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RECONSTRUCTING PAST POPULATIONS' BEHAVIORS DIET, BONES AND ISOTOPES IN THE MEDITERRANEAN

ESKİ TOPLULUKLARIN YAŞAM BİÇİMLERİNİN TANIMI AKDENİZ HAVZASI'NDA BESLENME, KEMİKLER VE İZOTOPLAR

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ABSTRACT

Beyond the natural objective to feed individuals, food acquisition, consumption and preparation reflect cultural specificities, in which biological (e.g., sex, age), socioeconomical (e.g., working class vs. ruling class), religious, or medical aspects interfere. Thus, through the dietary research questions tackled in archeology and archeo-anthropology provide insights into past populations' behaviors. Analyzing human diet through space and time provides a comparative and diachronic view into the richness of human practices. This article aims to review human dietary studies focusing specifically on stable isotope analyses carried out from the Neolithic to the Middle Ages in the Mediterranean region, an area well known as a biodiversity hotspot. Published studies as well as personal research are part of this review. However, it is a non-exhaustive presentation of this important research topic, yet it aims to provide a summary on both human paleodiet and state-of-the-art research on this subject.

ÖZET

Beslenme insanların doğal gereksinimidir; bu doğal sürecin yanı sıra, biyolojik (örn. cinsiyet, yaş), sosyoekonomik (örn. egemen sınıf karşısında işçi sınıfı), dinî ya da tıbbî etmenler de, besinin elde edilmesi, tüketilmesi ve hazırlanması sürecinde etkilidir. Bu bağlamda beslenmeyle ilgili olarak arkeoloji ve arkeo-antropolojinin yönlendirdiği soruların irdelenmesi, geçmiş toplumların yaşam biçimlerini anlamamızı sağlar. Beslenme alışkanlıkları zaman ve bölge boyutlarıyla karşılaştırmalı ve süreçsel olarak ele alındığında, toplumların beslenme alışkanlıklarında ne denli zengin bir çeşitliliğin olduğu görülecektir. Bu çalışma, önemli bir bio zenginliğe sahip olan Akdeniz Bölgesi'ndeki Neolitik dönemden Ortaçağ'a kadar olan süreçte beslenme alışkanlıklarıyla ilgili verilerin elde edilmesinde stabil izotop analiz yöntemiyle yapılan çalışmaların genel değerlendirmesini içermektedir. Bu çalışma bir yanda önceki çalışmaların yayın taramasına, öte yanda kişisel olarak yapmış olduğumuz çalışmalardan elde edilen verilerin sonuçlarına dayanmaktadır. Beslenme konusu son derece zengin bir içeriğe sahiptir; burada ayrıntılara girmeden daha önce yapılmış olan nitelikli araştırmaların sonuçları özetlenmiş ve kişisel katkılarımız bir bütün olarak sunulmaktadır.

INTRODUCTION

Beyond the natural objective to feed individuals, food acquisition, consumption and preparation reflect cultural specificities, in which biological (e.g., sex, age), socioeconomical (e.g., working class vs. ruling class), religious, or medical aspects interfere (e.g. see Flandrin and Montarani 1996). Thus, dietary research questions tackled in archeology and archeo-anthropology provide insights into past populations' behaviors. Analyzing human diet through space and time provides a comparative and diachronic view into the richness of human practices.

DIET AND ARCHEOLOGICAL REMAINS

Plant and Faunal Remains

Discussions of diet and subsistence economy of past human populations are primarily based on plant and faunal archeological remains. Archeobotany and zooarcheology have widely improved their surveying and analysis methods to provide detailed data on species determination and ratios (Carrère and Forest 2003; Vigne 2005), hunting, herding and domestication (Vigne 1993; Willcox 2003; Pearson et al. 2007), seasonality of slaughter (Gourichon 2004; Helmer et al. 2005) and birth (Balasse et al. 2003), growth patterns (Zazzo et al. 2006), climatic changes (Parker et al. 2004), etc. These studies give intra- and intersite information about human groups/populations, which can potentially be specialized (e.g., agriculture, hunting), and provide also a diachronic synthesis.

Human Remains

Human health status is a good indicator of dietary habits. In archeological context, bone and teeth can provide such information if and when pathologies linked to diet left traces on them (Roberts and Manchester 2007). Oral diseases perturbation growth, such as caries, calculus and periodontal damage, as well as enamel hypoplasia can be favored by and developed because of food intake (e.g. carbohydrates for caries, alkaline foodstuffs for calculus, and diet disruption for hypoplasia) (Goodman and Rose 1991; Aufderheide et al. 1998; Lieverse 1999; Esclassan et al. 2009). Dietary problems can also cause growth breaks, called Harris' lines, visible on bones through radiography. Enamel hypoplasia and Harris' lines are non specific stress markers, so not necessarily induced by food problems but potentially increased by them. Moreover, cribra orbitalia and cranial porotic hyperostosis, visible as widespread bone porosities in the orbits and on the cranial vault, can be caused by iron as well as vitamins B12 deficiencies in relation to infectious diseases, poor sanitation and/or malnutrition (especially meat/animal products deficiencies) (Stuart-Macadam 1985; Aufderheide et al. 1998; Walker et al. 2009). Other metabolic disorders can cause bone damage. Rickets and osteomalacia, which result in abnormal bone calcification due to vitamin-D deficiency, are visible mainly on the lower limb long bones, which are deformed and bowed (Aufderheide et al. 1998). In the same category, scurvy, linked to vitamin-C deficiency, leads to bone tissue disorders and hemorrhages, and is visible for example as tooth loss or as the ossification of subperiosteal hemorrhages (Aufderheide et al. 1998).

