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Food and Foodways in Phoenician and Punic Sardinia

NEW DATA FROM ORGANIC RESIDUE ANALYSIS ON COOKWARE

Leonardo Bison

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Abstract

The project aims to uncover new information about foodways, culinary practices and vessel use in Phoenician and Punic Sardinia (8th-2nd centuries BCE), through the application of organic residue analysis (GC; GC-MS; GC-C-IRMS) to 368 sherds of vessels involved in food cooking and preparation from six different archaeological sites. In Phoenician and Punic Sardinia, ceramic technology and vessel shape changed significantly, especially due to the movement and encounter of people and ideas, but the study of foodways and vessel use on the island has been largely based on written and iconographic sources and vessel shape. Organic residue analysis was chosen as the analytical technique for its potential for detecting the commodities processed in single vessels, and to tackle questions regarding consumption and use of products, like milk or honey, which are not archaeologically detectable without organic residue analyses. Research questions are: 1) what commodities were processed in the main ceramic categories involved in cooking and food preparation practices?; 2) what do the detected commodities suggest about vessel use and specialisation?; 3) what do the detected commodities suggest about changes in cuisine and diet over time?; 4) are infra-site and inter-site spatial patterns identified through ORA?.

The results obtained through ORA have been contextualised within the previously available material and written sources, including archaeological, literary, epigraphic, iconographic, palaeobotanical, faunal and anthropological data. This led to obtain the first direct evidence of milk processing in ancient Sardinia, the first significant evidence of widespread honey use, and new information about vessel-specific uses. New questions, about continuity of foodways over time and possible coexistence of different culinary cultures on the island, have been set for further research. Finally, a first major organic residue dataset on pottery in Phoenician and Punic Sardinia and in central and western Mediterranean has been created, able to orientate and stimulate further analyses.

COVID-19 Statement

Lockdowns and restrictions caused by the widespread of COVID-19 caused no major problem to this research. However, I prefer to briefly enumerate the impact they had, in two different ways.

I left Bristol in September 2019 to end writing my dissertation in Italy. I brought with me all the materials I perceived as useful or necessary. The original plan was to travel to Bristol every time I needed, especially to double-check potentially useful information in the labs. But I visited Bristol and the University labs for the last time on March 7th. The few times I realised I needed information I did not have with me I asked colleagues. No additional analysis was needed to conclude the dissertation.

I had no access to public libraries from March to June, and from November until the submission day. I needed a limited number of volumes and I was able to borrow them during the summer: everything else was online. No deficiency caused by this situation is known. However, it is not excluded that it could have caused a loss of information, especially referring to recent publications and to impossibility of double-checking some references.

Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is the candidate's own work. Work done in collaboration with, or with the assistance of, others, is indicated as such. Any views expressed in the dissertation are those of the author.

SIGNED [redacted] DATE December 9th, 2020

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List of abbreviations

APAA ω-(*o*-alkylphenyl)alkanoic acid

DAG diacylglycerol

DCM dichloromethane

DHA docosahexaenoic acid

DHYA vicinal dihydroxy acid

EPA eicosapentaenoic acid

FAME fatty acid methyl ester

FFA free fatty acid

FTIR fourier-transform infrared spectroscopy

GC gas chromatography

GC/MS gas chromatography/ mass spectrometry

GC/C/IRMS gas chromatography/ combustion/ isotope ratio mass spectrometry

HPLC High Performance Liquid Chromatography

HTGC high temperature gas chromatography

IFA isoprenoid fatty acid

MAG monoacylglycerol

MNI minimum number of individuals

NISP number of identified specimens

ORA organic residue analysis

SIM selected ion monitoring

SIMS secondary ion mass spectrometry

TAG triacylglycerol

TLE total lipid extract

TMS trimethylsylilated

TMTD 4,8,12-trimethyltridecanoic acid 17

Site Codes

GSM Nuraghe San Marco (Genuri)

NRBS Nora (Pula)

NRBS Nora (Pula)

OLB Olbia

OM Olbia, via del Mercato

SAC Sant'Antioco/Sulky

SUB S'Urachi (San Vero Milis)

Glossary

Marzeah = Phoenician banquet or institution characterised by the organisation of feastings, often associated to the Greek symposium (Phoenician: MRZH).

Nuraghe = Tower, built in the Bronze Age, characterising the Sardinian landscape.

Nuragic = Adjective use to define people and materials related to the archaeological culture which developed in Sardinia during the Bronze Age (1800-1200 BCE), continuing without evident discontinuities until the 6th and, in some areas, the 3rd centuries BCE.

Phoenicia = Name used by archaeologists to define the ancient region corresponding to modern Lebanon and the Carmel coast of Israel down to Tel Dor, where the cities of Tyre, Byblos, Sidon, Arwad, Saraepta and Berytus are located.

Phoenician = Adjective use to define people and materials related to region of "Phoenicia" between the 12th and the 4th century BCE and the archaeological culture and settlements that people living in that region brought to the central and western Mediterranean between the 9th and the 6th century BCE.

Punic = Adjective used to define people and materials culturally related to Carthage and the culture which developed in modern day Tunisia after the rise of Carthaginian power, widespread in the central and western Mediterranean between the 5th and the 2nd century BCE.

Tophet = Sanctuary, typical of the Phoenician and Punic settlements in the central Mediterranean (Sicily, Sardinia, North Africa) characterised by the presence of burials of children and animals indicated with stelae.

Sulcis = Region located in the south-west of Sardinia, named after the Phoenician settlement of Sulky.

Sulky = Name used in archaeology and history to define the ancient city of Sant'Antioco (Phoenician: SLK).

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Chapter 1
Introduction

1.1 Why foodways?

“You are what you eat or you eat what you are?”
(Caplan 1997)

The way we eat, what we eat, the way we cook and prepare food, the way we define meals and eating: are all related to a tangled network of ideas, choices, needs and relationships. Proving the accuracy of this statement does not require many arguments, being evident to anyone who has experienced a meal with a group of people from different social, cultural or ethnic extractions. And in brief, this explains why we study foodways.

While undertaking the current research and writing this PhD dissertation, I lived in Bristol as a migrant. It was a situation which constantly forced me to reflect about foodways and experience what I was reading about (Sutton 1998). I recreated family recipes using British ingredients, I accepted some British meals in my diet and excluded others. I struggled with language and words: not only is what we cook and how we cook it (or when and why) highly cultural, but even how we define it (La Cecla 2005; Shields-Argelès 2010). Meeting “the other” leads to a self-reflection about how identity and language are expressed: cuisine is part of this expression, and often one of the most visible aspects during inter-cultural encounters (Hastorf 2017; Goode at al. 2003). Food and foodways in migratory and multicultural contexts are one of the current topics and perspectives of the anthropology of food (Medina et al. 2010; Crenn et al 2010b; Sammartino 2010; El-Bachouti 2015). It is a topic closely related to this research, since Phoenician and Punic Sardinia was an island of multicultural interactions (see 3.1). Anthropologists focus on the individual choice of the migrant in defining their foodways (Giraud 2010; Mescoli 2015; Brown 2015) and their relationships with the local community (Toguslu 2015; Crenn et al. 2010a).

The current debate is wide and varied. Due to its cultural relevance, an interest in food, eating, and feasts has existed since the rise of anthropology as a discipline in the 19th century (for a summary, see Goody 1982: 10-12; Mintz and Du Bois 2002). However, the contemporary debate and interest in foodways only started to spread in the 1960s. Interest in this field can be ascribed especially to scholars such as Claude Lévi-Strauss (1962; 1964; 1966; 1968) and Mary Douglas (1966, 1975, 1984). Lévi-Strauss’ most famous and impactful result is the culinary triangle of raw, cooked and rotten (Lévi-Strauss 1965), which, in his opinion, is useful to define every meal in every cuisine in the world. He likewise thought it was possible to analyse wider aspects of a people and humanity in general through cuisine, based on the idea that foodways in human societies relate to a “deep structure”, or *esprit humain* (Lévi-Strauss 1964, 1966, 1968). Mary Douglas’ work focused on the classification of foodways and their relationship with hierarchy and social grouping (Douglas 1966; Vroom 2015). She argued (1975) that the detection of the “code” of foodways makes it possible to use food as a marker of ethnic, cultural, generational, and gender differences in a society. This is particularly relevant to current archaeological approaches to foodways (Vroom 2015; see below, 1.1.1.1).

Several other anthropologists could be mentioned, since in world anthropology, especially in the English-speaking world, a parallel production of volumes dealing with the anthropology or sociology of foodways and society spread from the 1960s (examples include Farb and Armelagos 1980; Douglas 1966, 1984; Keller Brown and Mussell 1984; Bryant et al. 1985). Marvin Harris (1968; 1985) argued for a close relation between foodways, food taboos and economic or adaptive needs. His theories supplied a theoretical background to processual archaeologists (see below, 1.1.1). Jack Goody, in *Cooking, Cuisine and Class* (1982) established a relationship between the appearance of high and low cuisine and the appearance or reinforcement of hierarchies and classes. In opposition to Lévi-Strauss, he argued that it is not possible to study the cuisine of one people or culture at the same time as avoiding observation of inter-class differences, or to use the same categories for all the cuisines of the world (Goody 1982: 219-220).

The topic of food and diet is still a focus in current anthropological debate (Murcott 1998; Counihan and Van Esterik 2013; Dietler and Hayden 2001), following a trend which refers to other disciplines and societies in general (Marrone 2014; Mintz and Du Bois 2002). Discussions about food and foodways are in progress, facing a myriad of themes with different perspectives: the kind of ideas, choices, needs and relationships involved in foodways, the role these aspects fulfil in the creation or preservation of foodways, how foodways can be used to understand culture (Counihan and Van Esterik 2013; Bescherer Metheny and Beaudry 2015; Hastorf 2017). Many food-related topics are discussed in anthropology, including the role of capitalism (Watson and Caldwell 2005); food as a means to build or reinforce communities and genders (Counihan 1999; Counihan and Kaplan 1998; Sutton 1998) or ethnic groups (Kelle Brown and Mussell 1984), also in contexts of migration (Toguslu 2015; Crenn et al. 2010a); commensality (Kerner et al. 2015) and family (Caplan 1997); and, following Goody, food and classes (Ashley et al. 2004). This introduction describes the main lines of research and developments in the anthropology and, especially, archaeology of food and foodways during the past decades. It serves as a premise to this dissertation, highlighting the contemporary state of the discipline.

1.1.1 Food and foodways in archaeology: historical perspectives and research trends

Archaeological interest in foodways has had a somewhat different development from the anthropological one outlined above. The fundamental works of anthropologists noted above have also impacted the archaeological debate (Twiss 2007a: 4-5) during the rise of New Archaeology, i.e. processual archaeology, and the reactive spread of post-processual archaeology (Giannichedda 2016). Processual and post-processual archaeologists approached the theme of foodways in different ways, following their chosen theoretical frameworks and opinions (economic/environmental on one side, relativist and culturalist on the other (Twiss 2007a: 4-6, with references)).

