gutiérrez, et al. 2019)
18	Gandía, Valencia	24	13th – 16th	-17.2 ± 1	10.3 ± 0.8	(Alexander, Gerrard, et al. 2015)
19	Évora, Portugal	11	8th – 13th	-17.8 ± 0.7	11.9 ± 0.4	(MacRoberts 2017)
20	Cacela-a-Velha, Portugal	42	13th	-17.9 ± 0.9	10.9 ± 1.4	This study
Trophic offset between domestic herbivores and humans						

Table 3 (continuation)

N°	Location	n=	Domestic herbivore $\delta^{13}C$ (‰)	Domestic herbivore $\delta^{15}N$ (‰)	$\Delta^{13}C$ (‰) diet-consumer	$\Delta^{15}N$ (‰) diet-consumer
1	Necropolis of Santa Maria do Olival, Tomar, Portugal	6	-21.05	6.30	2.45	4.60
2	Necropolis and church of San Salvador de Valdedios, Asturias	17	-20.40	6.05	1.40	3.65
3	Necropolis of Castro de Chao Samartín, Asturias	17	-20.40	6.05	1.60	4.15
4	Cemetery of San Pedro de Nora, Asturias	17	-20.40	6.05	2.10	4.25
5	Church of San Miguel de Lillo, Asturias	17	-20.40	6.05	2.90	4.35
6	Cathedral of San Salvador, Asturias	17	-20.40	6.05	1.80	5.95
7	San Pedro de Plecín, Asturias	17	-20.40	6.05	1.60	5.95
8	Dutantzi, Basque Country	24	-20.60	5.65	1.80	3.45
9	Aistra, Basque Country	24	-20.60	5.65	1.70	2.35
10	Zaballa, Basque Country	24	-20.60	5.65	0.70	3.75
11	Treviño, Basque Country	24	-20.60	5.65	1.10	4.05
12	Zornoztegi, Basque Country	24	-20.60	5.65	2.40	2.35
13	Santa María, Galicia	13	-20.65	6.80	4.45	6.10
14	San Bartolome, Galicia	13	-20.65	6.80	3.75	4.90
15	Palacio de la Sierra, Castile	22	-19.40	5.1	0.60	4.30
16	Las Gobas, Castile	5	-20.91	3.43	1.81	5.17
17	Valencia	8	-20.10	6.50	1.70	4.40
18	Gandía, Valencia	14	-18.55	5.50	1.35	4.80
19	Évora, Portugal					
20	Cacela-a-Velha, Portugal	5	-20.30	7.20	2.40	3.70

The faunal baseline values of most of the studies showed similar values with Cacela domestic herbivores $\delta^{13}C$ values with exception of Palacio de la Sierra and Gandía (see Table 3). Meanwhile, $\delta^{15}N$ values of Cacela baseline were the highest in comparison with the others (see Table 3). Since local isotope baseline changes according to climatic conditions and anthropogenic factors, the trophic offset between humans and livestock was used to understand similarities and differences in the diet of the previously mentioned sites.

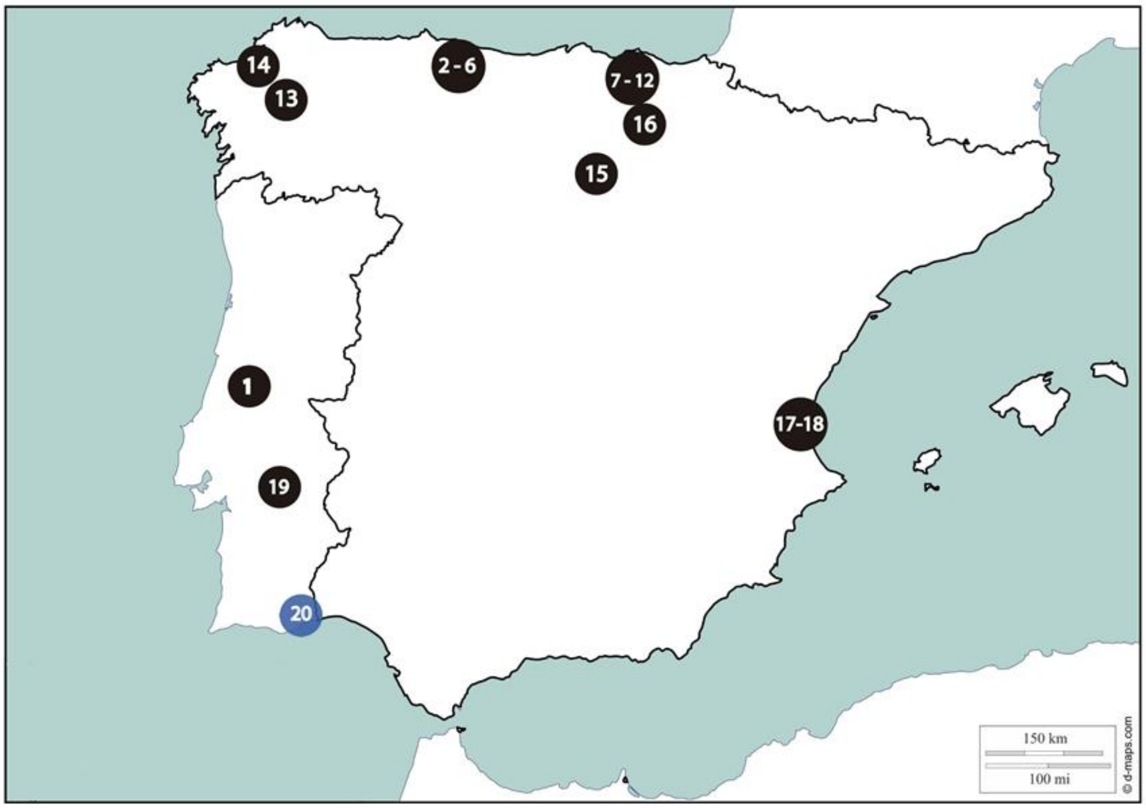

Figure 26 Map showing the location of the enlisted sites in Table 3 in the Iberian Peninsula. Adapted from d-maps.com

As it is possible to appreciate in Figure 27, there is a tendency of low $\delta^{13}C$ values among the sites, that could mean that their diet was based mainly on the consumption of C_3 plants. Such negative $\delta^{13}C$ values could indicate that also the fauna that those populations used as food were fed with C_3 plants. In contrast to that, the populations of Gandía in Valencia (13th – 16th AD) [18], Santa María (13th – 17th AD) [13] and San Bartolome (13th – 15th AD) [14] in Galicia, showed more positive $\delta^{13}C$ values than Cacela. In the case of the sites of Galicia, their increase is explained because they belonged to fishermen communities, whose main source of protein were marine products (López-Costas and Müldner 2019). In the case of Gandía, it was a coastal population whose food base was C_3 plants with an intake