One other approach is human paleoparasitology. This discipline aims to reconstruct the history of parasitism and the evolution of relationships between host (e.g., humans) and parasites. It provides information on human as well as animal parasitological diseases, but also on diet and cooking modes, as well as the surrounding environment and hygienic behavior (Harter and Bouchet 2002; Carvalho Goncalves et al. 2003). Some parasites enter the human body via infected food, as caprid, pig meat or fish. Paleoparasitological material is mainly found in archeological contexts in the form of chitin wrapping remains of parasite eggs found in mummies, but also in organically rich contexts such as burial soils (e.g., near the trunk and pelvis of the deceased), coprolites, latrines, dwelling soils, etc. (Bouchet 2002; Harter and Bouchet 2002). In the Near East for example, the analysis of paleoparasitological material from the Neolithic sites of Shillourokambos and Khirokitia (Cyprus) have yielded evidence, among others parasites, of Taenia eggs, linked to the consumption of raw/poorly cooked beef and pork meat (Le Mort 2007). Finally, certain exceptional cases like mummification, give unique data on food remains through stomach content, as evidence of the last meal (Roberts and Manchester 2007).

DIET AND ISOTOPES

Methodology

Isotopes are variations of chemical elements having a different number of neutrons and so a different mass. Isotopes are considered 'stable' if they are not radioactive. Thus, when archeological remains are well preserved, the stable isotope ratio measured reflects the ratio originally present during the life of the organism. Human remains found in archeological context are often in skeletal form, and more rarely as preserved soft tissue (e.g., hair, nails, skin, etc). Bone and tooth are composed of both organic and inorganic matter. The organic matter is almost only collagen protein (ca. 90% of all organic matter), and the mineral part is mainly hydroxyapatite (calcium phosphate mineral; ca. 70% of all mineral matter). These components have specific stable isotope ratios, which reflect their chemical formation and their photosynthetic pathway (Ambrose and Norr 1993). Collagen records carbon, nitrogen, and sulphur isotope ratios (Hydrogen and oxygen are also studied in collagen but more rarely, Kirsanow et al. 2008), which are linked to protein consumption (Ambrose 1990; Ambrose and Norr 1993; Richard et al. 2001). In the bone and tooth (enamel) mineral portion, carbon, oxygen, strontium, calcium isotope ratios, and some others as lead are recorded. These are linked to the main diets and drinks (Ambrose 1990; Ambrose and Norr 1993; Bentley 2006; Reynard et al. 2011). A stable isotope ratio is expressed as δ, with a measurement unit in per mil (‰), and measured thanks to an IRMS (Isotope Ratio Mass Spectrometer). The measurement and calculations follow a specific equation for each isotope. For example, the equation for carbon is $\delta 13C = [[(13C/12C\ sample)/(13C/12C\ standard)] - 1] \times 1000$. The international standard is specific to each element according to the IAEA (International Atomic Energy Agency) recommendation.

Stable isotope ratios in collagen inform mainly on the position in the trophic, the environment exploited and mobility. Those from the mineral component give data mainly on mobility, climate, seasonality, dairy consumption and a part of the diet (carbohydrates and fat).

Bone and tooth have distinctive growth patterns and tissue formation (Hillson 1996; Scheuer and Black 2000). Human bone is modeled and remodeled all along an individual's life with a turnover assessed at ca. 10-15 years (Ambrose 1990), but the rate of turnover depends strongly on the age and health status. On the other hand, human teeth (crown and root) are formed at specific times during infancy and childhood, according to a quite precise growth calendar (Hillson 1996). To sum up, chemical elements and dietary/mobility information recorded in bone are linked to the last years of an individual's life, as opposed to the data recorded in teeth which are linked to the period of early tissue formation (i.e., mainly infancy and childhood).

This paper mainly focuses on C and N stable isotope methods and case studies. However, even in the Mediterranean, many studies have been conducted using other elements and/or a combination of some of them. The study of δ13C and δ15N in human bone collagen lets us reconstruct the type of environment from which individuals draw their resources (e.g., marine vs. terrestrial; e.g. Schoeninger and DeNiro 1984) and their place in the food chain (e.g., herbivore, carnivore; e.g. Bocherens 1997) (Fig. 1). Nevertheless, these analyses are not able to distinguish different protein sources issued from the same species (e.g., meat proteins vs. milk proteins). In order to reconstruct human dietary behavior, the study of δ13C and δ15N in animal bone collagen is essential to characterize the isotopic signal range of known diet species (e.g., plant consumers) for each specific archeological environment (e.g., Bösl et al. 2006; Herrscher and Le Bras-Goude 2010). Moreover, due to numerous studies on living mammals (e.g., Ambrose and Norr 1993; Sponheimer et al. 2003), including humans (e.g., Minagawa 1992; O'Connell and Hedges 1999), the relative isotopic variability between different types of human diets for a specific environment is well described. Different techniques can be applied to extract bone and tooth collagen (e.g., Longin 1971; Bocherens 1992; Richards and Hedges 1999) depending on the need and the will to use powder or entire samples, to use ultrafiltration or not, etc. These methods are based on collagen solubilization. Percentages of C and N as well as isotopic values are measured from 0,5 mg of freeze-dried collagen and analyzed with an IRMS and elemental analyzer (EA). The element composition (C and N wt%), C/N ratio and collagen yield assess, on the one hand, the preservation of collagen extracted, and, on the other hand, the potential of the materials for radiocarbon dating and paleodietary studies (Bocherens et al. 2005). Only then are stable isotope (13C/12C: δ13C and 15N/14N: δ15N) measurements conducted on human and animal bone collagen in order to evaluate protein intake.