However, papers focusing on foodways in archaeology are rare for the 20th century as a whole. Too often archaeologists considered foodways, cooking practices and social rituals related to the consumption of meals as undetectable because these aspects were non-material. Between the 1970s and the 1990s, food was targeted mainly from an economic point of view, thanks to the development of zooarchaeology (e.g. Crabtree 1990), with limited focus on social strategies (a strong exception is Bats 1988, see 1.1.1.2). The current global, i.e. English-speaking, debate is briefly discussed here; then the Mediterranean and Italian debate is outlined. All constitute the benchmark for the current research.

1.1.1.1 The archaeology of food in the 21st century English-speaking debate

Foodways became a central topic in archaeology during the last few decades of the 20th century and the beginning of the 21st. In 2001, a volume edited by Michael Dietler and Brian Hayden (*Feasts: Archaeological and Ethnographic Perspectives on Food, Politics, and Power*, 2001) marked a pivotal shift in interest. In this work contributions are mainly based on archaeological data (ceramic assemblages, stratigraphy, spaces, etc.). It was a symbolic watershed also because the volume is based on the cooperation of two major scholars with different theoretical perspectives. This interesting cooperation leads to common conclusions and was itself carried out during a period in which archaeological scholarship was trying to bridge the opposition between processual and post-processual approaches (Dietler and Hayden 2001: 2). The volume tried to achieve several outcomes: understand how to identify feasts and their meaning in the archaeological record; establish classifications and labels; and compare different cases and approaches. More importantly, this was done within a single volume, rather than isolated articles, and the amount of data and approaches offered a remarkable tool for archaeologists, encouraging many subsequent scholars to consider the theme and propose new, more comprehensive approaches (Twiss 2007a; Hastorf 2017; Bescherer Metheny and Beaudry 2015).

Since 2001, the number of studies dealing with different aspects of food and consumption in archaeology has increased dramatically, (Mee and Renard 2007; Mullins 2011; Dietler 2006; O' Connor 2015; Kerner et al. 2015; Hastorf 2017; Twiss 2007a, 2012). The first volume to explicitly consider the "archaeology of food" was Katheryn Twiss' edited volume, *The Archaeology of Food and Identity* (2007a). The relevance of an archaeology of food as an independent, albeit not separate branch of contemporary archaeology is expressed in subsequent works (Twiss 2012; Hastorf 2017). In addition, the first issue of the new journal *Archaeology of Food and Foodways* will be published by Equinox in 2020. These elements, in addition to many others, promote food and foodways as an important topic in the contemporary archaeological debate.

Foodways are nowadays approached by archaeologist in several different ways. Some works, which may be regarded as more "processual" approaches to subsistence, are focused on a more descriptive analysis of diet. They focus on economy and on the relationship between people and environment, and they are decreasing in popularity in contemporary discussion (Barker and Gamble 1985; Pluciennik 2001; Hayden 2001; Sherrat 1999; Woolgar et al. 2006). Other approaches and topics are, on the contrary, more widely discussed and targeted.

The relationship between food and pottery has been a largely debated topic. Pottery is the most common material found in archaeological excavations, and this has led some scholars to focus specifically on investigating its relationship with foodways. A good example of this research trend is the major collection of essays *Ceramics and Culture* (Spataro and Villing 2015), where both anthropologists and archaeologists offered several approaches, case studies and insights that enable better comprehension and contextualisation of this relationship. Papers focusing on "pottery and foodways" as a core theme have been numerous across the world over the past few years (e.g. Eusebio 2015; Gjianto 2017). In particular, it is necessary to mention the volume *Ancient Cookware from the Levant* (London 2016) that uses ethno-archaeology to investigate the production of pottery, the consumption of pottery, and the food and commodities processed in Middle Eastern vessels throughout the past and in the present. As will be explained below (1.1.1.2), this topic has also been addressed in the area of the western Mediterranean with an outstanding volume (Bats 1988) that had a limited impact in world archaeology due to being written in French.

Other research themes have risen to the forefront of archaeological debate on foodways in the past few decades. This is the case of the theme of "food and identity" (Twiss 2007a; Grottanelli and Milano 2004; Banducci 2013; Frantzen 2014; Hastorf 2017: 219; Watson 2015; Marin-Aguilera 2016; Dietler 2015; Mullins 2011; Delgado and Ferrer 2011a). In K. Twiss' words, "identity is taken to mean the affiliation of an individual or group with a selected broader group and not with other groups. It is a dynamic and situationally specific phenomenon, one that both shapes and is shaped by cultural practices and experiences. Identity is also a multidimensional phenomenon, and each individual has multiple identities" (Twiss 2007a: 2). In other words, identity is the whole of practices, activities, thoughts and realities (material and immaterial) that allow an individual to perceive him or herself as part of a group; practices, activities, thoughts and realities can be chosen consciously or undergone unconsciously (Remotti 2007). Food practices are, naturally, part of these practices (see section 3.1 for a wider dissertation about the issue (Xella 2014; Lopez-Bertran 2011: 87)). In the macro-topic of "foodways and identities" food taboos have raised a particular research interest (for an overview, see Mintz and Du Bois 2002). Papers on food taboos in archaeology focus on the description and detection of food taboos (Van Wyk 2014; Vila and Dalix 2004; Grau-Sologestoa 2016) or on their unexpected absence (Moreno Garcia 2004). In some contexts, for example ancient Palestine or Medieval Spain, research has focused on the possibility of distinguishing ethnicities through zooarchaeological assemblages and food taboos (Finkelstein 1997; Hesse and Wapnish 1997; Alexander et al. 2015).

Moreover, the use of food to create gender and class distinctions has also been investigated to assess what kind of foodways develop in a gender-divided or class-divided environment (Goody 1982; Caplan 1997; Counihan and Kaplan 1998; Parsons 2015; Parkin 2006). Using foodways to investigate gender through the archaeological record is carried out by analysing ceramic vessels, assemblages, contexts and spaces. By combining and contextualising these elements it is often possible to reassess use, function and attribution, enabling scholars to detect connections with genders and meanings of this specific attribution (Delgado 2016; Dietler and Hayden 2001: 11; Whitehouse 1998; London 2016). The use of foodways to create or maintain class divisions (Goody 1982; Ashley et al. 2004) is tackled via the study of feasting (Dietler and Hayden 2001; Klarich 2010; Freedman 2015), faunal assemblages and their location (Twiss 2007b; Crabtree 1990), or by using isotope analyses on human bones (Ambrose et al. 2003; Alexander et al. 2015).

Foodways in multicultural and migratory contexts is one last widely investigated field. Some of the most interesting topics in anthropology can be detected and documented in the foodways of migrant communities: the rise, creation or re-creation of identities and cultures; the results of an encounter with people; and the strategies adopted by people to adapt their culture to a new environment. In last decades, archaeologists have increasingly focused on the detection of foodways, and their preservation or modification in colonial, migratory or general multicultural contexts (Dietler 2006, 2015; VanDerwaker et al. 2007; Scott 2007; Twiss 2012; Jordà et al. 2010; Spataro and Villing 2015; Curé 2015;

Delgado 2016; Flexner 2015; Brighton 2015). Post-processual approaches to archaeology have produced an increasing number of works that considered cooking and consumption practices in colonial societies (Mullins 2011). Foodways and consumption practices, when detectable, offer the archaeologist a useful perspective on cultural changes and hybrid practices related to the merging of cultures (Bats 1988; Dietler 2015: Schucany 2005; Van Dommelen and Gomez Bellard 2008; Hastorf 2017: 247; Godbout 2015; Marin-Aguilera 2016).

As predicted, these different topics and approaches are largely interrelated: diet is necessary to understand social differences, and class and gender roles are often part of the same phenomenon. Subsistence can be a matter of identity. In the present years, the archaeology of foodways is becoming increasingly mature (Hastorf 2017: 13; Bescherer Metheny and Beaudry 2015). It is now well-established that foodways can be archaeologically analysed with comparative methods such as ceramic shape, production and fabric; domestic spaces; environmental and faunal assemblages and their location (Douglas 1984; Spataro and Villing 2015; Hastorf 2017). The interrelation with ethnography and ethnoarchaeology is leading to more accurate and comprehensive results and interpretation (Twiss 2007a; Hastorf 2017; Dietler 2006, 2015), as is the application of scientific techniques on bones and pottery (Cramp et al. 2014; Cramp et al. 2011; Fuller et al. 2010). In short archaeological approaches to food have made clear that is possible to make the invisible visible through the connection between food and material culture.

1.1.1.2 The archaeology of food and foodways in the Mediterranean and in Italian archaeology

Mediterranean research trends on the archaeology of foodways were partially different to the ones described above. Until recently, in Mediterranean countries research on past foodways was the prerogative of some historians (e.g. Andrè 1981; Dosi and Schnell 1984). They worked with and on written sources (Grottanelli et al. 1988; Longo-Scarpi 1989; Montanari 2004; Grottanelli and Milano 2004), with limited or no interest in material remains. The only significant exception to this picture is an outstanding book on the topic published in 1988 (Bats 1988; see below).

There are many reasons to explain the delay in researching foodways within Mediterranean archaeology as well as the themes related to domestic and everyday life (Whitehouse 1998). Until recently, Mediterranean archaeology focused more on the classification of pottery and monuments than on understanding past societies (Morel in Bats 1988: 11-13; Giannichedda 2016; Barbanera 1999; 2015). This is due to both the quantity of available classical remains in Italy, Spain and Greece and to the politics of these regions. The interest in showing an idealised classical imperial past as a matter of national identity was necessary for the new Italian and Greek states created in the 19th century, and this was reinforced by the fascist regimes ruling Italy until 1945, Greece between 1967 and 1974, and Spain until 1975 (Barbanera 1999: 35). After the fall of the fascist regimes, academia continued to be led by the same scholars (Barbanera 1999: 156-157). Thus, there was limited space for studying past "national" communities and societies in a different way. For this reason, non-classical (Greco-Roman) archaeology was marginalised for decades in the heartlands of Mediterranean civilisations (Giannichedda 2016; Barbanera 2015).

Such political issues are reflected in works concerning foodways in the ancient world. Classical archaeologists approached the study of foodways in a "descriptive" manner: written and iconographic sources were analysed to describe ancient foodways, and no explicit theoretical framework was used or perceived as useful. This first strand of studies about foodways was influenced by the debate that originated after Lévi-Strauss' publications (1964, 1966, 1968), but they lacked anthropological or socio-cultural reasoning. Examples of such studies are many (e.g. Dosi-Schnell 1984; Andrè 1981; Sparkes 1962). Similar approaches are still alive also in English-speaking scholarship, especially the Classics (Wilkins and Hill 2006). In the Mediterranean basin, similar studies outside the Greek and Roman world have only been undertaken in a few other areas and cultures; these include the Mesopotamian area (Bottéro 2004; Sasson 2004), Egypt (Woods et al. 2010), and some medieval examples (Lewicka 2011; Trepanier 2014). Although a descriptive approach is useful and complementary to theoretically grounded research based on material culture, it can only be productive for societies which provide a large amount of written evidence (Bats 1988).