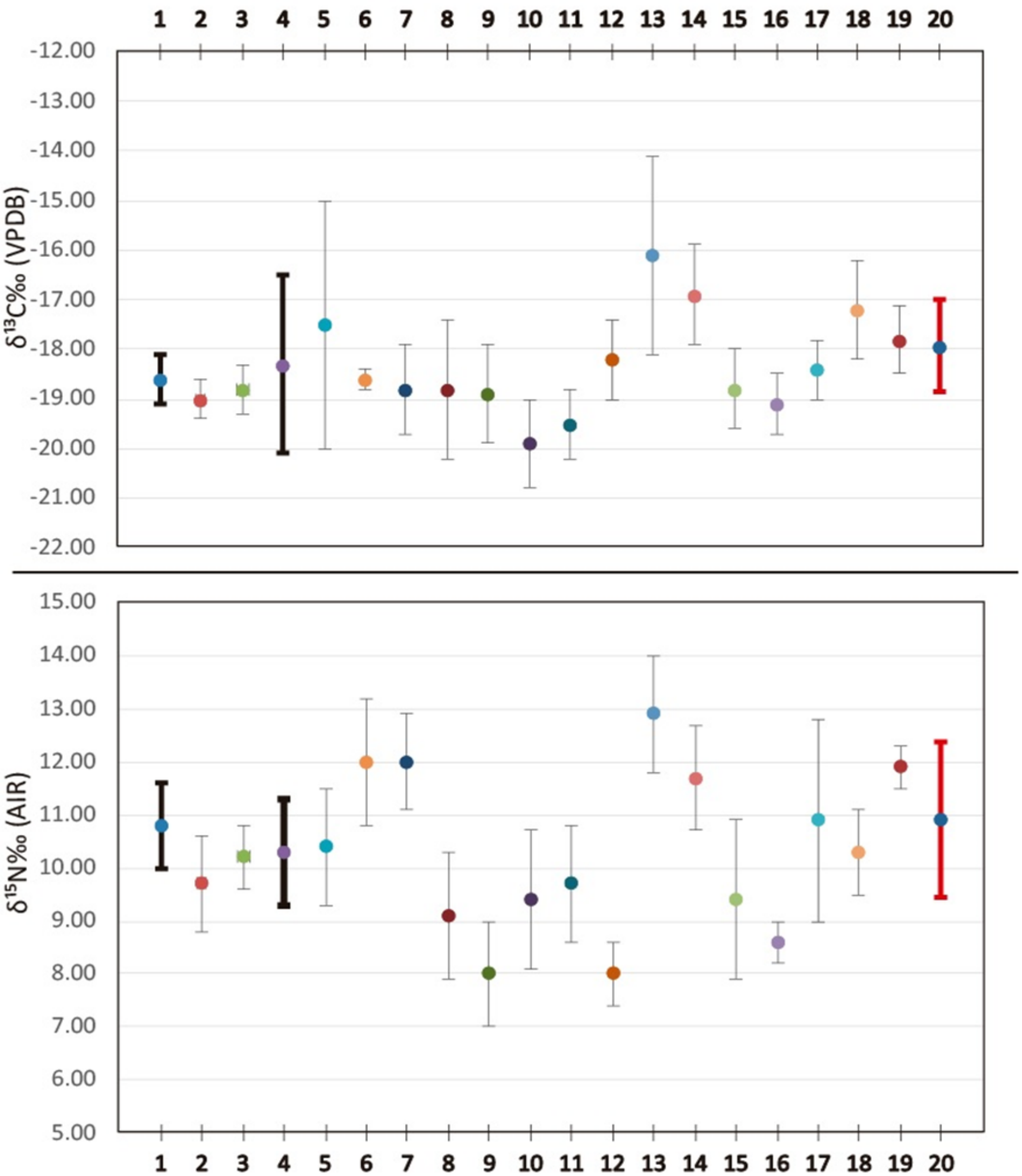

Figure 27 Plots showing the diverse $\delta^{13}C$ and $\delta^{15}N$ values with one standard deviation of the sites listed on Table 3. Cacela values are marked in red. Tomar and San Pedro de Nora are marked in black due to their similarities in human/domestic animals spacing.

of C_4 plants, while its protein sources are mainly domestic animals, with some intake of marine products (Alexander, Gerrard, et al. 2015).

The individuals of Cacela had more positive $\delta^{13}C$ values than the average values obtained of the set. The sites that had closer $\delta^{13}C$ values to Cacela's are those of Evora in Portugal (8^{th} – 13^{th} AD) [19] and that of Zornoztegi in the Basque Country (12^{th} AD) [12]. The former population was composed by members of the Évora militia (organization that in subsequent years became the military order of Avis), who had a diet based on C_3 resources with an important intake of C_4 plants. In the case of the population of Zornoztegi, the population consumed both C_3 plants and C_4 plants in similar proportions. In contrast, these two sites do not seem to have similarities in $\delta^{15}N$ values. Although the $\delta^{15}N$ values of Evora fell within the mean+1σ range of Cacela, the averages differ between each other (11.9 ± 0.4‰, 10.9 ± 1.4‰, respectively). The population of Evora had a greater increase of ^{15}N probably related with consumption of high quantities of meat and a possible marine resources intake (MacRoberts 2017). These values were similar to some individuals in this study, nevertheless there is no faunal baseline to compare to. Meanwhile in Zornoztegi, $\delta^{15}N$ values are lower than Cacela's values and Lubritto et al. (2017) concluded that the consumption of protein sources was mainly vegetable.

Any trend of $\delta^{15}N$ values among the populations was not evidenced, and it could be because many factors can influence nitrogen ratio in nature, such as diverse agricultural practices, salinity, aridity and intake of different sources of protein (vegetal, land animals and marine resources).

The populations that had trophic offset values that were more similar to the ones of Cacela ($\Delta^{13}C$: 2.40‰; $\Delta^{15}N$: 3.70‰) were San Pedro de Nora (12^{th} – 15^{th}) [4] and Tomar (11^{th} – 17^{th} AD) [1] (see Table 3 and Figure 28). Not only they were similar in the trophic offset but also in $\delta^{15}N$ values (see Figure 27). The individuals from San Pedro de Nora ($\Delta^{13}C$: 2.10‰; $\Delta^{15}N$: 4.25‰) had a diet based in C_3 plants with freshwater fish as main protein source, with some intake of terrestrial animals (MacKinnon 2015). Similar to the latter, Tomar ($\Delta^{13}C$: 2.45‰; $\Delta^{15}N$: 4.60‰) resultant $\delta^{15}N$ values were related mainly with consumption of freshwater resources with a lower consumption of terrestrial animals (Curto, et al. 2019). This would not mean that in Cacela there was a consumption of freshwater resources, but it could be related with the overlapping of freshwater carbon and nitrogen isotopic values with the ones of mollusks, that were most probably consumed in Cacela evidenced not only by stable isotope data, but also by the zooarchaeological remains. Besides, Tomar was also ruled by a military order (Templar Knights and later the Order of Christ) and Curto *et al*. (2019) that there is the possibility that algae were used as manure in fields, increasing the ^{15}N of the terrestrial animals that were consumed by that population.

To sum up, within the context of the Iberian Peninsula, the humans of the Necropolis of Poço Antigo had a higher enrichment of ^{13}C rather than most of the sites, and it could be related with C_4 plant consumption, that, in both Christian and Muslim societies, was related with lower classes. Sorghum consumption in Andalusian society has been well documented in the Algarve; meanwhile, millet consumption was extended among the peasants in the Christian kingdoms, because its cultivation was no taxed by the feudal lords (Peña-Chocarro, Pérez Jordá, et al. 2019). To understand which kind of C_4 plants were consumed by the Christian populations during the Late Middle Ages in this region, archaeological excavations in the future are encouraged to use flotation devices in order to study carpological and palynological remains.