Materials and Sampling

As explained above, bone and tooth have their own process of tissue formation and growth pattern. This provides isotopic data from different periods of an individual's life. Thus, the anatomical sample is chosen according to the aims and objectives of the study, and a multi-sampling procedure can be conducted for a specific research question (e.g., breastfeeding, weaning; Balasse 1999; Herrscher 2001).

Unlike the DNA restrictive sampling procedure, the selection of samples for stable isotope analysis can be done directly in the field or on an osteological collection without contamination problems. In the field, samples can be collected (after all the necessary archeological and anthropological records have been completed) and stored in labeled 'Ziplock' bags with all the relevant information. Samples should be stored in a dry environment in order to avoid fungus development on bone and thus damage to the organic matter. On an osteological collection, the sampling follows the same procedure; however, if a consolidating solution or glue was used on the remains, the nature (chemical composition) and time of its use should be documented. Indeed, the presence of old coating on skeletal material is not rare and sometimes not visible anymore. An analysis conducted on old consolidated materials demonstrated the presence of exogenous collagen in the coating (probably an animal collagen glue) of human bones at the beginning of the 20th century (Müller et al. 2009; Goude et al. accepted manuscript). This exogenous material is problematic for all biochemical studies (including stable isotope, radiocarbon dating and perhaps DNA). However, being extremely hydrophilic and having a weak penetration into the bone, it seems possible to remove it without contamination, by means of surface and internal deep cleaning of the bone (e.g., sandblaster abrasion). At the time being and considering the lack of information on this problem, further studies are being carried out (personal work in process).

Interpretation of stable isotope data is also closely linked to environmental and archeological contexts. For this reason palaeodietary studies should ideally be conducted on well documented materials. Biological parameters like age-at-death, sex, stature, health conditions, as well as social information like grave goods and/or funeral practices are essential to the understanding of isotopic variation and differences between and within populations.

DIET IN THE MEDITERRANEAN REGION: SOME CASE STUDIES

The Mediterranean region has been widely researched by archeologists and anthropologists for decades, and the application of biochemical methods on archeological remains from this region occurred quite early in the discipline's history. One of the earliest works was conducted by Francalacci (Francalacci and Borgognini Tarli 1988; Francalacci 1989) in Italy. A lot of studies have focused on Prehistoric periods, especially in the Near East where questions on the origins of plant and animal domestication as well as dietary strategies are crucial. Moreover, the Upper Paleolithic and Mesolithic-Neolithic transition as well as changing food consumptions of costal populations were, and still are, favored research areas (e.g., Richards et al. 2001; Pettitt et al. 2003; Garcia Guixé et al. 2006; Lai et al. 2007; Mannino et al. 2008). Antiquity and the Middle Ages have been less studied, but research topics on diet, weaning and mobility have increased over the past few years (e.g., Bourbou and Richards 2007; Al Bashaireh et al. 2010).

The following review presents a diachronic synthesis, from the Neolithic to the Middle Ages, of several studies conducted in around the Mediterranean, focusing on C and N stable isotope analyses, and also on personal research (Fig. 2). Notwithstanding, this review is not an exhaustive topical outline of studies carried out in this area, and thus, more bibliographical references are proposed in the conclusion.

PRE- AND PROTOHISTORY

Prehistoric and protohistoric periods have been those preferentially studied in the Mediterranean. Some studies on the Upper Paleolithic, as well as on the Mesolithic, were conducted in Spain and Italy (Pettitt et al. 2003; Garcia Guixé et al. 2006; Mannino et al. 2008; Garcia Guixé et al. 2009; Craig et al. 2010), and more rarely in France (Pouydebat 1997; Bocherens 1999; Vigne 2004). These studies mainly show a diet widely based on terrestrial animal protein, with some mixed patterns (fish and meat) for a few individuals within each time period and place.