Meanwhile, a second research strand existed. Approaching the archaeological record from a Marxist perspective led to a number of works interested in mainly one aspect of foodways: the creation or re-creation of subsistence practices and of consumption patterns by a state or a power (Rodriguez-Alegria 2015; Berryman 2015) for its own interest (Ampolo 1980; Bondí 1985; Lopez Castro 1993; Ponisch 1988). In the Mediterranean region, this approach is not related to what was happening in the post-processual field in the English-speaking world, and followed different research lines, focusing instead on states, powers and productions rather than on culture and identities. This economic and environmental approach has also characterised Sardinian scholarship, referring especially to Nuragic (i.e. pre-Phoenician) archaeology (e.g. Depalmas et al. 2015; Manconi 2000). These analyses, while useful and necessary to highlight historical and archaeological questions, present a weakness that cannot be ignored: an orthodox application of Marxist theory can only be undertaken for stable state societies, both territorial and city-states, not for societies where power and roles are under negotiation. Many Mediterranean societies were not state societies, and Marx's insights on consumption and control can only be applied with a degree of risk in these situations or may even hinder the broader understanding of issues related to food and culture (Hastorf 2017: 143).

A third path can be found. In recent years, descriptive studies on ancient foodways based on written and iconographic sources are flanked by similar works that incorporate archaeological remains into the debate. These works are not only related to the Greek and Roman worlds (Curtis 2001), but also to other Mediterranean peoples (Campanella 2008; 2003; Vendrell Betì 2016; Soderlind 2015). However, they are usually based only on pottery typologies and use archaeological data to confirm the interpretation derived from written classical sources (see below, 2.1.1); nevertheless, these studies are slowly enabling Mediterranean archaeology to study food and foodways more comprehensively.

The only significant exception is Michel Bats' 1988 volume, *Vaisselle et alimentation à Olbia de Provence : v. 350-v. 50 av. J.-C. : modèles culturels et catégories céramiques*. This book is considered the most relevant forerunner for archaeological studies about foodways in the Mediterranean, for the approach it presents is still valuable today. It was not discussed above (1.1.1.1) because its impact in world archaeology has unfortunately been limited due to linguistic obstacles. With the aim of detecting information about foodways in the area of Olbia (Massalian colony, Provence) through the study of the site's ceramic assemblages, the author explains the current state of research regarding the debate about foodways and his theoretical framework. He then considers comparisons with the most well-known cultures that influenced Olbia's material culture: the "Greek maritime" (i.e. Athens) and the Roman, including an in-depth analysis of the words used to define vessels and cooking procedures in Greek and Latin. At the end of this preliminary contextualisation, he proceeds with an analysis of all the typologies and assemblages in Olbia. This is not a catalogue, but a list of types. In the final part of the volume, he provides interpretations and conclusions about the use of vessels and the structure of diet. The ceramic assemblages in the territory of Olbia are not analysed as a uniform block, but through comparison with different sites, dividing urban and rural areas, and checking the differences and meanings of those differences. This is an informative and innovative technique that is often forgotten by archaeologists. The modernity and accuracy of this volume cannot be underestimated; as stated by J.P. Morel in the introduction: "Michel Bats did not invent ceramology, but probably he reinvented it" (Bats 1988: 11). Its approach is still valuable today and it stands out from among many of the volumes published later. It is possible that Mediterranean archaeology was not ready for this kind of study in 1988; nothing similar followed this publication and even Bats abandoned this research line in his later works. This milestone remained isolated for decades.

Recently, the rediscovery of past works, otherwise ignored until the beginning of the century (Bats 1988; Vendrell Betì 2016), and the spread of post-processual theory in Mediterranean archaeology (Whitehouse 1998; Van Dommelen 1998; Marin-Aguilera 2016; Banducci 2013), have led to a new archaeological interest in Mediterranean foodways . The most relevant works between the late 20th and early 21st centuries have focused on Greece from prehistory to the Ottoman period (Vroom 2000; Halstead-Barret 2004; Mee-Renard 2007) and Iron Age southern France (Dietler 1990; 1999). Other relevant publications include the outstanding works by historians (Montanari 2004; Flandrin and Montanari 2007), often focused on religions (Longo and Scarpi 1989; Longo and Cremonesi 2002), and works on foodways focusing on the Mesopotamian area (Schmandt-Besserat 2001; Grottanelli and Milano 2004; Sasson 2004) and on the Middle East in general (Lev-Tov and McGeough 2007).

Some of these works (e.g. Vroom 2000; Halstead and Barret 2004; Mee and Renard 2007; Dietler 1990; 1999) are among the first to present foodways as a central topic in Mediterranean archaeology. They deal with foodways from a strictly archaeological perspective, and they apply more modern, innovative approaches to the Mediterranean area (with the already mentioned exception of Bats 1988). Vroom's volume (2000), for example, tried to highlight the relation between invasions, occupation and culinary changes by analysing changes in diet in central Greece during the Byzantine and Ottoman periods and contextualising and interpreting material culture using ethnoarchaeological and written sources. Dietler's works (1990, 1999), described below, applied ethnoarchaeological data about foodways to the study of colonial encounters in the Iron Age Mediterranean. Finally, the volume edited by Christopher Mee and Josette Renard (2007) dealt with the topic of Aegean culinary customs during the Neolithic and Bronze Ages through a plethora of different contributions focused on foodways, including faunal, paleoenvironmental and archaeological data from ceramic assemblage to spaces and buildings. These techniques build a multifaceted and varied understanding about diet in these periods and the approaches related to it.

The role of English-speaking scholarship in this process is evident. Several papers and contributions are published by English-speaking institutions and scholars (e.g. Mylona 2008; Riva 2010; Balducci 2013). But the number of papers about foodways written by archaeologists based in Mediterranean countries and writing primarily in their national languages also grew in the same years (e.g. Spanò Giammellaro 2005; Campanella 2003; Campanella and Niveau de Villedary 2005;

Campanella and Zamora 2010; Delgado 2008, 2010). Some of the most relevant works referring to the Phoenician and Punic world (e.g. Campanella 2008) will be analysed in the next chapter (section 2.1). Foodways were symbolically sanctioned as an important topic in Mediterranean archaeology by a Spanish conference (Mata et al. 2010) and its importance further highlighted with the choice of "food" as the topic of the 50th conference of the Italian Prehistory Institute (Rome, October 5-9 2015). Its acknowledged significance continues, as testified by its presence in several Phoenician and Punic archaeology conferences (see 2.1). This fertile environment has led to a wider interest in the relationship between food, commensality, pottery and culture (Klarich 2010; Spataro and Villing 2015; Delgado 2016; London 2016), and the history and development of foodways in specific areas (Vroom 2000; Dietler 2015; Spatafora 2015; Vendrell Betì 2016; Lewicka 2011; Trepanier 2014; Grau-Sologestoa 2016).

Despite this, organic residue analysis and other scientific analyses pertaining to past diets have been rarely applied to the general Mediterranean world let alone that of the Phoenicians and the Mediterranean Iron Age. This lack of research is especially true in comparison with other areas of the world, although this is changing (Rathmann et al. 2016; Guglielmino et al. 2015; Giorgi et al. 2010; Pecci et al. 2013; Carrer et al. 2016) as will be explained in Chapter 4 (4.4).

Despite these developments, until recently archaeologists interested in foodways were quite isolated in the Mediterranean area, and they often lacked a strong theoretical framework. The gap is being reduced owing to the rise of research groups (e.g. Mata et al. 2010; for further details see section 2.1.1) and the work of two key researchers: Ana Delgado and Michael Dietler. Both apply post-processual approaches and postcolonial theories, and are focused on the theme of foodways in the Mediterranean Iron Age, respectively in Catalunya and the Phoenician world, and in southern France.

Influenced by Michel Bats' volume (1988; Dietler 2015), Michael Dietler focuses on colonial encounters and their related cultural changes. Foodways, including alcohol (Dietler 2006) and feasting (Dietler 2001), are the topics he tends to discuss. In contrast to many other archaeologists working in the Mediterranean Iron Age, he uses large-scale ethnoarchaeological data (Dietler 2006; 2007) to introduce new evidence and data in the interpretation of past Mediterranean encounters. For the Mediterranean area, I consider his volume *Archaeologies of Colonialism: Consumption, Entanglement and Violence in Ancient Mediterranean France* (2015), which dedicates an entire chapter to "culinary encounters", the best example of how a study on food and culinary customs can be used to create a broader archaeological picture. Two aspects of this volume are particularly innovative for the western Mediterranean area: Dietler's understanding is based on ethnoarchaeological and archaeological comparisons, and, moreover, the archaeological record is analysed as a whole, with divisions and chapters built around the theme and not the material. These two features enable the author to argue his hypothesis and interpretations with well-established data and comparisons independent from written (foreign) sources.

Many of the themes explored by Dietler are also examined by Ana Delgado, often in cooperation with Meritxell Ferrer (2007; 2011; 2012). Delgado's perspective is explicitly focused on gender. As a scholar of the Phoenician and Punic world, her work will be discussed in the next chapter (2.1).

This renewed research interest also reached Sardinian archaeology. A shift, overcoming approaches limited to subsistence and environment, occurred with the recent publication of a monograph about the site of Nuraghe Arrubiu in Orroli edited by Fulvia Lo Schiavo and Mauro Perra (2017). The volume includes comprehensive and detailed faunal, environmental, isotopic and archaeometric data. Moreover, it deals with data about domestication techniques, meat processing and treatment, animal diet, dining areas and much more. In 2018, Mauro Perra published a new and more ambitious synthesis on foodways in Nuragic Sardinia clearly transitioning from food to foodways, titled *Alla mensa dei Nuragici: mangiare e bere al tempo dei nuraghi* (Perra 2018), i.e. "The Nuragic table: eating and drinking in nuragic times". In addition to the enumeration and description of available resources, the volume contains broad comparisons with the contemporary Mediterranean world and, more importantly, information about food storage, processing, preparation, and consumption; farming and livestock rearing techniques; cheese and honey production; and drinking and feasting. Some of this information will be discussed in the following chapter (2.2). Although the volume is primarily based on the site of Nuraghe Arrubiu, it is easy to hypothesise that this book will mark a change in how foodways in Sardinia are studied.