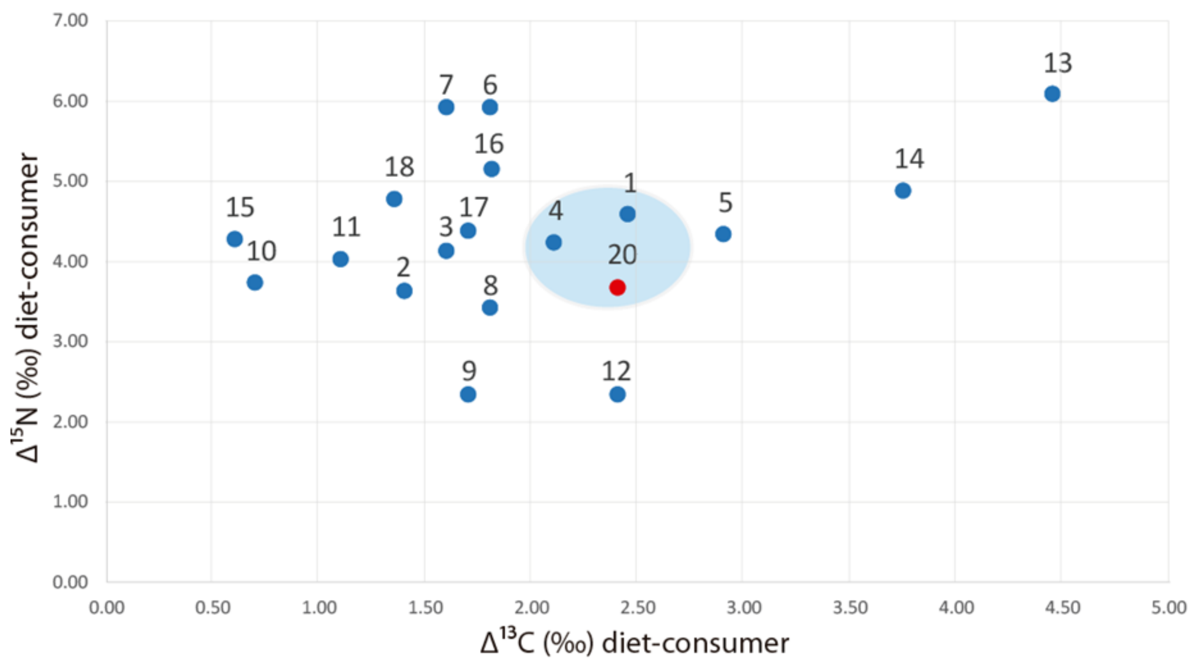

Figure 28 Graph depicting trophic offsets from the sites listed in Table 3. A red point represents Cacela. A blue oval shows the similarities between San Pedro de Nora and Tomar values with Cacela.

Also, the enrichment of ^{13}C in Cacela's population can be explained through consumption of bivalves, that it is evidenced by malacological remains present in silo 7 and its availability in the surroundings of the town.

The $\delta^{13}C$ and $\delta^{15}N$ values from human bone collagen in comparison to coetaneous sites of the Iberian Peninsula showed a relation with two other populations reigned by military orders; a peculiarity that may suggest that diet was influenced by religious beliefs or rule. Besides, Cacela's $\delta^{15}N$ values shared equivalences with two populations that had as main source of protein freshwater fish. Resource that share similar values with mollusks. population

The latter gives an idea of how much influence not only the availability of resources but also social and cultural factors influence the diet of societies. During the medieval period, the Christian dogma and its institutions ruled behavior and life, both politically and socially. There was a direct intervention from part of the institutions in the diet of the individuals. An example of this is that Christian philosophy and the medicine traditions in western Europe during the middle ages gave attributions to food products. The food was classified as wet, dry, humid and hot, no by their physical characteristics, but ontological (MacKinnon 2015). The food was related with substances in the body called "Humors" (blood, yellow bile, black bile and phlegm) that depending on the consumption of each food, these substances would increase, and, if there would be an imbalance of these, the person would sick. Therefore, specific foods had specific features that were more consumed by specific population sectors.

Besides Humorism, religious practices such as Lent and fasting influence the way that the societies fed. Altogether the Christian holydays that forbidden the consumption of meat sum up to 150 days per year (Alexander, Gerrard, et al. 2015). Furthermore, food was deeply linked with sin in the Christian beliefs, in which eating was a practice closer to sin rather than redemption and to hunger was synonym of holiness. For Saint Catherine of Siena: "in hunger one joins with Christ's suffering on the cross; to serve because to hunger is to expiate the sins of the world" (Walker Bynum 2013, 251-252). This, of course, was not a practice of the everyday; nonetheless, it illustrates the cosmovision that ruled in the food practices in the Christian medieval society.

One of the products that Christianism promoted was chicken, because of the lighter color of its flesh, and fish, symbol itself of the Christianity in that epoch. It is plausible that rabbit meat was appreciated as well following the same logic. In the case of the fish, its consumption was allowed during the period of Lent, and usually, it had a strong social connotation in populations that were far inland, because fresh fish was not available so often. This last was not the case of Cacela-a-Velha, nevertheless, during Lent, the fish demand increased, producing shortage sometimes in areas close to the sea. This shortage was even stronger with white flesh fish, since the demand was higher due to the purity that represented. In Cacela the proportion of fish remains found in Silo 7 was lower than mollusk remains, but this could be related with the high abundance of these sea animals in the immediate landscape, as well as the fact that fish bones are more prone to decline because of its high lipid content. Another source of proteins that replace the meat during Lent were pulses.

In Cacela, could be the case, that the Christian cosmovision influenced even more directly, since it was ruled by the military Order of Santiago, that could apply more restrictions. According to the book of rules and statutes of the Order of Santiago (Regras estatutos diffinicoens e reformac, am da ordem & cavallaria de Santiago da Espada 1694), the *freyres* should fast all days during Lent, every Friday from the day of Saint Michael (September 29th) to Pentecost (May-June), and fast all the days from the day of the Four Crowned Martyrs (November 8th) to Christmas day (December 25th). Besides, the *freyres* could only eat Lent food the Fridays that went from Pentecost to Saint Michael day, and the *freyres* that would be punished could only eat bread and water. Lent food consisted in eggs, fish and dairy products.

These practices not only would influence directly in the products that were allowed to consume by the community, but also such practices like fasting in a regular basis through long terms could influence $^{15}N/^{14}N$ and $^{13}C/^{12}C$ ratios (Fuller, et al. 2005, Hobson, Alisauskas and Clark 1993).

There is the possibility that some individuals of the studied population were local and others were from the vicinities. Stanislawski (1963) mentions that part of the Muslim population of the Algarve was converted to Christianism, and Tété Garcia (2015) indicates that even no converted Muslims stayed at Cacela until the year 1264, when they were relocated in *morerias*. It is documented that one *moreria* was inside the term of Cacela in the subsequent years.

The fact that part of the population could be composed by New Christians opens the possibility that the Order placed a stricter diet. It is plausible that the Order of Santiago abolished certain products and practices and promoted other ones in order to ensure conversion. This is by no means a far-fetched scenario, since, in the close future, there were inspectors that verified if the New Christians had pork products in their kitchens such as lard and meat, and, if they bred pigs (MacKinnon 2015).

Another idea, that is not new either, is that this control in the food products by the Order was with the objective of punish the civil population, since there is evidence of practices with other conditions but the same objectives. For example, during the first conquest of Silves, the military orders killed more than 600 members of the Mozarab community, even though they were Christians. This act was condemned by the Portuguese army of Sancho I, and the explanatory reason that the military orders gave to the king was that it was a sort of punishment (Borges Coelho 2011).

On the other hand, if all the population or only a part were Christian and they were part of the conquest force does not mean that they had a high-quality life. While it is true that the religious Order of Santiago had an elitist character, the bulk of its communities were made up of pawns that did not even belong to the Order. It can be inferred that because the conquest of southern Portugal was not made by a demographic need, but by religious orders and Portuguese militia, the military body could have an extreme need condition (Tété Garcia 2015). A social class that had nothing to lose.

The common diseases registered in the bone remains of the population of Cacela that have relation with nutritional deficiencies, such as tooth enamel linear hypoplasia (HLED), *Spina Bifida* that indicates lack of folic acid during pregnancy, a case of scurvy, anemia, dental abscess and lose of teeth *ante mortem* show a fragile health and a bad nutrition. This, together with the fact that the population had a higher ratio of male individuals, a big amount of young deaths (38% of subadults and 20-29 years population), and signs of physical hard work like fractures that were not consolidated point to characteristics of a lower social class (see Table 5 in Appendix). There is evidences in which lower classes were forced, through sumptuary laws, to eat bad quality cereals and root crops in order to make more evident their condition (MacKinnon 2015).