The Neolithic is probably one of the most studied periods throughout the Mediterranean (Tykot et al. 1999). At that time, humans start to domesticate their environment; agriculture and herding develop, first in the Near East, and then spread out to the rest of the Mediterranean basin. This new way of life and foodstuff economy offer populations a more diversified choice and more abundant food. From this time on, human foodstuff acquisition is dictated by various cultural choices in combination with climatic and environmental changes along time. Stable isotope analysis was used in this context in order to determine, among other things, (1) the environment exploited, especially along the shore (marine vs. terrestrial food resources), (2) the type of food production (agriculture vs. herding), and (3) intra- and inter-population differences, related to biological/social distinctions. In Turkey, Lösch et al. (2006) have analyzed the Pre-Pottery Neolithic B (PPNB) site of Nevalı Çori (ca. 8500-7500 BC), and established a mixed diet (meat and vegetal), but mainly based on plant protein intake and probably the consumption of pulses by both humans and animals (Lösch et al. 2006). This study has demonstrated that the place of humans in the trophic chain is not so high, unlike previous assumptions. A mixed diet is also proposed by Richards et al. (2003), on the Turkish site of Catalhöyük (ca. 7600-5500 BC). However, contrary to Nevalı Çori, animal protein intake seems more important and mainly based on sheep/goat meat and milk (Richards et al. 2003). Moreover, Catalhöyük data support the consumption of C4-plants by some humans and animals, a resource not highlighted until now (Richards et al. 2003). In Cyprus, a few human samples were analyzed on the site of Khirokitia indicating a terrestrial-based diet (7th mill. BC; Lange-Badré and Le Mort 1998). However, the Neolithic Cypriot material shows very poor collagen preservation with a modified amino acid profile for most of the sample (Lange-Badré and Le Mort 1998), thus data are difficult to interpret. Further west, palaeodietary studies were conducted in Greece (Papathanasiou 2003; Bourbou and Richards 2007; Richards et al. 2008; Triantaphyllou et al. 2008; Petroutsa et al. 2009; Vika 2009; Petroutsa and Manolis 2010) mainly on Neolithic and Bronze Age populations. Six Neolithic sites along the shore and inland have been studied by Papathanasiou and data were combined with health status information (Papathanasiou 2003). This study supports a general trend observed in different regions of Europe, i.e., a subsistence economy turned toward agriculture and herding, even close to the sea. Indeed, except for some individuals, the Greek Neolithic diet seems to have been widely based on terrestrial resources, especially in the inland sites, where less animal protein intake, compared to the coastal human groups, is noticed (Papathanasiou 2003). The author suggests a possible correlation between the poor health status recorded on human skeletons (e.g., high frequency of cribra orbitalia and porotic hyperostosis) and a little diversified diet, mainly based on vegetal protein (Papathanasiou 2003). A terrestrial based diet is also mentioned by Petroutsa and Manolis (2010) and Triantaphyllou et al. (2008) in Greek Bronze Age populations without any significant amount of aquatic resources, but with animal protein intake varying between individuals. This pattern is confirmed by Vika (2009) in spite of individuals' mobility and the possibility to exploit different environments (i.e., coast and inland; Vika 2009). The lack of marine resources in coastal populations' diets is also visible in southern France, as well as in Spain (McClure et al. 2011), even at the beginning of the Neolithic (Goude 2007; Le Bras-Goude 2008). Neolithic French and Italian groups studied (ca. 5500-3400 BC) show that in Eastern Provence and in Liguria, there is obviously a quite homogeneous dietary pattern all along the Neolithic, with a subsistence economy strongly turned toward herding for meat and milk (Le Bras-Goude et al. 2006b, 2010a, 2010b). Some individuals differ, with less animal protein consumption, but these results are often linked to specific conditions or status (e.g., trauma or disease) (Le Bras-Goude et al. 2006a). Unlike Eastern Provence, Middle Neolithic humans in the southwest appear to have had a diet with more varied animal protein intake (1) according to the area (Le Bras-Goude et al. 2006c; Herrscher and Le Bras-Goude 2008, 2010;

Le Bras-Goude and Claustre 2009) and (2) according to the social/funeral context (Le Bras-Goude et al. in press). Biological data, as sex, age-at-death, or stature, do not correlate with stable isotope data. The isotopic variability observed, especially for the Middle Neolithic, should be linked to other factors (e.g., social distinctions) not clearly highlighted by archeological evidence (Le Bras-Goude et al. 2009). Furthermore, in Spain at Cova de la Pastora, McClure et al. (2011) observe no significant marine resource consumption among humans and a homogeneous terrestrial diet all along the period studied (from the late Neolithic to the Bronze Age; ca. 3800-1500 BC; McClure et al. 2011; results also observed in the study of Lai et al. 2007, on Sardinian populations dated from 4th to 2nd BC).

Concerning the Chalcolithic and the Bronze Age, very few studies have been conducted in the Near East. Recent data were difficult to obtain on Cypriot material because of poor preservation of the organic matter. Yet they gave information on (1) sampling strategy for further studies (e.g., location and anatomical region), and (2) on possible paleodietary differences between Chalcolithic and Bronze Age individuals (Goude et al. in press). In Jordan, Al-Shorman (2004) studied the enamel δ13C of several Middle/Late Bronze Age individuals buried in three different tombs, and demonstrated that their diet was mainly based on C3 plants, as mentioned also by King (2001) for later periods in the same area (King 2001 in Al Bashaireh et al. 2010). Finally, a diachronic study conducted in Egypt on Predynastic and Dynastic individuals (ca. 5500-343 BC) also revealed a diet based on resources coming from a C3 environment (meat and vegetal), and the absence of consumption of C4 plants (Thompson et al. 2005). However, authors also pinpoint the probable contribution of freshwater fish as a protein source, and no statistical difference is witnessed through time.