To conclude, the work of scholars such as Michael Dietler and Ana Delgado and the international trends explained above are encouraging researchers to engage with the topic of foodways (Perego 2009; Mata et al. 2010; Marin-Aguilera 2016). These studies address formerly ignored and marginalised topics (Whitehouse 1998). Results obtained, combined with the great amount of archaeological, ethnoarchaeological, iconographical and written data available for the ancient Mediterranean, encourages us to be optimistic for the future vitality of this sub-discipline. This is true also for Phoenician and Punic archaeology, whose research trends will be outlined below (Chapter 2; 2.1). The current research locates itself in this path. It aims to obtain more information on foodways and culture carrying out organic residue analysis on cooking ware from Phoenician and Punic Sardinia.

1.2 Project, research questions and aims

This dissertation is entitled "Foodways and vessel use in Phoenician and Punic Sardinia: new data from organic residue analysis on cookware". The project is based on applying the technique of organic residue analysis to a total of 368 archaeological vessels involved in food preparation and cooking from six different sites in Phoenician and Punic Sardinia (8^{th}–3^{rd} centuries BCE). As an archaeological project that involves chemical analysis, both the analysis and the results will be introduced, contextualised and interpreted in the light of the existing historical, archaeological, and, in part, anthropological background. Here follows, in brief, the reasoning, ideas, and possibilities which lie behind this project. The significance of the project, the archaeological context, and the limits and the aims of the analytical techniques will be outlined in detail in the next chapters (see 1.3).

The broad aim of this project is to uncover foodways and culinary customs in a specific archaeological context, Phoenician and Punic Sardinia. Organic residue analysis has been recognised as a useful tool to obtain relevant insights and elements to be introduced into the archaeological and historical debate. In fact, the studied period, named "Phoenician" and then "Punic" (see Chapter 3, section 3.1 for definitions), is characterised by the movement of people, ideas, and the creation of new settlements. The study of food is considered a relevant research field to unlock the comprehension of cultural choices (see above) and vessel technology and change (see Chapter 3). In Phoenician and Punic Sardinia, ceramic technology and vessel shape changed significantly, especially due to the movement of ideas and people from the Levant, which were also locally reproduced (see Chapters 2 and 3). The study of foodways, culinary customs, and vessel use on the island has been largely based on written and iconographic sources and vessel shape (2.1). Organic residue analysis was chosen as the analytical technique for its potential for detecting the commodities processed in the vessels, and because it allows the connection of single vessels with organic content (see Chapter 4). Organic residue analysis has precise limitations (see Chapter 4). But it is recognised as a useful technique to highlight several archaeological issues not investigated enough previously, due to the impossibility to tackle those questions without the use of these analyses. This is the case, for example, of vessel use and specialisation, or consumption and use of products, like milk or honey, which are not archaeologically detectable without organic residue analyses (see Chapter 4).

The project has been funded by the Arts and Humanities Research Council (AHRC) through the South-West and Wales Doctoral Training Partnership (SWWDTP), and it has been created and developed through the cooperation of the Department of Anthropology and Archaeology, the Archaeological Chemistry labs and the Organic Geochemistry Unit at the University of Bristol, and the *Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Cagliari e le province di Oristano e Sud Sardegna* in Cagliari (Sardinia, Italy). The *Soprintendenza* itself asked to avoid a single-site based project, allowing sampling from six different sites, and enabling the first major organic residue analysis dataset to be generated for Phoenician and Punic Sardinia. Other institutions and scholars who cooperated in the project are noted in the acknowledgements.

The overarching research aim is to understand, in synthesis, how organic residue analysis on cooking ware can contribute to our knowledge and comprehension of culinary practices and culture in Phoenician and Punic Sardinia. This general aim can be structured and divided into the following research sub-questions:

1) What commodities were processed in the main ceramic categories involved in cooking and food preparation practices?
2) What do the detected commodities suggest about vessel use and specialisation?
3) What do the detected commodities suggest about changes in cuisine and diet over time?
4) Are infra-site and inter-site spatial patterns identified through ORA? What do they suggest?

With these questions in mind, it was decided to include in the project all vessel shapes connected to food preparation and cooking. Selected sherds come just from settlements rather than cemeteries or sanctuaries, to avoid comparisons between too different contexts (see section 5.1). To contextualise and interpret the chemical results obtained, only sites providing archaeozoological and palaeobotanical data have been selected (see sections 5.1). The sampling strategy will be outlined in detail in Chapter 5.

The project has a second, equally important aim: the creation of a first major organic residue dataset on pottery in Phoenician and Punic Sardinia. In the past, a very limited number of organic residue analysis investigations have been carried out on Sardinian pottery (see section 4.4). This situation provided very little information to support archaeological interpretation and to orientate further analyses. The same statement is true for the central and western Mediterranean, not only in the focus period of this research but in general, from the prehistory to the modern era. This current research will enable comparisons with existing databases in other parts of the world. More relevantly, it will open the door for the development of further projects that adopt the same approach in Sardinia and other politically, geographically, and archaeologically related regions and countries.

1.3 Structure of the dissertation

Reflecting the multidisciplinary nature of the project, the first chapters of the dissertation (Chapters 2–4) provide the necessary context for the project and the analyses undertaken for the research. The following chapters (Chapters 5–8) focus on the core of the project: the application of organic residue analysis on selected archaeological sherds and the results obtained from this investigation. In particular, each chapter addresses the following points.

Chapter 2 provides a snapshot of the existing research regarding foodways in Phoenician and Punic Sardinia. The first section describes the archaeological and historical literature and research trends on the topic (2.1.1), followed by a description of available sources for the study of food on the island (2.1.2). The second section of the chapter enumerates and discusses the available data and knowledge about food and foodways in Phoenician and Punic Sardinia (2.2). Particular attention is given to the commodities consumed and cookways since this project focuses on organic residue analysis of preparation and cooking vessels. The description includes data from across the Mediterranean to substantiate evidence when necessary, but it is more focused on Sardinia: given the apparent lack of strong discontinuity in diet between the pre-Phoenician and Phoenician/Punic periods, data about the pre-Phoenician and indigenous world will be included. This chapter establishes the background to the current research.

Chapter 3 describes the archaeological and historical context of both Phoenician and Punic Sardinia and the ceramic assemblages involved in this research. In the first section, a brief archaeological and historical contextualisation of Phoenician and Punic Sardinia and archaeological definitions will be stated (3.1). In the second section (3.2) sites involved in the analysis are described in their location, nature and historical and archaeological developments. In the last section, vessel categories (3.3) selected for the analysis are discussed illustrating shape, function and development over time, illustrating also limits and gaps in the current knowledge.

Chapter 4 discusses organic residue analysis (ORA), how it works, and what commodities can be identified through it. This introduction will identify the limitations and potential opportunities of the technique while enabling the contextualisation of the results obtained to avoid misunderstandings related to undetectable commodities (e.g. cereals or wine). The final part of the chapter (4.4) focuses on examples of archaeological issues investigated through organic residue analysis. The limited examples of the application of organic residue analysis in Sardinia and related areas are also summarised (4.4.3) to illustrate the limitations of the previous evidence base.

Chapter 5 describes the chemical and archaeological methodology adopted in this research. In the first section the selection process used to constitute the assemblage of analysed sherds is described (5.1). In the second section of the chapter (5.2), the experimental protocol is outlined. The protocol describes the sampling method, the procedure followed to extract lipids from the sampled sherd and make the extract suitable for analysis, and the analytical instruments and techniques. This protocol is standard for organic residue analysis and primarily follows previous publications and papers. The chapter is concluded by outlining the methodology used for data management and interpretation (5.2.7).

Chapter 6 focuses on the results of the analysis, illustrated per site (sections 6.1 – 6.6). Data directly relevant for the comparison and contextualisation of results, as faunal and environmental or results of past lipid analyses, ceramic assemblage, environmental conditions, are summarised per each site. Results are then described quantitively (lipid concentration) and qualitatively (identified compounds and commodities) per each site. In each site-section, results are described following the different vessel categories analysed in that site, with specific focus on the most interesting lipid extracts. Existing differences and patterns are also outlined in each site.

In Chapter 7 results of the analysis are discussed per main topics, answering the research questions exposed above (1.2). Section 7.1 is focused on the commodities detected (or not detected) that need more attention since they do not match original expectations, or they significantly broaden previous knowledge. In section 7.2 results are discussed per vessel category, offering a detailed description of insights, issues and questions raised by the data obtained. In the following section (7.3) the topic of continuity and changes over time is discussed. The last section (7.4) focuses on results discussion and interpretation when comparing them between sites, identifying and interpreting local and regional differences.

The conclusions in Chapter 8 briefly summarise the answers to the research questions enumerated above (1.2) and offer insights about foodways in Phoenician and Punic Sardinia that emerged from this research. The dissertation concludes in section 8.3 by outlining possible applications of organic residue analysis related to foodways connected and relevant to this project.