Finally, since Portugal was on a political crisis during the decade of 1240's, together with conflicts that had with the kingdom of Castile to define the border, and because of that, the deep violence that the region lived were factors that could influence the availability of products. Moreover, during the Medieval Warm Period (MWP) (9^{th} – 14^{th} AD) (Hughes and Diaz 1994, Büntgen, et al. 2011) the population of Europe had doubled, producing a major demand on animal products, and as consequence, it caused increases on prices and, therefore, less availability of such products in the everyday food of the consumers (Boserup 1983).

Chapter 6 Conclusion

In conclusion, due to the variability of the $\delta^{15}N$ values among faunal samples, and due to their characteristics already exposed, it is possible to distinguish different animal husbandry practices. On one hand, there would be a breeding practiced in a closer space that would feed of plants that are constantly manured. Historical and ethnological evidences show that, not only in Algarve but in many regions of the western part of Iberian Peninsula, the fields were manured with algae and plants of the genus *Salicornia* besides animal dung. Meanwhile, the livestock with lower $\delta^{15}N$ values could indicate that it was bred in a wider environment. It is probable that they were taken to graze to areas with different altitudes in diverse year's periods. Also, this livestock showed a trophic offset in between the human values concordant to the literature, thus, doing more plausible that they were the animals bred for the consumption of the community.

This provides two scenarios. The first is that both livestock groups were bred in Cacela through diverse breeding practices and the fact that makes their $\delta^{15}N$ values different is because one belonged to a specific social class or specific owner, whose bones have not been analyzed in this study. The second scenario, is that the difference of the values is due to commerce in which some animals had been bred in another environment with other conditions or were fed with fodder from other places.

Regarding the population that lay in the Necropolis of Poço Antigo, it is possible to conclude that the diet of the individuals was heterogeneous, in which there were individuals with higher consumption of marine resources, other with higher ingestion of domestic herbivores, some that had more intake of omnivorous animal products, meanwhile others whose consumption was based on marine resources of low trophic levels such as shellfish. There are also some in which their intake of animal protein was low, and whose major source of protein were more probably vegetables and legumes. Besides, heterogeneity of the individuals' diet appears to become more homogeneous while their age advances. Through this study was not possible to reach a solid conclusion about this aspect, nevertheless, it appears to be a future streak of research.

Sulfur stable isotope evidenced that part of the diet of the humans was constituted by products from places where $\delta^{34}S$ values inside the foodweb were low. Through sulfur analysis it was possible to observe two different groups of animals, in which most probably, one group was composed by fauna that bred in the area of Cacela, while others were brought through commerce. Also, it was possible to see how the spray effect had an impact on the set of samples.

Such a steep difference among individuals' diets could be explained by four major reasons. First, it is possible that the distinctions are in terms of differences in social classes; nevertheless, this is debatable, since there are pathological evidences that oppose to this approach. A second explanation to the heterogeneity is that if it is the case that this population belonged to a low social class, it is possible that the population fed with whatever they had to eat. A third approach, and perhaps one of the most likely, is that it was a cemetery where Christians and converts or New Christians were buried. Finally, the last explanation, which does not contradict any of the above, is that it is due to the fact that in the Necropolis of Poço Antigo was constituted by local and non-local individuals.

Therefore, having all these explanations in mind, it is possible to conclude that local and foreign individuals, converts and Christians have been deposited in this cemetery and whose social class is most likely low. This conclusion is based on the location of the cemetery around the population where there are other cases on the peninsula where cemeteries of poor Christians were located on the periphery where they normally lived (López-Costas and Müldner 2019). Future studies of isotopes in individuals whose social class is clearly differentiated would serve to understand the reality of this population.

Meanwhile, Grau-Sologestoa (2017) mentions that there are some zooarchaeological indicators that can be used to assess social classes. Silo 7 content showed all these indicators, making it appear as evidence of consumption from a high social class, in which there are some contrasting elements such as shellfish remains. This opens the possibility that this silo did not represent the whole population, and this idea is reinforced by the fact that it was excavated in the Fortress of Cacela. There is the possibility that the remains belonged to different periods of time (Almohad and Christian), therefore, it will be necessary future radiocarbon dating. Also, it is important to mention that a heterogeneous diet inside a population, as is the case of Cacela, could present the indicators mentioned by Grau and could make the Silo 7 appear as an evidence of a higher class. Therefore, this leads to the conclusion that those stablished indicators should be taken with caution and be interpreted taking into account the general context.

Finally, Cacela, despite being conformed by a Christian population and being located by the sea, did not show a diet entirely based on marine resources; there were some who showed a low consumption of them, which lead to ponder on two aspects: the first, that the idea that Christian diet was greatly enriched by marine products, such as fish, which is based on Christian doctrine and ideology, was not necessarily so deeply rooted in populations. Therefore, it leads to understand that while Christianity dominated the lives of medieval Iberian Society, reality is much more ambivalent and showed an image of a less monotonous society. On the other hand, a coastal Christian community with a diet that was not so enriched in marine resources may also mean that a kind of restriction existed on certain marine products from part of the authority. It is possible that marine resources were regularized or prohibited to certain classes e.g. sumptuary laws. This would not be an isolated element in medieval Christian society, as heterogeneity in isotopic values is not an isolated case either. Among the set of sites in Table 3, Palacio de la Sierra [15] and Valencia [17] had more heterogeneous values than Cacela, as it is possible to see in Figure 27, and this can be due to a policy that through food and many other manners, the ruling class aimed to create an evident and vertical differentiation between social classes.

On account of that, diet studies through stable isotopes analysis in conjunction with historical and anthropological approaches can help to give an idea of power relations and which were its scopes and limitations. In this way, it is possible to reach closer conclusions of the importance of a site, if it was part of the core or the periphery. Besides, it helps to have a better understanding of the complexities of medieval societies and the way that they understood their reality.

References

Alexander, Michelle M., Alejandra Gutiérrez, Andrew R. Millard, Michael P. Richards, and Christopher M. Gerrard. "Economic and socio-cultural consequences of changing political rule on human and faunal diets in medieval Valencia (c. fifth-fifteenth century AD) as evidenced by stable isotopes." *Archaeological and Anthropological Sciences*, 2019.

Alexander, Michelle M., Christopher M. Gerrard, Alejandra Gutiérrez, and Andrew R. Millard. "Diet, society, and economy in late medieval Spain: Stable Isotope evidence from muslims and christians from Gandía, Valencia." *American Journal of Physical Anthropology* 156, no. 2 (2015): 263-273.

Ambrose, Stanley H. "Preparation and characterization of bone and tooth collagen for isotopic analysis." *Journal of Archaeological Science*, no. 17 (1990): 431-451.

Ambrose, Stanley H., and Lynette Norr. "Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate." In *Prehistoric Human Bone. Archaeology at the molecular level*, by Joseph B. Lambert and Gisela Grupe, 1-38. Heidelberg: Springer-Verlag, 1993.

Blanz, Magdalena, et al. "Seaweed fertilisation impacts the chemical and isotopic composition of barley: Implications for analyses of archeological skeletal remains." *Journal of Archaeological Science* 104 (2019): 34-44.

Bocherens, H., and D. Drucker. "Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems." *International Journal of Osteoarchaeology* 13 (2003): 46-53.

Bogaard, A., T. H. E. Heaton, P. Poulton, and I. Merbach. "The impact of manuring on nitrogen isotope ratios in cereals: archaeological implications for reconstruction of diet and crop management practices." *Journal of Archaeological Science* 34 (2007): 335-346.

Bonafini, M., M. Pellegrini, P. Ditchfield, and A. M. Pollard. "Investigation of the "Canopy effect" in the isotope ecology of temperate woodlands." *Journal of Archaeological Science* 40, no. 11 (2013): 3926-3935.

Borges Coelho, Antonio. *Portugal Medioevo.* Lisbon : Editorial Caminho, 2011.

Boserup, Ester. "The impact of scarcity an plenty on development." *The Journal of Interdisciplinary History*, 1983: 383-407.