Figure 3 presents a comparison of a stable isotope dataset from early Neolithic populations in the eastern (Turkey) and the western (France) Mediterranean. This comparison shows two important results: (1) the populations on these opposite sides of the Mediterranean basin had distinct dietary patterns, and (2) the analysis of faunal remains on each site was essential to understanding and comparing the sites between us. Although the two Turkish groups have different food resource acquisition strategies, they seems to exploit vegetal (both C3 and C4 plants as well as pulses) much more than in Eastern Provence (France), where an important consumption of animal protein is suggested. Indeed the isotopic relationship between faunal and human remains for each site is different, particularly for nitrogen (Δδ15Nhuman-animal: Nevalı Çori +0.4‰; Çatalhöyük +2.4‰; Pendimoun +3.6‰, excluding a specific case, the data is also valid for the following Neolithic period in Eastern Provence and Liguria), witnessing different dietary strategies for each region, that could be linked to the beginnings of agriculture at this time in the Near East, and to the settling of "neolithized" human groups much later in the West.

ANTIQUITY AND THE MIDDLE AGES

Even if dietary diversity is clearly highlighted in the Antique world, terrestrial resources still obviously dominate the protein diet in the Mediterranean. Indeed, carbon and nitrogen stable isotope analyses conducted on teeth, in Jordan on the site of Natfieh (1st BC to 4th AD), bear witness to an identical dietary pattern throughout childhood, based on terrestrial animal protein, which the author interpreted as reflecting similar social status (Al Bashaireh et al. 2010). While few studies were conducted on the Near East, major work in the Mediterranean was conducted by Prowse et al. on the famous site of Isola Sacra Necropolis (NIS, 1st-3rd AD). More than 100 individuals were analyzed for dietary profile (on collagen and apatite), as well as over 50 juveniles for transitional feeding and weaning patterns. The authors clearly demonstrate different food consumption between adults and children and also within the adult group (Prowse et al. 2005). Diet is mixed with protein coming from aquatic (fish and possibly garum) and preferentially terrestrial resources. The dietary pattern seems related to age, and also sex, with higher nitrogen stable isotope values recorded in older men, witnessing a more important consumption of marine foods (Prowse et al. 2005). These results could show a relationship between marine food consumption and high status and power. The contemporaneous site of ANAS (Azienda Nazionale Autonoma delle Strade), more inland, indicates a more terrestrial protein based diet, in accordance with its location. However, the ANAS dietary profile also supports the presence of possible migrant workers (coming from the coast) (Prowse et al. 2004). Moreover, at NIS, infant transitional feeding is recorded at the end of the first year and complete weaning around two years of age (Prowse et al. 2008). Further south, in the site of Velia (1st-2nd AD), the diet is slightly different compared to NIS. Humans acquire their resources mainly from the terrestrial environment, with a cereal based diet (Craig et al. 2009). As for ANAS, some specific individuals differ from the rest of the group, with marine protein intake. No correlation between age-at-death, burial context and isotopic data was evident. However, and once again, mainly male subjects seem to have access to fish resources (Craig et al. 2009). Similar observations were recorded on the site of Lucus Feroniae (LFR, 1st-3rd AD), a cemetery including low status people as slaves and war veterans. Carbon and nitrogen stable isotope data highlight at LFR a diversified diet, mainly based on terrestrial resources, with only few individuals consuming fish or marine resources (Tafuri et al. in press). The dietary profile of LFR is closer to ANAS and Natfieh than NIS, supporting the importance of the site location and close environment in dietary choices. On the other hand, fish consumption seems to be more important in the southern Mediterranean. Figure 4 presents a comparison between carbon and nitrogen stable isotope data of all roman sites previously mentioned, as well as data from Leptiminus (Tunisia, 4th-5th AD). Isotopic values recorded at Leptiminus witness a large consumption of fish/marine foodstuffs by this population, mixed with terrestrial plant resources (Keenleyside et al. 2009). While previous studies, in the northern Mediterranean, minimize the exploitation of the shore ecosystem during Antiquity, the Leptiminus data give a new insight on foodstuff economy. More data on the African coast should help to understand whether or not diet differed from one coast to another, and if it was linked to social, economical or environmental context.

Late Antiquity and Medieval periods testify of more different dietary patterns along time. A comparison between the roman site of LFR and the Lombard one of la Selvicciola (7th AD, Latium, Italy), clearly indicate a more homogeneous diet entirely land based for the Lombard population (Tafuri et al. in press). An analysis, conducted by Salamon et al. on two medieval sites in Italy (6th and 15th AD; Salamon et al. 2008), demonstrates that a dietary shift occurred in Medieval times in Italy, obviously correlated to a trade opening between Atlantic and Mediterranean regions, around the 14th century (Salamon et al. 2008). Indeed, as for La Selvicciola, the subsistence economy of Castro dei Volsci (6th AD) is based on land foodstuffs with a variation of animal protein intake between individuals, while a significant amount of fish resources seems to contribute to the diet of subjects living in Rome during the 15th century (Salamon et al. 2008).