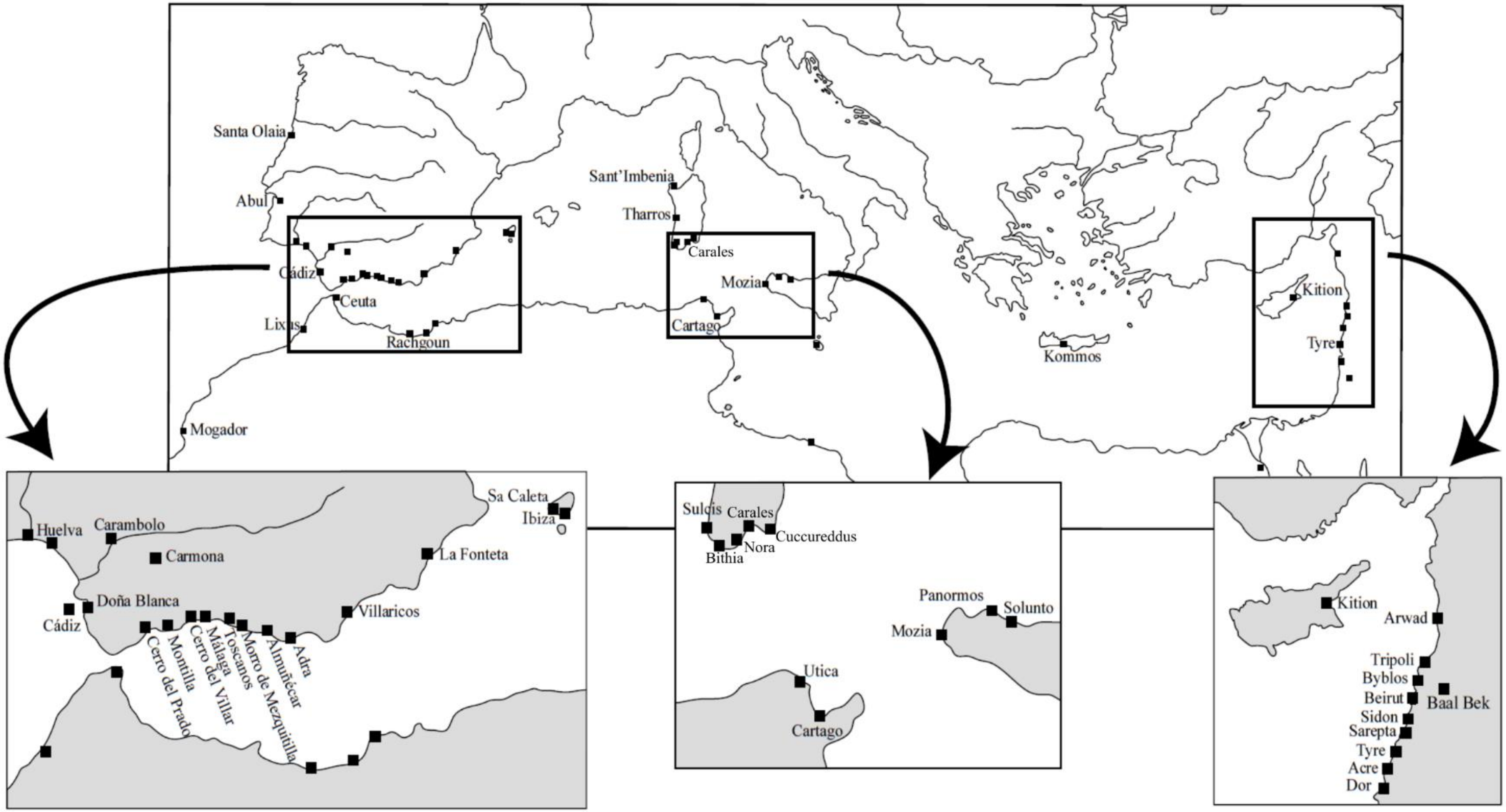


Figure 1. Phoenician sites in the motherland and in other Mediterranean areas, reworked from Delgado-Ferrer 2011b.

Chapter 2
Food and foodways in Phoenician and Punic Sardinia

2.1 Investigating foodways in Phoenician and Punic Sardinia: past and present perspectives

This section builds on the above background to describe the research developments, trends and advancements specifically connected with foodways in Phoenician and Punic Sardinia, i.e. from the 8th century BCE to the 2nd century BCE (for historical development and definitions see Chapter 3). It will outline the discipline's current state-of-the-art and illustrate the contemporary food-related knowledge and available data for the island in the target period.

The section focuses mainly on Phoenician and Punic archaeology, because non-Phoenician archaeology in Sardinia has followed a different path, as outlined by several scholars (e.g. Van Dommelen et al. 2018: 141; Bernardini and Perra 2012). This difference is also evident in the field of foodways. Most of the available synthesis and papers dealing with foodways in Sardinia between the 8th and the 2nd centuries BCE are written by archaeologists focusing on the Phoenician and Punic world. However, as explained in Chapter 3 (sections 3.1.2, 3.3), indigenous ("Nuragic") and Phoenician people interacted for centuries on the island. For this reason, the reconstruction of foodways in Phoenician and Punic Sardinia in this dissertation will also include and describe data and papers focused on Nuragic Sardinia, when possible and useful as a comparison.

2.1.1 Main approaches to the theme and research trends in Phoenician and Punic archaeology

> "Food-related practices are the best-recognized maintenance activities represented in the archaeological dossier: a series of basic procedures, among which personal and gender networks are established, marked by a deep relation of learning and knowledge. This set of specialized activities represents the basis for the creation and reproduction of individual and collective identities, for the legitimization of power relationships, for the negotiation of gender and age and for the creation of intricate and dynamic networks"
>
> *Michele Guirguis, lecturer in Phoenician and Punic Archaeology at the University of Sassari*
>
> (Guirguis 2019a: 123)

It has not been easy to achieve this level of awareness regarding the study of foodways, particularly in the research area of Phoenician and Punic archaeology. The first stage in the development of Phoenician and Punic studies in the 1970s and 1980s followed the pattern of all other branches of Classical and Near Eastern archaeology (Spataro and Villing 2015: 12): when not wholly ignored, foodways were marginalised and discussed as part of "daily life" in general (Moscati 1972). A chapter about "nutrition" is included in the first overviews written about the Phoenicians by Sabatino Moscati (e.g Moscati 1972: 20-31), but it is missing in subsequent editions (e.g. Moscati 1989). In the first decades of the discipline, the first attempts to reconstruct a "Phoenician" way of food and cuisine presented foodways as more or less unchanging over time and geographic region. Descriptions and references to foodways followed two main lines: the first was an analysis and comparison with the Bible or with Latin sources, such as Apicius (Moscati 1972: 20-31); the second was broad assertions made on the basis of the shape of archaeological vessels.

This second line of research is the most interesting for the present study as it is based on material culture, but the hypotheses arising from it lacked robust supporting data. A good example of this trend is Bartoloni's assertion (1996) about a shift in taste and foodways based only on a change in the shape of the dishes. In demonstrating that more recent dish rims were flatter and larger than earlier styles, Bartoloni argued for a shift from liquid meals consumed in the dish to solid meals placed on the rim of the dish, with sauces in the middle. Despite being counterintuitive - food is not placed on dish rims in modern Italy - this idea has been widely accepted (Bondì et al. 2009: 342: Campanella 2008: 79) despite it being more an assumption than a hypothesis based on archaeological or even ethnoarchaeological data.

Beyond these two main research lines established by Sabatino Moscati, some exceptions exist. However, they are only represented by brief papers and contributions. Some focused on the economy (Aubet 1987; Ponisch 1988), or industry and production with regard to nutrition (*alimentazione* in Italian, Bondì 1985; Bartoloni 1994). The foods or products that caused the most scholarly interest were wine and oil (Greene 1996; Heltzer 1993; Lopez Castro 1998; Ponisch 1988). These studies try to highlight contacts, routes and trade between Phoenicia and other parts of the Mediterranean, and local specialisations in agro-faunal productions inside the western Punic world. Other studies mentioning food or consumption in the title mainly highlight archaeological or archaeozoological data (Cardoso 1993; Garcia Petit 1999). None of them focus properly on foodways, i.e. food processing and consumption.

To my knowledge, only two brief papers about Phoenician and Punic diet or consumption practices were published prior to 1999. The first was published by J.-P. Morel and the second by M.L. Uberti. Morel (1998) asked "What did the Punic people drink?" focusing his paper on Punic wine as a whole (trade, plantation, production, social role and consumption) and using archaeological sources (amphoras and vessels) to provide an overview of the issue. The relevance of Uberti's paper (1987-1988) is due to the fact that it focuses for the first time on Phoenician and Punic diet as a whole, or rather on subsistence: the focus is "the energizing constituents of Phoenician diet", seen as proceeding from environmental and geographical conditions and physical needs. Based wholly on written sources, the paper contributed to establishing the basis for subsequent developments in the area, but it was unable to lead further from the data enumerated by eastern Mediterranean (non-Phoenician) and Roman sources. The author often repeats "we do not know" (*non sappiamo*) and "we ignore" (*ignoriamo*), providing a snapshot of the research on Phoenician and Punic foodways at the end of the 1980s.

Until the 21st century, the only kind of commensality widely studied for the Phoenician and Punic world was funerary feasting (Ramos 1990; Jimenez 1994; Quercia 2000; Niveau de Villedary 2006). This was done through a perspective which closely connected feasting with the funerary world and the study of burials, rather than with nutrition and food consumption. As the present study focuses on cooking and preparation vessels from settlement contexts rather than cemeteries, I will not examine the content of such funerary studies in depth, although some information is provided in section 2.2.1.

In 1999, a chapter about "Phoenician and Punic foodways" (Spanò Giammellaro 1999) was included in the major work *Storia dell'Alimentazione* by Flandrin and Montanari (2007). Although based primarily on written sources, this chapter signals the beginning of the integration of Phoenician foodways into the wider debate about ancient foodways in the Mediterranean. Since then, papers focused on foodways in the Phoenician and Punic world have been published more frequently, with wider analyses and perspectives (Spanò Giammellaro 2005; Sarà 2015; Niveau de Villedary 2006; 2011; Campanella 2001, 2003, 2008; Campanella and Niveau de Villedary 2005; Campanella and Zamora 2010; Delgado 2008, 2010, 2016).

In 2008, Lorenza Campanella published the current leading study on foodways in the Phoenician and Punic world: *Il cibo nel mondo fenicio e punico d'occidente: un'indagine sulle abitudini alimentari attraverso l'analisi di un deposito urbano di Sulky in Sardegna.* As the largest study dealing with non-Greco-Roman foodways in the ancient Mediterranean, it is more or less a collection of all available data about foodways in the Phoenician and Punic world, and it is the first attempt to comprehensively analyse them as a whole.

Campanella's work is a benchmark for everyone researching the topic of foodways, allowing outstanding progress to be made in the discipline. However, I also need to highlight some of its limitations because they partially impact the present research. Despite its title, the volume focuses more on pottery than on foodways, being a publication of one of the largest ceramic catalogues for the Phoenician and Punic era: vessels without a relation to cooking and consumption practices are also included. Unfortunately, it lacks a theoretical framework and anthropological or ethnoarchaeological comparanda on food, foodways and culture (the only anthropologist mentioned is Lévi-Strauss [Campanella 2008: 17-29]), and it also overlooks contemporary scholarship from world archaeology about food and foodways (see 1.1). As a result, her interpretations are based almost entirely on ceramic shapes and traces of charring when available. As the standard practice in Italian classical archaeology is to clean all pottery with water, it is likely that many relevant traces were washed away before the study (Vidale 2007). Furthermore, the topic of foodways is treated in the first part of the volume via a combination of archaeological, iconographic and written sources to outline the features of Phoenician and Punic diet. The mix of Biblical, Latin, Egyptian and western Punic data, referring to distant time periods and regions, hinders interpretation and reduces the study to being too descriptive. Despite these criticisms, this volume constitutes the starting point for my present research, playing a fundamental role in the development of food archaeology in the Phoenician and Punic field, and offering a complete overview of relevant research.

Moreover, Campanella's work includes the only organic residue analysis on Phoenician and Punic cooking and preparation vessels in Sardinia undertaken or published to date. This makes the volume essential for my own research.

However, only eight fragments were analysed (Campanella 2008: 260-263), hindering any comprehensive interpretation. These results will be illustrated in Chapter 4 (section 4.4) and considered more widely in the results and discussion chapters.