Brickley, M. B. "Cribra orbitalia and porotic hyperostosis: A biological approach to diagnosis." *American Journal of Physical Anthropology*, 2018: 896-902.

Brown, T. A., D. E. Nelson, J. S. Vogel, and J. R. Southon. "Improved collagen extraction by modified Longin Method." *Radiocarbon* 30, no. 2 (1988): 171-177.

Büntgen, Ulf, et al. "2500 years of European Climate Variability and Human Susceptibility." *Science* 331 (2011): 578-582.

Catarino, Helena. "A sociedade e a economia." *AL-ÚLYÁ* II, no. 6 (1997/1998): 662-712.

Colombini, M. P., G. Giachi, F. Modugno, and E. Ribechini. "Characterisation of organic residues in pottery vessels of the Roman age from Antinoe (Egypt)." *Microchemical Journal*, 2005: 83-90.

coord. da Cruz Coelho, Maria Helena, and Armando Luís de Carvalo Homem. *Portugal em definição de fronteiras (1096-1325) Do condado Portucalense à crise do século XIV.* Vol. III. Lisbon: Editorial Presença, 1996.

coord. de Oliveira Marques, A. H. *Portugal. Das Invasões germânicas à "Reconquista".* Vol. II. Lisbon: Presença, 1993.

Curate, Francisco. *Necrópole Cristã de Cacela Velha.* Coimbra: Instituto de Antropologia da Faculdade de Ciências e Tecnologia da Universidade de Coimbra, 2001.

Curto, Ana, Anne-France Maurer, Cristina Barroca-Dias, Patrick Mahoney, Teresa Fernandes, and Geraldin E. Fahy. "Did military orders influence the general population diet? Stable isotope analysis from medieval Tomar, Portugal." *Archaeological and Anthropological Sciences*, 2019: 3797-3809.

De Pina Manique e Albuquerque, J. "Dinamismo Climático da Região Algarvia no conceito de Lautensach & Freymann." *Separata da Agronomía Lusitana* XVI, no. III (1954): 214-230.

DeNiro, Michael J. "Postmortem alteration and preservation of in vivo bone collagen isotope ratios in relation o palaeodietary reconstruction." *Nature* 317 (1985): 806-809.

DeNiro, Michael J., and Stephen Weiner. "Chemical, Enzymatic and Spectroscopic characterization of "Collagen" and other organic fractions from prehistoric bones." *Geochimica et Cosmochimica Acta* 52 (1988): 2197-2206.

Fahy, G. E., C. Deter, R. Pitfield, J. J. Miszkiewicz, and P. Mahoney. "Bone deep: Variation in stable isotope ratios and histomorphometric measurements of bone remodelling within adult humans." *Journal of Archaeological Science*, 2017: 10-16.

Feio, Mariano. *Le Bas Alentejo et l'Algarve.* Évora: Centro de Ecologia Aplicada da Universidade de Évora, 1983.

Fernandes, Hermenegildo. *D. Sancho II.* Rio de Mouro: Temas e Debates, 2011.

Ferreira, Antonio Miguel Pereira Jorge. *Dados Geoquímicos de Base de Sedimentos Fluviais de Amostragem de Baixa Densidade de Portugal Continental: Estudo de Factores de Variação Regional.* Aveiro: Universidade de Aveiro, 2000.

Forseth, Irwin N. «The Ecology of Photosynthetic Pathways: The Nature Educational Knowledge Project.» *Nature Education Knowledge* 3, nº 10 (2010).

Fuller, B. T., T. I. Molleson, D. A. Harris, L.T. Gilmour, and R. E. Hedges. "Isotopic evidence for breastfeeding and possible adult dietary differences from late sub-Roman Britain." *American Journal of Physical Anthropology* , 2006: 45-54.

Fuller, Benjamin T., James L. Fuller, Nancy E. Sage, David A. Harris, Tamsin C. O'Conell, and Robert E. M. Hedges. "Nitrogen balance and δ15N: why you're not what you eat during nutritional stress." *Rapid Communications in Mass Spectrometry*, 2005: 2497-2506.

Gamza, T., and J. Irish. "A comparison of archaeological and dental evidence to determine diet at a predynastic Egyptian site." *International Journal of Osteoarchaeology*, 2010: 398-408.

García Sánchez, Expiración. "La alimentación en la Andalucía islámica. Estudio histórico y bromatológico. I: Cereales y leguminosas." In *Andalucía islámica. Textos y estudios, II-III*, by Universidad de Granada, 139-178. Granada: Universidad de Granada, 1983.

Grau-Sologestoa, Idoia. "Socio-economic status and religious identity in Medieval Iberia: The zooarchaeological evidence." *Environmental Archaeology*, 2017: 189-199.

Guede, Iranzu, et al. "Isotopic evidence for the reconstruction of diet and mobility during village formation in the Early Middle Ages: Las Gobas (Burgos, northern Spain)." *Archaeological an Anthropological Sciences* , 2018: 2047-2058.

Harris, Marvin. "Foodways: Historical Overview and Theoretical Prolegomenon." In *Food and Evolution: Towards a theory of human food habits*, by Marvin Harris and Eric B. Ross, 57-92. Philadelphia: Temple University Press, 1987.

Herodoto. *Los nueve libros de la Historia.* Madrid: EDAF, 1989.

Hobson, Keith A., Ray T. Alisauskas, and Robert G. Clark. "Stable-Nitrogen Isotope Enrichment in Avian Tissues Due to Fasting and Nutritional Stress: Implications for Isotopic Analyses of Diet." *The Condor* 95, no. 2 (1993): 388-394.

Hughes, Malcolm K., and Henry F. Diaz. "Was there a "Medieval Warm Period", and if so, where and when?" *Climatic Change*, 1994: 109-142.

Instituto de Conservação da Naturaleza e das Florestas. "Plano de Ordenamento do Parque Natural da Ria Formosa - Documentos - Aspectos físicos - Geología." *Instituto de Conservação da Naturaleza e das Florestas.* January 24, 2007. http://www2.icnf.pt/portal/pn/biodiversidade/ordgest/poap/popnrf/popnrf-doc (accessed June 14, 2019).

—. "Plano de Ordenamento do Parque Natural da Ria Formosa - Documentos - Aspectos físicos - Geomorfología." *Instituto de Conservação da Naturaleza e das Florestas.* January 24, 2007.

http://www2.icnf.pt/portal/pn/biodiversidade/ordgest/poap/popnrf/popnrf-doc (accessed June 14, 2019).

Jiménez-Brobeil, S. A., Z. Laffranchi, R. M. Maroto, F. A. López Sánchez, and A. Delgado Huertas. "How royals feasted in the court of Pedro I of Castile: A contribution of Stable isotope study to medieval history." *Journal of Archaeological Science: Reports*, 2016: 424-430.

Lautensach, Herman. *Geografía de España y Portugal.* Barcelona: Vicens-Vives, 1967.

Longin, R. "New method of collagen extraction for radiocarbon dating." *Nature*, 1971: 241-242.

López-Costas, Olalla, and Gundula Müldner. "Boom and bust at a medieval fishing port: Dietary preferences of fishers and artisan families from Pontevedra (Galicia, NW Spain) during the Late medieval and Early modern period ." *Archaeological and Anthropological Sciences*, 2019: 3717-3731.

Lubritto, C., M. I. Garcia-Collado, P. Ricci, S. Altieri, C. Sirignano, and J. A. Quirós Castillo. "New dietary evidence on medieval rural communities of the Basque Country (Spain) and its surroundings from Carbon and Nitrogen Stable Isotopes Analyses: Social insights, Diachronic changes and Geographic comparison." *International Journal of Osteoarchaeology*, 2017: 984-1002.

MacKinnon, Amy T. *Dietary reconstruction of medieval and early modern spanish populations using stable isotopes of Carbon and Nitrogen.* Chico: California State University, 2015.