CONCLUDING REMARKS

The studies presented here give an overview of palaeodietary behavior from the Neolithic to the Middle Ages in the Mediterranean region from the standpoint of biological anthropology, and particularly through the use of stable isotope analysis. To sum up more than 10.000 years of human practices, even along a limited area, is almost impossible because the relationship between humans, their environment and their beliefs is so rich and varied. Notwithstanding, some trends and aspects can be evaluated. Through time, the consumption of marine resources seems to reflect a quite complex process, lead more by economic and "religious" aspects than by location or social arguments. The influence of hierarchy or status on food consumption becomes more evident during historical times than in prehistoric ones. In the Mediterranean some places should be further investigated to give a better understanding of this complex scheme. Unfortunately, the material preservation (specifically of organic matter in the Near East and North Africa) limits some approaches. Finally, it seems important to stress, on the one hand, the fact that pertinent palaeodietary behavioral studies must include multi-disciplinary approaches, and, on the other hand, that the data presented are not exhaustive. Thus, further information on periods, studies and/or isotope analysis in the Mediterranean can be found in the following literature: on Neanderthal mobility in Greece: Nowell and Horstwood 2009; Richards et al. 2008; on Greek mobility during Protohistory: Nafplioti 2008; Garvie-Lok 2009; on millet consumption in Italy: Tafuri et al. 2009; on fish in Turkey: Dufour et al. 2007; on pottery residue analysis: Gregg et al. 2009; on historical studies: Fornaciari 2008; Rutgers et al. 2009; and on faunal aspects: Wiedemann et al. 1999.

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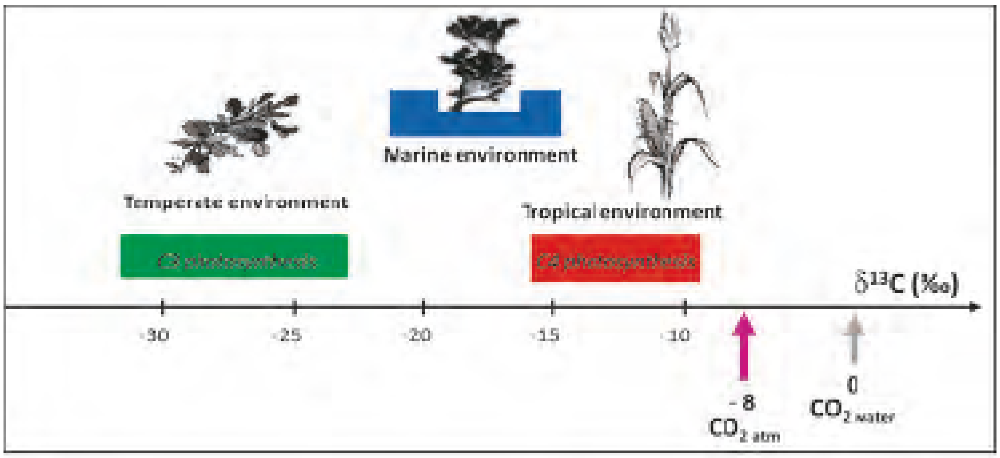

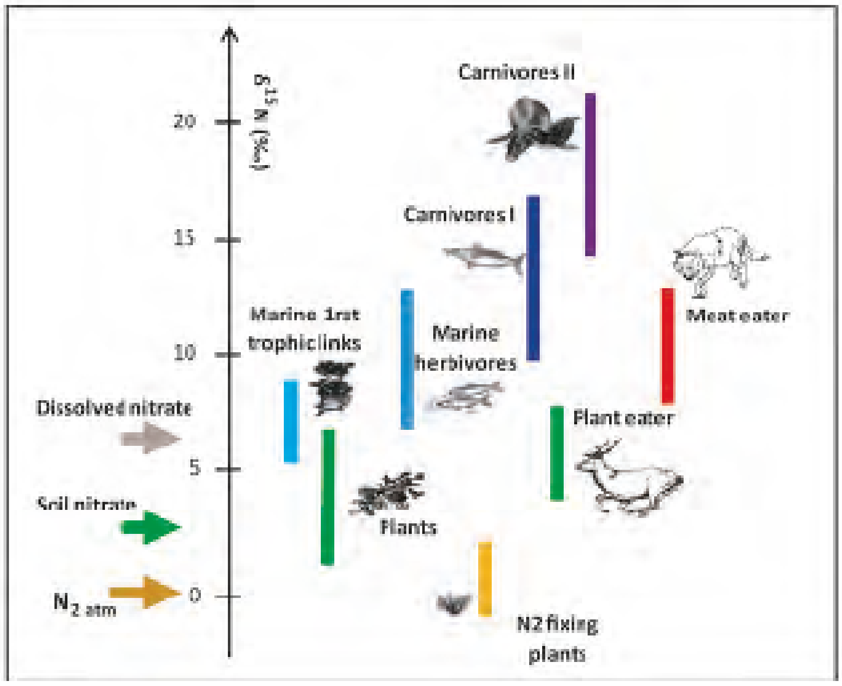

Fig. 1 - Theoretical carbon and nitrogen stable isotope variation according to environmental and trophic levels (data from Smith and Epstein 1971; Schoeninger and DeNiro 1984; Bocherens 1997).