As already noted (Chapter 1; 1.1.1.2), the scholar who has made the most relevant advances in the discipline of the archaeology of food in the Phoenician and Punic world is Ana Delgado. She has analysed the structure of Phoenician diet and foodways, how they change between the eastern and western Mediterranean, and their social implications (Delgado 2008). She has explored the role of women in domestic and public colonial life, trying to overcome the traditional "separate-sphere" vision (Delgado 2016). This is deeply interconnected with the study of foodways because, in many societies, "cooking falls largely into the female sphere of domestic responsibility and is transmitted from mother to daughter" (Spataro and Villing 2015: 14). Together with her colleague Meritxell Ferrer, she has investigated women's agency in the preparation of funerary meals (Delgado-Ferrer 2011a) and in the creation of a colonial culture, in which culinary customs play a relevant part (Delgado-Ferrer 2012). They have also analysed the role of staple foods and everyday meals in the Phoenician diaspora (Delgado-Ferrer 2011b), a topic which has been largely ignored by scholarship (see 2.2.2.1). In contrast with other Phoenician or Punic foodway studies, Delgado's works are largely based on comprehensive archaeological data (ceramic assemblages, spaces, structures) and interpreted under the lens of explicit and well-established theoretical frameworks, following a post-processual, feminist and postcolonial pattern (Twiss 2007a, 2012; Dietler 2015). She aims to "make visible agencies and give to practices and their key players the relevance they deserve" (Delgado and Ferrer 2012: 127). In her papers, archaeological assemblages useful to address her questions, such as artisan districts (Delgado 2016) or cemeteries (Delgado and Ferrer 2011a), are comprehensively analysed, compared and presented, coherently combining materials, objects and spaces. This approach, following the basis of an explicit theoretical (feminist) framework, is still innovative in western Mediterranean archaeology and particularly relevant for my research. Her insights and assertions, despite not being focused on Sardinia, will often be mentioned in my interpretation in Chapters 6 and 7. Her works constitutes a benchmark for any social study about cooking and consumption practices in the Phoenician and Greek colonial world.

The topic of Phoenician and Punic foodways is likely to become a key subject in archaeology over the next few years, thanks to the work of Carlos Gomez Bellard's research group at the University of Valencia (Spain). The group has already published papers focusing on foodways in Ibiza (Vendrell Betì 2016) and Sardinia (Morales et al. 2010), but the most relevant event took place recently, with a conference called *La alimentaciòn en el mundo punico* (Foodways of the Punic world, Valencia, 15-16 June 2017), and the subsequent volume (Gomez Bellard et al. 2020). For the first time, scholars from across Europe researching the theme of Phoenician and Punic foodways, even tangentially, met to discuss ideas, perspectives and experiences. Researchers at the conference included archaeozoologists, environmental archaeologists, palaeobotanists, pottery experts and physical anthropologists. After decades of food studies appearing as an isolated topic in Phoenician archaeology, this represented a huge advancement for the discipline. A volume proceeding from the conference will be published soon, serving as a new benchmark for anyone undertaking the study of foodways in the Phoenician world and in the ancient Mediterranean.

The discipline is currently experiencing an expansive, interdisciplinary and experimental phase. The topic is no longer neglected (Morales et al. 2010; Sarà 2015; Marin-Aguilera 2016), and, as evidenced by the recent Valencian conference, it is being introduced to many different perspectives. It should be noted that the recently formed international research group *AGEMO-Archéologie du goût en Méditerranée occidentale dans les sociétés phénicienne et punique ,* which organised a conference of the same name in Tunis in November 2019, is following up with a conference about taste and foodways ("*Les goûts et les habitudes alimentaires*"). This will be a new, relevant step for the discipline. Additional recent developments include: social approaches to ceramic production (London 2016; Klarich 2010; Vendrell Betì 2016); consideration of archaeofaunal data (Crabtree 1990; Russell 2012; Cardoso et al. 2016) in the Phoenician and Punic world in relation to human diet and behaviour; the application of organic residue analysis (Beehr and Ambrose 2007; Campanella 2008; Oggiano and Botto 2012) and isotope analysis (Fuller et al. 2010). This dissertation locates itself at the heart of the debate, aiming to study and combine archaeological approaches, environmental and faunal data, and the results from organic residue analysis.

2.1.2 Main sources for the reconstruction of foodways in the Phoenician and Punic world and Sardinia

The sources used throughout this dissertation are composed of literary, epigraphic, iconographic, archaeological, palaeoenvironmental, archaeozoological, archaeometric, anthropological and ethnoarchaeological references. I will briefly describe them and their potential, their limitations and their availability.

Written sources used to be the most common basis for the reconstruction of Phoenician and Punic foodways (see above 2.1.1). They are widely used in this study since they offer extensive information about recipes or traditions (e.g. Cato, *De Agri Cultura,* 85; Columella, *De Re Rustica,* XII, 46, 5-6). However, all literary sources dealing with Phoenician and Punic foodways are foreign sources, and often quite distant in space and time from the context of this project. The most important are Biblical, Egyptian, Assyrian and Ugaritic texts referring to the East, and Greek and Roman sources (specifically about agronomy, e.g. Cato, Pliny) referring to the West (Campanella 2008: 15). With the exception of the epigraphic texts described below, direct sources in the Phoenician language dealing with foodways are not available. However, it is possible to find direct references to Punic sources and authors written in Latin. The most important is the Carthaginian author Mago, who in the 3rd century BCE wrote a treaty on agronomy that was later translated into Latin. As explained above, the coherence of Phoenician and Punic culture over time is highly debated, so these sources offer only limited information about Sardinia.

Epigraphic sources available in Sardinia refer to votive or funerary inscriptions and rare words painted or engraved on vessels (Campanella 2008:54; fig. 2); these inscriptions, however, do not deal with food. Punic writing related to sacrifices, offerings or feasting instead often focus on the sacrificed and consumed food (Amadasi Guzzo 1988; 1990), but these sources are related to ritual or religious contexts, limiting their relevance for the study of everyday foodways; moreover, the most informative ones do not come from Sardinia.

Figure 2. Ceramic fragment with Phoenician letters from the settlement of Sant'Imbenia (Guirguis 2017, fig. 24).

Iconographic sources, for example terracotta figurines and models, stelae or clay stamps (Vendrell Betì 2016: 366-367), constitute the direct production of the investigated culture. For the western Phoenician world, statuettes are particularly relevant because some of them offer representations of cooking, preparation and consumption scenes, related not only to rituals but also to everyday life (Delgado and Ferrer 2011a: 200) (fig. 3). Unfortunately, themes are limited to activities that were more socially relevant, and only a few figurines related to food processing or consumption are attested in Sardinia. These mainly represent offerings. Other types of iconography, demonstrated in objects related to the funerary or ritual practices (e.g. stelae, sarcophagi), are less suitable for comparisons and analyses focusing on domestic foodways.

Archaeological data used to detect and reconstruct foodways are numerous and varied: approaches can focus on ceramics (shape, assemblage, fabric, consumption; a good overview specifically related to foodways is in Spataro and Villing 2015), domestic and public spaces, structures used for cooking and dining. They are the most important sources about everyday life and food in many of the lands of Phoenician migration, where written and iconographic sources are few. In Phoenician and Punic archaeology, however, these sources had a limited use until recently. Many articles written by archaeologists were primarily based on written sources (see above, 2.1.1), thus often hindering the wider understanding of local foodways. This situation has changed in the last ten years: archaeological analysis of cookware (Campanella 2008) and more general data about spaces and structures obtained from archaeological excavations (Delgado 2008; Marin-Aguilera 2016) are now included in every paper dealing with Phoenician and Punic foodways, as has been explained in section 2.1.1.

Archaeozoological data, i.e. faunal remains, are probably the most suitable data about foodways and diet available for Phoenician and Punic Sardinia. The collection and publication of data in Phoenician and Punic contexts started decades ago (Lancel et al. 1982; Sorrentino 1992), and, compared to literary or iconographical sources, the Sardinian evidence base is relatively large (Manconi 2000; Farello 2000; Wilkens 2012; Depalmas et al. 2015), allowing comparisons with other time periods and geographical areas. However, flaws and biases in this database have to be considered. Beyond the limitations and differing quality of the studies (e.g. butchery marks have only rarely been published or analysed), the biggest problem is the systemic non-scientific or non-methodical collection of bones, often undertaken by archaeologists who were unaware of archaeozoology. As noted by Crabtree (1990: 181), "the lack of wet-screening will not only dramatically reduce the quantities of bird and fish bones recovered but will also impair the recovery of the smaller bones of medium-sized mammals such as sheep, goats, and deer which leads to a general under representation of fish, birds, small mammals and small bones in general". This kind of collection is unfortunately very common in the target area and easy to identify in the publications (Wilkens 2012: 14). However, this bias is well known and can be taken into account. It is simple to avoid misunderstandings based on the absence (or rarity) of some animals in the archaeological record.

Figure 3. Clay figurine showing food preparation (left) and clay figurine representing three baskets of bread (right), Tyre (Lebanon), 8th-6th century BCE (Delgado-Ferrer 2011b).

Palaeoenvironmental data, such as palynology and seed analyses, can offer a picture of the contemporary environment and economic or exploitation strategies. Although a recent article by Sabato and his colleagues (2018) stated that "Phoenician and Punic archaeobotany is still in its infancy" and that "in Sardinia, plant remains also are scarce due to the lack of systematic recovery there" (Sabato et al. 2018: 10), the development of such studies has been significant in recent years. Starting from isolated past studies (Wetterstrom 1987; Bakels 2002), recent papers are providing additional information both about the Phoenician and Punic period (Di Rita and Melis 2013; Buosi et al. 2016; Sabato et al. 2018) and the previous and following periods (Sabato et al. 2015; Ucchesu et al. 2014a; b). The information is limited and distributed over time and geographic area, but still suitable and informative for the present research.

Palaeopathology and bioarchaeology can potentially be informative about past diets. They can reveal diseases connected with deficient nutrition or gender and age gaps in food behaviour and access (White 2015). Unfortunately, anthropologists have rarely been involved in the excavation of Phoenician and Punic necropolises in the past (Màrquez-Grant 2006), but new data from Sardinian contexts have been recently published (Guirguis et al. 2017; Pompianu 2017). To my knowledge, isotope analysis on bones enabling the detection of the individual's diet (White 2015) have been applied only once in a Phoenician or Punic context (Fuller et al. 2010), and this did not occur in Sardinia. It is possible that new isotopic data will be published soon for a Sardinian context (Pompianu 2017).

As already discussed, organic residue analysis is extremely informative, but it has had a limited application in Sardinia and the western Mediterranean. Due to the nature of this project, the application and results of organic residue analysis in Sardinia and the Phoenician and Punic world will be described in-depth in Chapter 4, section 4.4.