MacRoberts, Rebecca Anne. *Diet and dynamic of Christians and Muslims – A picture of Évora in the 8th-13th AD.* Evora: Universidade de Évora, 2017.

Malpica Cuello, Antonio. "La vida agrícola y la ganadería en el Al-Andalus y en el Reino Nazarí de Granada." In *Homenaje al Profesor Dr. D. José Ignacio Fernández de Viana y Vieites*, by Rafael coord. Marin López, 213-228. Granada: Universida de Granada, 2012.

Mays, Simon. *The Archaeology of Human Bones.* London: Routledge, 1998.

Nehlich, Olaf. "The aplication of sulfur isotope analyses in archaeological research: a review." *Earth Science Reviews* , 2015: 1-17.

Nehlich, Olaf, and Michael P. Richards. "Establishing collagen quality criteria for sulphur isotope analysis of archaeological bone collagen ." *Journal of Archaeological and Anthropological Science,* 2009: 59-75.

O'Leary, Marion H. "Carbon isotopes in photosynthesis. Fractionation techniques may reveal new aspects of carbon dynamics in plants." *BioScience* 38, no. 5 (1988): 328-336.

Oliveira, J. T. *Carta Geológica de Portugal. Escala 1/200 000. Notícia explicativa da folha 8.* Lisbon: Serviços Geológicos de Portugal, 1992 .

Peña-Chocarro, Leonor, and Guillem Pérez-Jordá. "Los estudios carpológicos en la Peninsula Ibérica: un estado de la cuestión." *Journal of Western Mediterranean Prehistory and Antiquity,* 2018: 7-45.

Peña-Chocarro, Leonor, et al. "Roman and medieval crops in the Iberian Peninsula: A first overview of seeds and fruits from archaeological sites." *Quaternary International,* 2019: 49-66.

Polibio. *Historias.* Madrid: Consejo Superior de Investigaciones Científicas, 1982.

Regras estatutos diffinicoens e reformac, am da ordem & cavallaria de Santiago da Espada. Lisboa: Ordem de Santiago da Espada, 1694.

Renfrew, Colin, and Paul Bahn. *Archaeology. Theories, methods and practice.* London: Thames & Hudson, 2012.

Ribeiro, Orlando. *Portugal o Mediterrâneo e o Atlântico.* Lisbon: Edições João Sá da Costa, 1993.

Ribeiro, Orlando, Hermann Lautensach, and Suzanne Daveau. *Geografia de Portugal. O Ritmo climático e a Paisagem.* Vol. II. Lisbon: Edições João Sá da Costa, 1999.

Richards, M. P., B. T. Fuller, M. Sponheimer, T. Robinson, and L. Ayliffe. "Sulphur isotopes in palaeodietary studies: A review and results from a controlled feeding experiment." *International Journal of Osteoarchaeology,* 2003: 37-45.

Rodríguez Blanco, Daniel. «La organización institucional de la orden de Santiago en la edad media.» *Historias. Instituciones. Documentos.*, nº 12 (1985): 167-192.

Schneider, Heike, Dana Höfer, Carmen Trog, and Roland Mäusbacher. "Holocene landscape development along the Portuguese Algarve coast. A high resolution palynological approach." *Quaternary International*, 2016: 47-63.

Schoeninger, Margaret J., y Michael J. DeNiro. «Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals.» *Geochimica et Cosmochimica Acta* 48 (1984): 625-639.

Sealy, J., M. Johnson, M. Richards, and O. Nehlich. "Comparison of two methods of extracting bone for stable carbon and nitrogen isotope analysis: Comparing whole bone demineralization with gelatinization and ultrafiltration." *Journal of Archaeological Science*, 2014: 64-69.

Stanislawski, Dan. *Portugal's Other Kingdom.* Austin: University of Texas Press, 1963.

Tété Garcia, Cristina Alexandra. *Cacela-a-Velha no contexto da Actividade Marítima e do Povoamento Rural do Sudoeste Peninsular nos seculos XII-XIV*. Huelva: Universidad de Huelva, 2015.

Tykot, R. H. "Stable isotopes and diet: you are what you eat." *Proceedings: International School of Physics "Enrico Fermi"*, 2004: 433-444.

Valente, Maria João. *Report on the zooarchaeological identifications of fauna samples from Largo da Fortaleza de Cacela-a-Velha (Vila Real de Santo António).* Zooarchaeological report, Faro: FCHS-Universidade de Algarve, 2019.

Valente, Maria João, and Tété Garcia. "Food in times of Conflict: Zooarchaeology from Largo da Fortaleza in Medieval Cacela-a-Velha (Algarve, Portugal)." *From the Mediterranean to the Atlantic: themes in European zooarchaeology. The Archaeology of Animals –30 Years. In honour of Simon Davis.* Lisbon: Universidade do Algarve, 2017.

Walker Bynum, Caroline. "Fast, Feast and Flesh: The Religious Significance of Food to Medieval Women." In *Food and Culture. A reader*, by Carole Counihan and Penny Van Esterik, 245-264. New York: Routledge, 2013.

White, Tim D., Michael T. Black, and Folkens Pieter A. *Human Osteology* . Oxford: Elsevier Academic Press, 2012.

Wolf, Eric R. *Europa y la gente sin historia.* Mexico City: Fondo de Cultura Económica, 2005.

Appendix

Table 4 Analyzed faunal samples.

Sample	Taxonomy	Anatomy	Age
CVF 2	*Bos Taurus*	Mandible	Mature
CVF 3	*Cervus elaphus*	Metatarsal	Mature
CVF 4	*Ovis aries/Capra hircus*	Scapula	Mature
CVF 5	*Sus sp.*	Scapula	Probable mature
CVF 8	*Ovis aries/Capra hircus*	Phalanx 2	Mature
CVF 9	*Cervus elaphus*	Metatarsal	Mature
CVF 10	*Oryctolagus cuniculus*	Tibia	Mature
CVF 11	*Bos Taurus*	Phalanx 2	Mature
CVF 13	*Ovis aries/Capra hircus*	Mandible	Probable mature
CVF 14	*Bos Taurus*	Tibia	Mature
CVF 16	*Cervus elaphus*	Mandible	Mature
CVF 19	*Ovis aries/Capra hircus*	Calcaneum	Mature
CVF 20	*Bos Taurus*	Radius	Mature
CVF 21	*Ovis aries/Capra hircus*	Radius	Mature
CVF 23	*Gallus gallus dom.*	Coracoid	Mature
CVF 24	*Ovis aries/Capra hircus*	Metacarpal	Mature
CVF 25	*Bos Taurus*	Tibia	Probable mature
CVF 26	*Sus sp.*	Metacarpal 4	Probable mature
CVF 27	*Bos Taurus*	Femur	Mature
CVF 29	*Vulpes Vulpes*	Scapula	Mature
CVF 30	*Sus sp.*	Scapula	Mature
CVF 31	*Oryctolagus cuniculus*	Tibia	Mature
CVF 32	*Oryctolagus cuniculus*	Tibia	Mature
CVF 33	*Oryctolagus cuniculus*	Tibia	Mature
CVF 34	*Oryctolagus cuniculus*	Tibia	Mature
CVF 35	*Gallus gallus dom.*	Humerus	Mature

Table 4 (continuation)

CVF 36	*Gallus gallus dom.*	Humerus	Mature
CVF 37	*Gallus gallus dom.*	tarsus-metatarsus	Mature