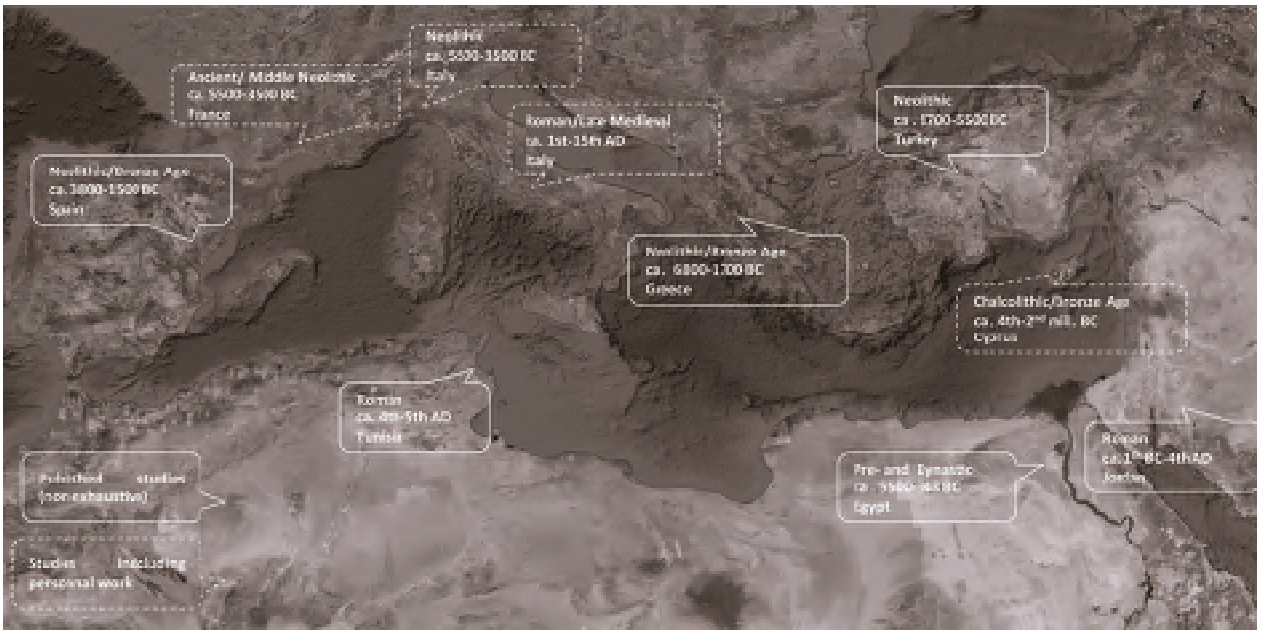

Fig. 2 - Distribution of Mediterranean studies reviewed in the text.