Finally, data from ethnography and cultural anthropology has also been included. These can be divided into two categories: direct comparison with societies considered in some way "similar" to past societies under investigation, and ethnoarchaeological data used to better understand customs and uses of pre-industrial societies. While the first set of data has been widely used in Phoenician and Punic archaeology, especially comparing Carthaginian vessels and tools with vessels still in use in contemporary rural North Africa (e.g. identification of Phoenician ovens [Peréz Jordà et al. 2010: 300]), only a few authors more broadly integrate ethnoarchaeological and anthropological data and approaches (London 2016; González Urquijo et al. 2000) in their analysis of the Phoenician and Punic past (e.g. Delgado 2008; Marin-Aguilera 2016). This field could significantly advance in the coming years.

2.2 Food and foodways in Phoenician and Punic Sardinia: current knowledge

In this section, the primary information available about food production, preparation and consumption in Phoenician and Punic Sardinia will be illustrated. Due to the nature of the sources (see section 2.1.2 above), the section will mainly provide an overview about Phoenician and Punic foodways,[1] or use papers that cover specific sites, both Phoenician and indigenous. For this reason, despite focusing on Sardinian data and contexts, data about non-Sardinian contexts, especially in the central and western Punic Mediterranean, will also be included. This approach can potentially cause misinterpretations or overinterpretations due to the variety of local cuisines and traditions in the so-called Phoenician and Punic world. However, I still consider the analysis of all available information about this archaeological culture, created by people coming from a coherent geographical area and speaking the same language, a useful tool to frame foodways in Phoenician and Punic Sardinia due to the rarity of locally written or iconographic sources.

Knowledge about foodways in Phoenician and Punic Sardinia is incomplete: although there are excellent publications containing archaeological, faunal or environmental data, not all chronological periods or geographical regions have such data available. As already mentioned, no comprehensive monograph or analysis has ever been published. For these reasons, this section will be organised using available sources, data and current discussions, reflecting the messy nature of the evidence base. A more formulaic structure, presenting sources and data in the same order, would be potentially misleading due to the very different quality of data and sources.

Information and data about foodways in Late Bronze Age and Iron Age Sardinia will also be considered and occasionally outlined because continuity in life practices is suggested for the two periods (Wilkens et al. 2015; Bakels 2002). This is a way to expand our available data for the island. Diet in the Nuragic period is likely to have been similar for the one

[1] The comprehensive volumes published by Lorenza Campanella (2008) and Alicia Vendrell-Betì (2016) will constitute the basis of this section.

described for the Phoenician and Punic periods. Cereals, legumes, vegetables and fruit likely constituted the main part of subsistence (Ucchesu et al. 2014b; Lo Schiavo et al. 2015), and the contribution of meat was relatively limited. Indeed, "the foundation of the Phoenician settlements […] signalled a new situation, but not one that was radically different from what had gone before (Tronchetti-van Dommelen 2005: 195)." For this reason, knowledge about pre-Phoenician Sardinian diet is a relevant interpretation tool.

I chose to divide this section between food categories (e.g. cereals, legumes, meat) because information about "foodways" as a whole is extremely limited. Relevant information related to the preparation and consumption of each commodity will be described in each paragraph. The information on commensality and consumption not directly related to one commodity or food category is instead described in section 2.2.1 below.

2.2.1 Introductory notes on consumption and commensality

In line with the research questions outlined in the introduction only vessels related to cooking and food preparation from settlement areas have been included in my project (Chapter 1; 1.2). Most archaeological knowledge about feasting and commensality in the Phoenician and Punic world and Sardinia comes from funerary sites (Niveau de Villedary 2006) and vessels such as dishes and cups, neither of which are included in this research. For this reason, limited attention is given to commensality in Phoenician and Punic Sardinia within this dissertation. The state-of-the-art about the topic of consumption and commensality will be briefly outlined here.

Commensality in Phoenician and Punic Sardinia has received limited research interest, as mentioned above in section 2.1. Published works previously focused more on wine than on commensality and feasting as a whole (e.g. Bartoloni 2017, see 2.2.2.7). Outside of Sardinia, several scholars focused on the more archaeologically detectable topic of funerary feasting (Ramos 1990; Jimenez 1994; Quercia 2000; Niveau de Villedary 2006; Delgado and Ferrer 2011a) as well as other feasts and everyday meals (Delgado 2010; Degado and Ferrer 2011b).

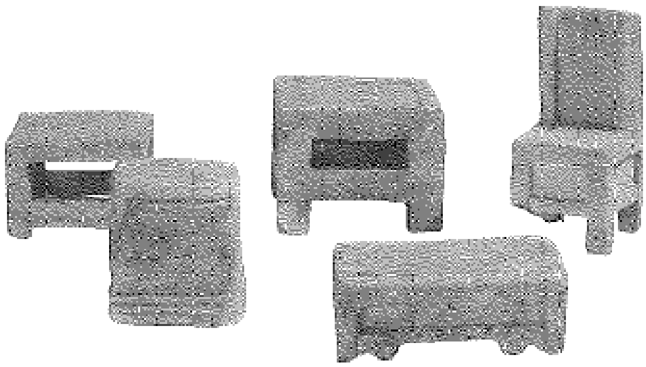


Figure 4. Clay furniture models from Carthaginian tombs (Campanella 2008: 52).

As in other archaeological fields, the emphasis in Phoenician and Punic archaeology has also been on extraordinary meals and feasting, portraying everyday meals as a mere way to obtain fuel for the body (Delgado and Ferrer 2011b: 186; see also 2.1). Only recently has this trend started to be overturned. It is likely that everyday meals were sometimes consumed sitting at small tables or chairs, as the ones shown in fig. 4, or, more often, sitting on the ground using carpets and mats (Campanella 2008: 52). As explained in section 2.2.2.1 below, the unifying everyday food for Phoenician and Punic people were cereal-based meals, such as breads or porridges, which were used to enhance relationships among different people in the western colonies (Delgado 2010). As stated by Ana Delgado and Meritxell Ferrer, “consumption of cereal-based breads and of certain porridges that were prepared following Eastern culinary traditions (as indicated by the shape of some of the cookware) suggesting that some of the inhabitants of these colonies used everyday food as a way of recreating memories that tied them to the homeland” (Delgado and Ferrer 2011b: 189).

Feasting in sanctuaries, certainly practised in the Phoenician and Punic cultures, has received limited research interest, and for this reason is not debated in this dissertation. The first synthesis published, to my knowledge, is dated to 2020, and focused on Cadiz in Southern Spain (Niveau de Villedary 2020). Far more is known about funerary feasting, the time-consuming and expensive ritual that occurred in the Phoenician and Punic necropolises. They were the last part of the funerary rite and used to commemorate the deceased. They involved the collective consumption of meals and the ritual breakage of dishes inside and near the tomb; feasts could last for several hours and be repeated multiple times for the same tomb (Bison 2015b: 45-48). Most of the authors underlined that in this migratory context feasts were used to build and strengthen communities and identities (e.g. Delgado and Ferrer 2007; Amadasi Guzzo 1988). “Sacred dumps” used during the feasting have been archaeologically identified (Niveau de Villedary 2006: 42). Feasting is attested in nearly every recently excavated Phoenician or Punic necropolis.

Funerary feasts are often associated in literature with the Semitic practice of *marzeah* (MRZH). However, as well established by several historians (e.g. Podella 1996; Amadasi Guzzo 1988), although Phoenician funerary feasting originated from the practice of *marzeah,* they are not synonymous. The Semitic practice of *marzeah* has been widely debated in the literature, with some sources attributing *marzeah* to societies or confraternities based on feasting practices (Bartoloni 2017: 330; Wecowski 2014: 150-159). The existence of such societies is attested by epigraphic sources on bronze or ivory plaques since the 2nd millennium BC in Ugarit, and it is widely recorded in the Phoenician West (Bartoloni 2017: 330; Amadasi Guzzo 1988: 118). These societies organised ritual banquets, dedicated offerings to deities (Amadasi Guzzo 1988) and were likely used in the West to both enhance relationships among people of different ethnicities and inside the Phoenician migrant community. There is no direct evidence relating *marzeah* to Sardinia, but there is no reason to exclude that these societies existed on the island.

2.2.2 The main constituents of diet, with notes on preparation and consumption

2.2.2.1 Cereals, porridges and breads

Cereals constituted the base of the diet in Phoenician and Punic Sardinia. They were the staple food for Phoenician and Punic people, as was common in the Syro-Palestinian area around the 1st millennium BCE (Delgado 2010). Cereals acted as a unifying element in the western Phoenician colonies (Delgado and Ferrer 2011b). They also served as the key dietary element for indigenous Sardinian people (Lo Schiavo et al. 2015; Ucchesu et al. 2014b). This assertion is confirmed by all available sources, and the topic has already been widely discussed in previous works such as Spanò Giammellaro 1999; Campanella 2008; Vendrell Betì 2016; Delgado and Ferrer 2011b. The main research outcomes are outlined here.

Diet and subsistence. The cereal species grown as crops and consumed are mostly described in written sources, combined with the available palaeobotanical evidence. As in the East (Delgado and Ferrer 2011b: 187), in the Phoenician and Punic western Mediterranean the most important cereals were generally barley and wheat (Campanella 2008: 57); the same cereals comprised the base of agriculture in Bronze Age Sardinia (Ucchesu et al. 2014b: 353), with no changes recorded in the Iron Age. Barley, more common in the earlier period, seems to have been gradually abandoned in favour of wheat across the ancient Mediterranean. In historical times, wheat was valued more than barley, both socially and economically (Delgado 2010: 31; Niveau de Villedary 2006: 59). In Sardinia, available data for the Phoenician and Punic period is limited. Palynological analysis undertaken in the Su Muru Mannu area of archaic period Tharros revealed a prevalence of grain (*Triticum sp.,* 73.68%) over barley (*Hordeum sp.,* 26.32%) (Campanella 2008: 57). In Nora, only oats (*Avena sp.*) have been identified in the Punic layers (Miola et al. 2009). In the Punic period at S'Urachi, wheat (*Triticum aestivum-durum*) is predominant, followed by barley, and millet (*Panicum limiaceum*) attested in the latter layers (van Dommelen et al. 2019: 153).

This data suggests wheat was the most important cereal in Phoenician and Punic Sardinia, confirming the written sources. In late Roman-era sources, Sardinia appears to be connected with growing wheat, while North Africa was linked with barley (Manfredi 1993). To summarise, despite the lack of palynological analyses for my target period, available evidence allows us to theorise the existence of an agricultural system based on cereals and the use of large estates in Sardinia from the Late Punic period, at least in the Campidano plain (Bondì 1985). This evidence includes the results of palaeoenvironmental studies (Acquaro et al. 2009; Miola et al. 2009; Di Rita and Melis 2009) combined with research on previous periods (Ucchesu et al. 2014b), written sources (Bondì 1985; Manfredi 1993) and archaeological data such as silos and stock rooms (Campanella 2008: 58; Miola et al. 2009). All this will be discussed further in section 2.2.2.3.