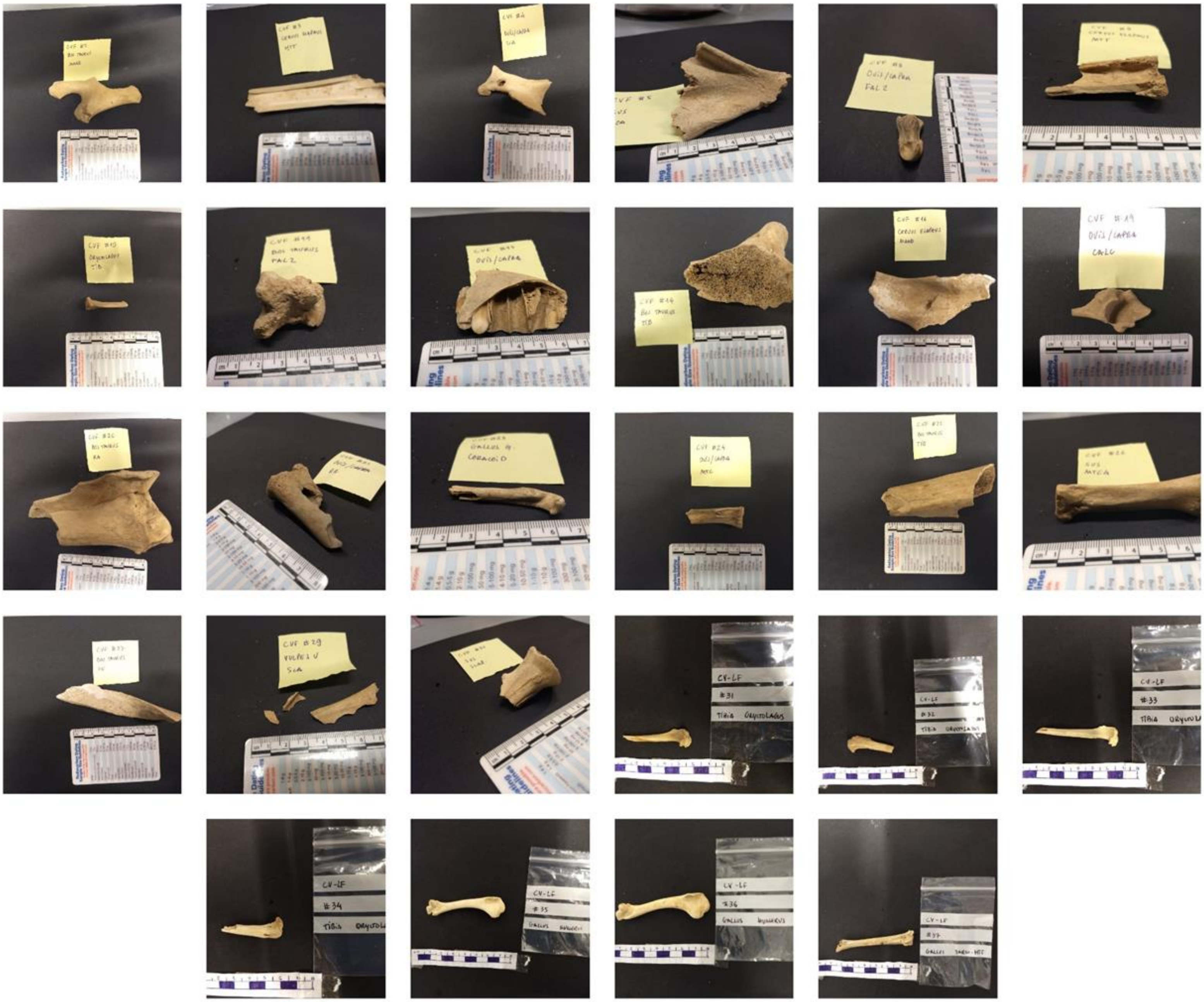

Figure 29 Faunal samples photos. From left to right are presented as they were mentioned in Table 4.

Table 5 Individuals analyzed. Diseases that were recorded in the bone tissue are presented.

Samples	Bone	Sex	Age	Health issues
H-CVPA 1	Femur	Female	20-29 years	Arthritis, periostitis in left fibula.
H-CVPA 2	Femur	Male	50-59	Arthritis, Diffuse idiopathic skeletal hyperostosis (DISH), Fractures in a rib and a vertebra. Several tooth wear present and one dental abscess
H-CVPA 3	Femur	Male	21-29 years	Schmorl nodes in thoracic vertebrae.
H-CVPA 4	Femur	Probably Male	sub-adult (14-16)	Two dental caries and two linear hypoplasia (HLED).
H-CVPA 5	Femur	Male	20-30	Lesions in the yellow ligaments of the vertebrae. Lumbar hernia. *spina bifida*. Periosterases reactions. 3 HLED.
H-CVPA 6	Femur	Male	19,4 ± 2,6	
H-CVPA 9	Femur	Male	35-39	Arthritis, lesions in Achilles tendon. Lesions in the yellow ligaments of the vertebrae.
H-CVPA 10	Femur	Female	50-60	Arthritis. Right tibia exhibits an infectious reaction.
H-CVPA 11	Humerus	Male	40-49	Arthritis. *Cribra orbitalia* Injuries in the yellow ligaments of all thoracic vertebrae. 2 teeth *ante mortem* and 2 dental caries. Cribra orbitalia
H-CVPA 13	Femur	Male	50-59	Arthritis. Eight HLED and six teeth lost *ante mortem*, periodontopathy and one dental caries.
H-CVPA 14	Femur	not estimated	sub-adult (14-16)	*spina bifida*. Fossa romboide.
H-CVPA 15	Femur	probably Female	Sub-adult	
H-CVPA 17	Femur	Male	25-29	Injuries in the yellow ligaments vertebrae with five Schmorl's nodes. Two HLED. Dental crowns destroyed before death.
H-CVPA 18	Femur	Male	45-49	Arthrogenic injuries with two Schmorl's nodes. The right ulna

Table 5 (continuation)

				has a Parry's fracture. Benign Neoplasm lesion. Mandibular teeth present strong tooth wear. 11 HLED.
H-CVPA 20	Femur	Female	not estimated	Enthesopathies.
H-CVPA 21	Tibia	Male	40-49	S*pina bifida.*
H-CVPA 22	Femur	Male	30-39	Arthritis. One Schmorl's node. Enthesopathies. A strong and active infection in left tibia and left fibula. Fracture in right ulna. 9 teeth lost *ante mortem.*
H-CVPA 23	Femur	Male	21-29	5 Schmorl's nodes. Fracture in clavicle a rib. 4 HLED and 4 teeth *ante mortem*.
H-CVPA 25	Femur	Female	40-44	Arthritis. Schmorl's nodes Injuries in the joints of both patellae. Two abscess, 4 teeth lost *ante mortem,* One dental caries, pronounced tooth wear and 1 HLED.
H-CVPA 26	Femur	Male	40-44	Arthritis. 2 Schmorl's nodes. Tibias and left fibula evidence an infectious reaction. Fracture in right clavicle, right fibula and in a rib. Spondylosis in vertebra L5. *Spina bifida.* 18 teeth lost *ante mortem*.
H-CVPA 27	Femur	Male	40-49	1 tooth lost *ante mortem* and 1 dental caries.
H-CVPA 28	Femur	Female	>30	Injuries in yellow ligaments and two Schmorl's nodes. 4 teeth lost *ante mortem*. Severe tooth wear.
H-CVPA 29	Femur	Female	>50	2 ribs fractured. Brucellosis.
H-CVPA 31	Femur	Male	50-59 years	Arthritis. 7 Schmorl's nodes. Depression caused by a hit with a sharp pointed object in the cranium. 5 teeth lost *ante mortem,* 1 abscess and 2 dental caries.