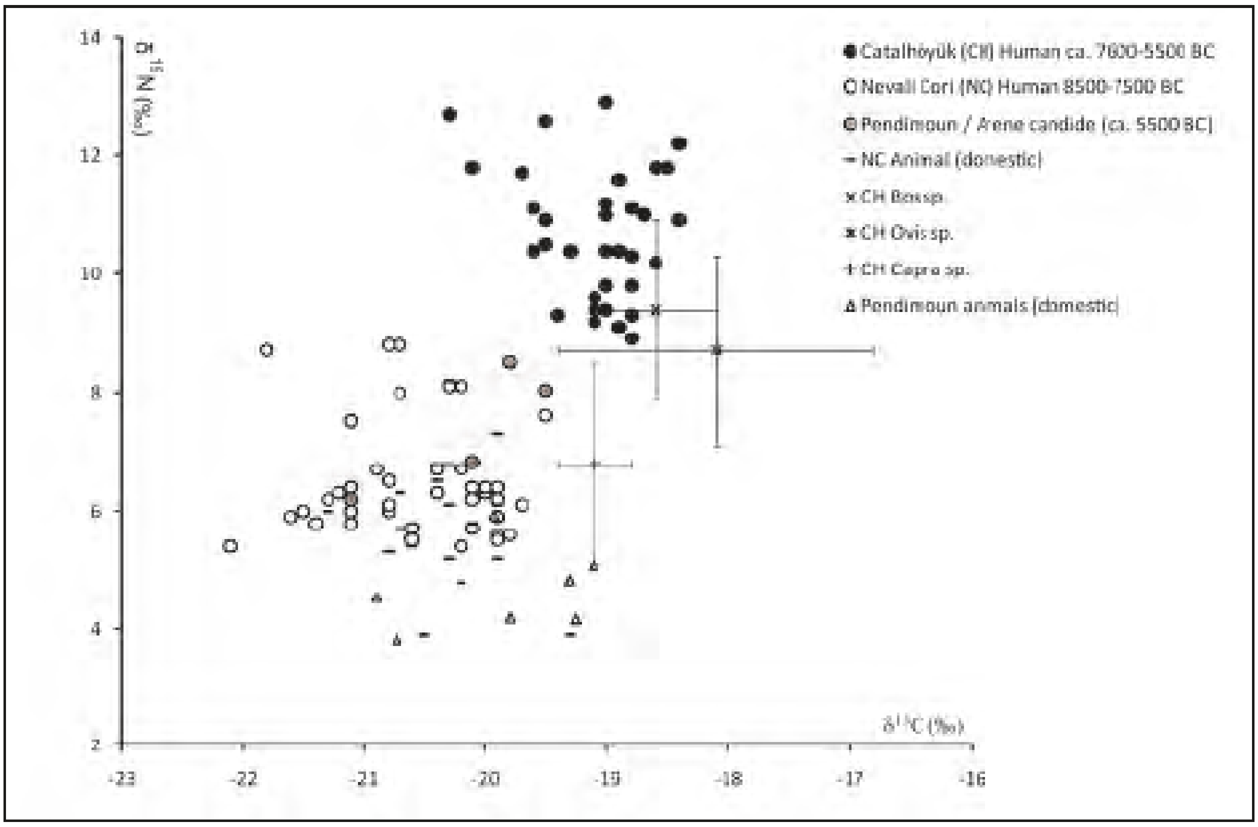

Fig. 3 - Bivariate plot of carbon and nitrogen stable isotope data from Turkish (from Richards et al. 2003; Lösch et al. 2006) and French (from Le Bras-Goude et al. 2006a) Early Neolithic groups.

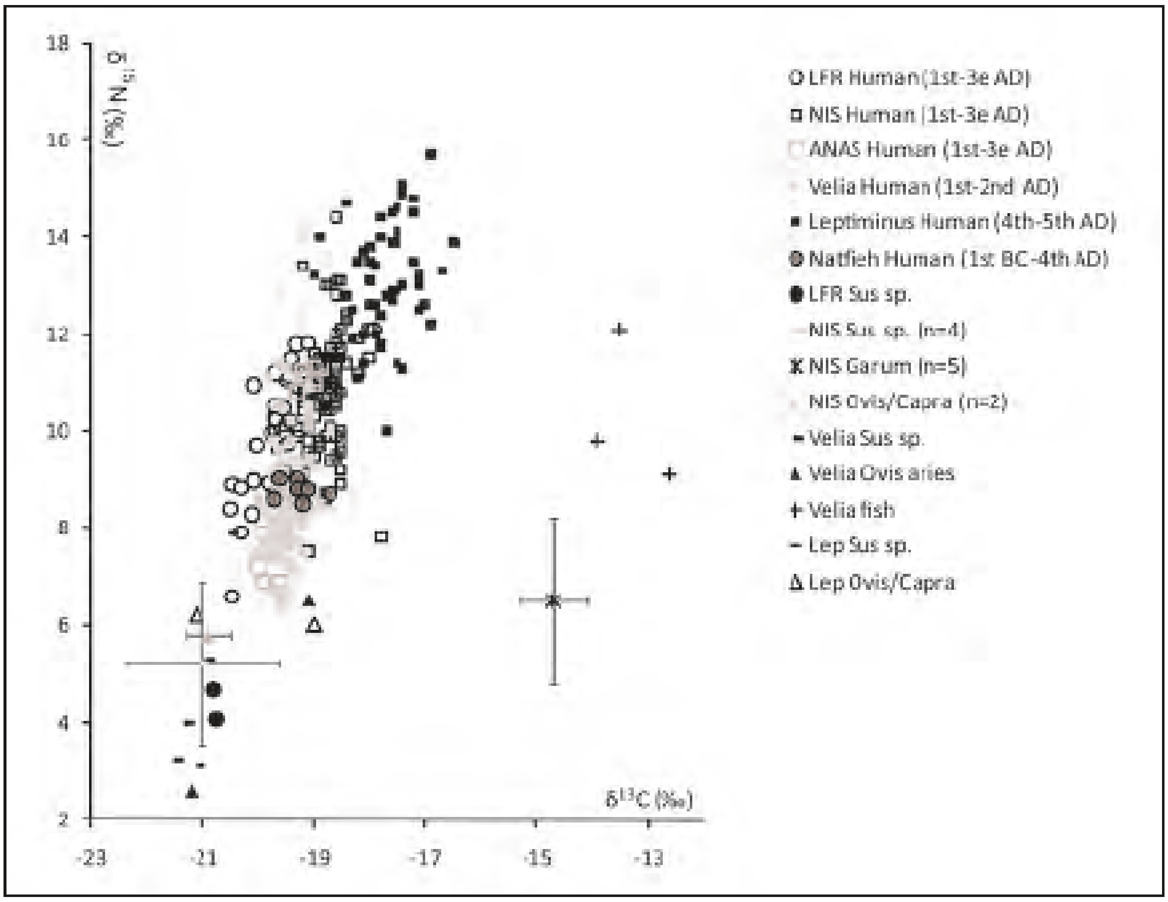

Fig. 4 – Bivariate plot of carbon and nitrogen stable isotope data from Roman sites. NIS: Isola Sacra Necropolis and ANAS (Prowse et al. 2004, 2005, 2008), LFR: Lucus Feroniae (Tafuri et al. in press), Velia (Craig et al. 2009), Lep: Leptiminus (Keenleyside et al. 2009), Natfieh (Al Bashaireh et al. 2010).