Table 5 (continuation)

H-CVPA 32	Clavicle	Probably Male	18-20	1 tooth lost *ante mortem*.
H-CVPA 33	Femur	Male	50-59	Arthritis. Enthesopathies. 7 teeth *ante mortem*.
H-CVPA 34	Femur	Female	25-29	Injuries in the ligaments and tendons of tibias, right femoral bicep, in the adductor hallucis of the left calcaneus and in Achilles tendon. Fracture in fibula and a left rib. 1 HLED and 4 teeth lost *ante mortem*.
H-CVPA 35	Fibula	Male	>20	Active periostitis in the moment of the death of the individual.
H-CVPA 36	Femur	Male	>40 years	Arthritis. Injury in the ligament of the right patella. Fracture in a phalanx of the left hand. 6 teeth lost *ante mortem*.
H-CVPA 37	Femur	Female	30-34	Arthritis. 5 Schmorl's nodes. Right tibia and fibula presented an infectious reaction.
H-CVPA 39	Femur	Male	50-59 years	Arthritis. 3 Schmorl's nodes. Enthesopathies. Fractures in left ulna and fibula. 1 HLED and 3 dental caries.
H-CVPA 41	Femur	not estimated	14-16	
H-CVPA 44	Femur	Male	50-59	Arthritis. Schmorl's nodes. 6 teeth lost *ante mortem*.
H-CVPA 45	Femur	Male	30-34	Depression in the frontal bone of the cranium probably caused by a traumatic event. 8 teeth lost *ante mortem,* 1 abscess, 1 fracture in the second mandibular molar and 2 HLED.
H-CVPA 46	Tibia	Probably Male	>19	
H-CVPA 47	Femur	Male	50-59	L5 vertebra connected with the sacrum.
H-CVPA 48	Femur	Female	24-29	Arthritis. Injuries in the yellow ligaments of vertebrae. 1 abscess and 5 HLED.
H-CVPA 49	Femur	Male	22-69	Arthritis. 7 HLED.
H-CVPA 50	Femur	Female	40-44	L5 vertebra connected with the sacrum.

Table 5 (continuation)

				8^{th} left rib has a fracture. 3 teeth lost *ante mortem* and 20 HLED.
H-CVPA 53	Femur	Male	not estimated	
H-CVPA 55	Femur	Male	50-59	Fractures in right fibula, a phalanx and 2 ribs. Traumatism on the cranium. Severe tooth wear. 1 abscess, 1 tooth lost *ante mortem,* 1 dental caries.
H-CVPA 56	Femur	Male	40-49	Arthritis. S*pina bifida*. 1 fracture in the third left metatarsal. 5 ribs present a layer of bone that is a result of an injury caused by an infectious condition in the lungs or guts. It could be Peritonitis. 2 dental caries.

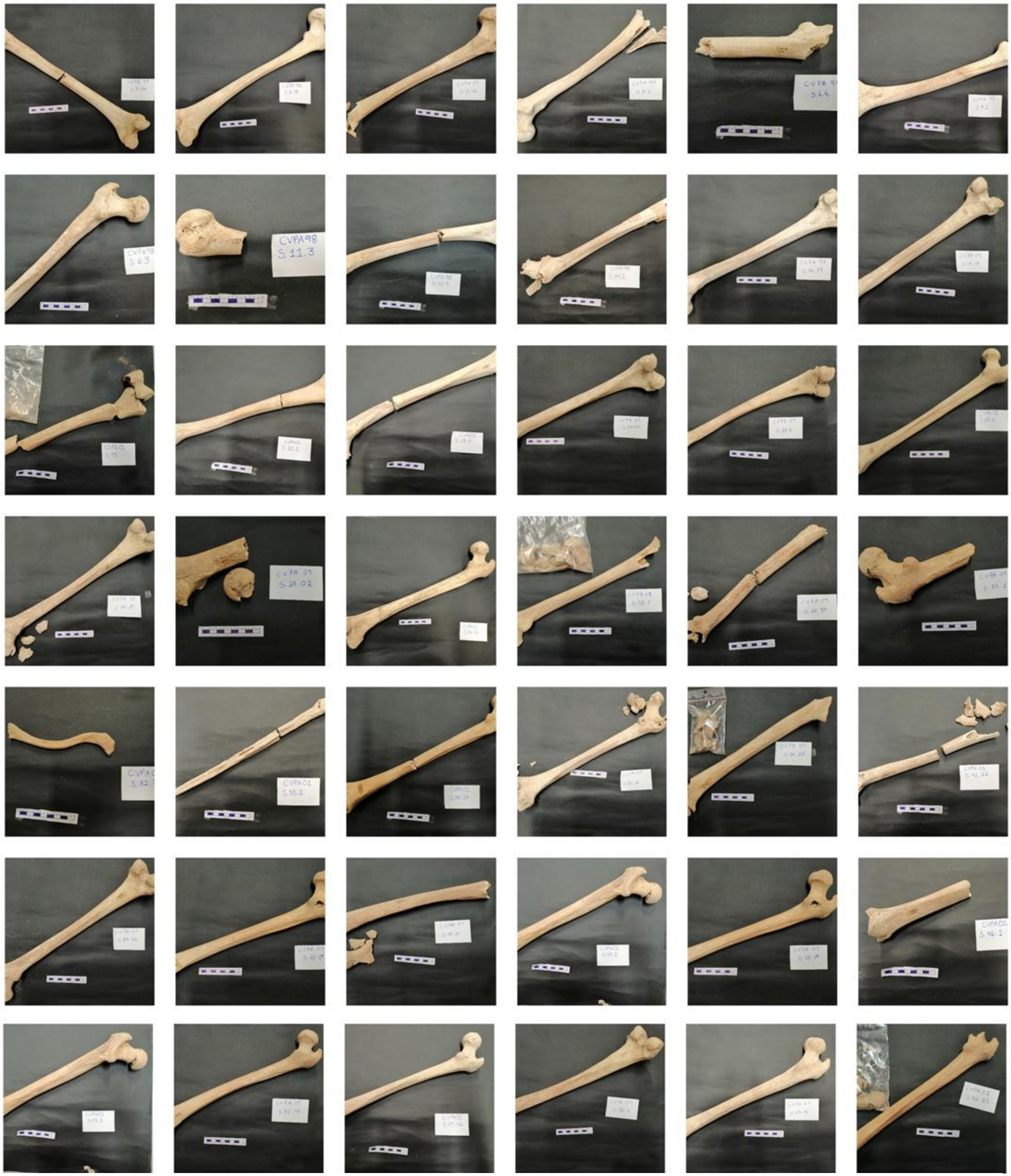

Figure 30 Human sample photos. From left to right are presented as they were mentioned in Table 5.

Table 6 Faunal and human samples used for sulfur analysis

Faunal samples for Sulfur analysis		**Human Samples for Sulfur analysis**
N° Sample	**Taxonomy**	**N° Sample**
CVF 2	*Bos Taurus*	H-CVPA 1
CVF 4	*Ovis aries/ Capra hircus*	H-CVPA 2
CVF 8	*Ovis aries/ Capra hircus*	H-CVPA 5
CVF 9	*cervus elaphus*	H-CVPA 6
CVF 11	*Bos Taurus*	H-CVPA 9
CVF 13	*Ovis aries/ Capra hircus*	H-CVPA 10
CVF 16	*cervus elaphus*	H-CVPA 13
CVF 19	*Ovis aries/ Capra hircus*	H-CVPA 14
CVF 20	*Bos Taurus*	H-CVPA 21
CVF 21	*Ovis aries/ Capra hircus*	H-CVPA 22
CVF 23	*Gallus gallus dom.*	H-CVPA 25
CVF 24	*Ovis aries/ Capra hircus*	H-CVPA 26
CVF 25	*Bos Taurus*	H-CVPA 32
CVF 27	*Bos Taurus*	H-CVPA 33
CVF 29	*Vulpes vulpes*	H-CVPA 34
CVF 31	*Oryctolagus cuniculus*	H-CVPA 36
CVF 32	*Oryctolagus cuniculus*	H-CVPA 37
CVF 33	*Oryctolagus cuniculus*	H-CVPA 39
CVF 35	*Gallus gallus dom.*	H-CVPA 48
CVF 37	*Gallus gallus dom.*	H-CVPA 49
		H-CVPA 50
		H-CVPA 53
		H-CVPA 56