The role of cereals in the Phoenician diet is also confirmed by isotopic analysis on contemporary skeletons from the island of Ibiza (Fuller et al. 2010), and by paleopathological analyses undertaken in Punic necropolises (Guirguis et al. 2017; Vendrell Betì 2016: 42-43). The populations analysed in Ibiza had limited access to proteins and vitamins, so they were unable to obtain a balanced diet. This isotopic data is consistent with bioarchaeological data in Punic Sardinia detecting diseases such as *cribra orbitalia* and *cribra cranii,* or dental decay and tooth loss in young individuals, typical of diets primarily based on cereals (e.g. Di Salvo 2004: 256; Guirguis et al. 2017).

Written sources offer additional insights about the role of cereals. Biblical texts offer several references to cereal consumption and preparation, some of which specifically reference the Phoenician people. In 1 Kings 17,12-13, for example, a poor woman from the Phoenician city of Zarephath is visited by Elijah and says, "*I don't have any bread—only a handful of flour in a jar and a little olive oil in a jug*", suggesting it as unusual and dramatic. In 1 Kings, 5, 11 wheat and barley seem to have been the two main staples on the Tyrian royal tables (Delgado and Ferrer 2011b: 187). These sources suggest cereals and breads as a unifying element for the inhabitants of eastern Phoenicia.

Late western sources seem to confirm cereals as a staple food for Punic people. In the 3rd century BCE, the Latin author Plautus uses the word *pultiphagus* (polenta eater) as a denigratory term for "Carthaginian" (Mostellaria, 828). Although this definition could have reflected more of a cliché than a contemporary reality[2], it is likely to have originated from genuine widespread consumption of cereals in the Punic world.

Cereal processing and consumption. Thanks to several recent works, information is available about preparation and consumption processes. It has to be highlighted that in the Syro-Palestinian area, and namely in Phoenicia, "archaeological, iconographic, and literary evidence suggests that […], household milling, cereals preparation, and baking activities – the basis of most households' daily diet – were carried out mainly by women" (Delgado and Ferrer 2011a: 2000). Although no written text is available, this also likely occurred in Phoenician communities in the west, including Sardinia (Delgado and Ferrer 2011b: 190).

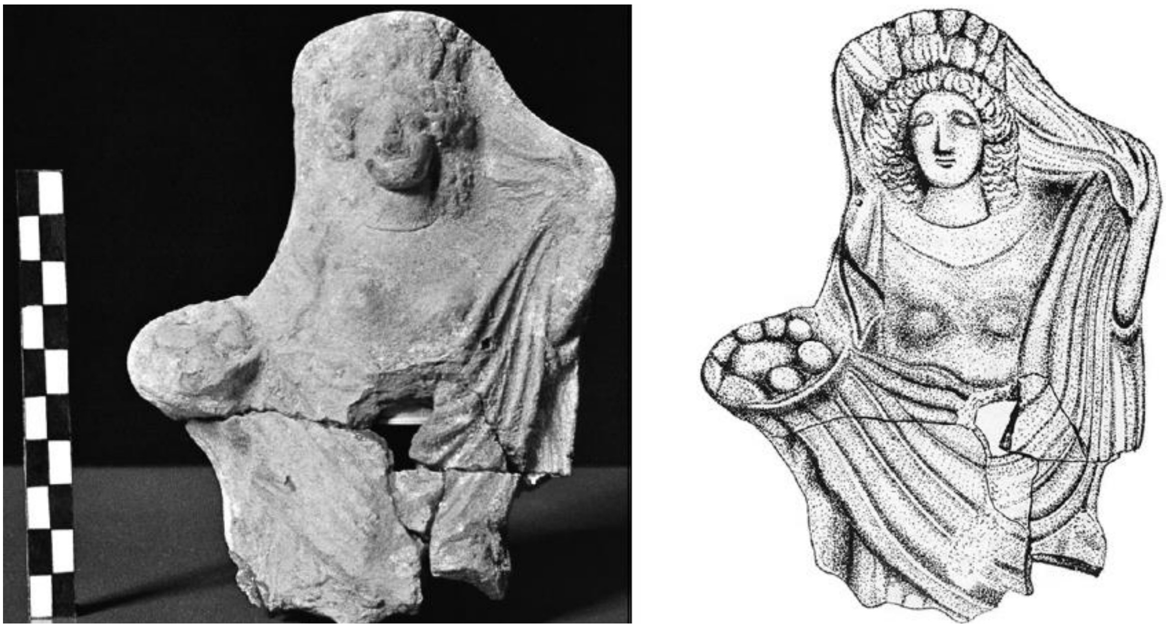


Figure 5. Clay female figurine carrying bread or cakes from Puente de Noy (Granada, Spain), 4th century BCE (Delgado-Ferrer 2011b).

Cereal grains were roasted or toasted (Campanella 2008: 58), but probably more often prepared in the form of breads or porridges (*puls*). These *puls*, a word usually translated in English as "porridge", were obtained by boiling grains for hours, a detail which is often lost in translation. These cereal preparation processes, from bread to porridges, fulfilled different social functions (Delgado-Ferrer 2014: 189; Marìn-Aguilera 2016: 206).

Bread, and other bread-like meals (cakes*, focaccia*), were probably the most socially evaluated way to process and consume cereals. The social relevance of breads is confirmed by the large number of figurines showing bread preparation (Vendrell Betì 2016: 367) or offerings (Delgado 2010: 35) (fig. 5), primarily involving women. Breads were mainly cooked in cylindric ovens, the so-called *tannurs* or *tabouna* (see 3.3.5), with the product placed on the wall of the oven as clearly shown by iconographic sources and modern comparisons to some rural areas of North Africa (Campanella 2008: 50; fig. 6). The task of bread making was undertaken at home or in communal areas shared among

[2] A similar denigrating definition, *polentone* (polenta eater) is used *today* in Italian as derogatory for northeast Italian and northern Italian in general. This comes from an historic reality: in several rural areas of northern Italy, poor people had to consume *polenta* nearly every day, at least until the 1940s. The word, however, is still used today when *polenta* is consumed at special occasions such as fairs and family roasts, having been substituted with bread in everyday meals.

several female neighbours; these have been found both in the Phoenician motherland and in the West (Delgado-Ferrer 2011b: 190; Delgado 2010: 42). This act of breadmaking and processing, which took place in every Phoenician household, was central to the construction and strengthening of social relations in these colonial settlements, as well established by several papers (especially Delgado 2010; Delgado-Ferrer 2011b). The act of sharing bread is still attested at contemporary fairs in specific areas of Sardinia, where the community makes bread together and shares it (Counihan 1999).

Figure 6. Heating system in Phoenician and Punic ovens (tannurs), from Campanella 2001.

Notably, archaeological evidence is not the same from the whole Phoenician and Punic western Mediterranean. Ovens are more widely attested on Sardinia and in the central Mediterranean than in other western Phoenician areas. They are very rare in southern Iberia and Morocco (Marin-Aguilera 2016: 206; Pérez Jordà et al. 2010: 300). The baking tray, another ceramic vessel usually related to breadmaking in Phoenician contexts (see Chapter 3, 3.3.4), is typically Sardinian, deriving from an indigenous tradition (D'Oriano 2012). The distribution of ovens and baking trays suggests that breadmaking was not the most common way to process cereals in Phoenician colonies of the extreme West (Delgado 2010: 35; fig.1).

Cereals were also consumed boiled in porridge. Consuming boiled grains in this way had a lower social standing and role (Delgado 2010: 31; Marìn-Aguilera 2016: 206) but it was extremely common, as suggested by the wide distribution of globular cooking pots across the areas of Phoenician migration (see Chapter 5.1). These globular cooking pots, originating in the East, become a cultural marker during the Phoenician diaspora (Spagnoli 2010; Mansel 2011). They are perfectly functional for stirring and retaining heat inside the vessel for the long time required for making *puls* (Spataro and Villing 2015: 6). The available evidence suggests that boiling cereals became the dominant form of cooking in the western and central Mediterranean in the Phoenician and Punic period (Delgado-Ferrer 2014: 200). This picture is confirmed by sources equating "porridge eaters" to Carthaginians. Moreover, one of the few Punic recipes (Cato, *De Agri Cultura,* 85) describes a *puls punica* made using wheat, fresh cheese, honey and one egg. It was probably common to obtain a porridge by mixing cereals with legumes, adopting the same pots and techniques for both. These recipes were probably popular due to the protein-based contribution but, based on the available palaeobotanical evidence, less common than cereal-only porridges, (see below; Campanella 2008: 59).

Figure 7. Clay stamp ("pintadera") to decorate bread from Tharros (5th century BCE?), Museo Archeologico Nazionale di Cagliari.

These cereal-based foods were also involved in rituals and offerings (Delgado and Ferrer 2011b: 194). In Sardinia, these offerings were probably bread-based. This is indicated by the existence on the island of Nuragic bronze figurines offering bread and of Punic and Nuragic clay stamps used to impress specific shapes on bread and *focaccia* (Campanella 2008: 61; Fariselli 2017: 312; fig. 7), the latter appearing to have been a local re-creation of an Eastern tradition (Delgado-Ferrer 2011b: 197). In other areas of Phoenician colonisation, especially the temple of Tas-Silg in Malta, porridge became an acceptable and common offering, differently from the eastern and previous tradition of offering breads and not porridges (Delgado-Ferrer 2011b: 199-200).

All along this section on cereals, local differences have been suggested in cultivation, consumption, processing or ritual uses. The detection of differences suggests that, despite cereals being a unifying commodity in the Phoenician and Punic world, the way these were processed and consumed varied between areas, as well established by Delgado and Ferrer (2011b). These variations depended on a multiplicity of aspects, as the migrant experience, the interaction with local communities and the role cereals had in the area before, and, in general, the development of foodways. This, once more, explains why focusing on consumed ingredients and foodstuff is only the basis of comprehension of past foodways.

2.2.2.2 Legumes

Legumes constitute a vital element in every carbohydrate-based diet characterised by limited animal products, a category to which the Phoenician and Punic diet appears to belong (Campanella 2008: 61; Vendrell Betì 2016: 57). Legumes are necessary not only as a substitute for animal proteins, but also as an iron provider, the lack of which leads to pathologies, as *cribra orbitalia*, occasionally found in Punic contexts (e.g. at Monte Sirai (Guirguis et al. 2017) or Palermo (Di Salvo 2005: 256)).

Together with references from available written sources (Biblical or Roman, see Campanella 2008: 62), palaeobotanical analyses offer robust data on legume consumption in the Phoenician and Punic West. At Phoenician and Punic sites, legumes never exceed a fifth of the overall remains of cultivated species, although they always represent the second largest plant category after cereals (Campanella 2008: 62). Legumes have rarely been recovered or recorded in Phoenician and Punic Sardinian contexts. *Leguminosae* pollens are known from Tharros (Acquaro et al. 2001: 49); lentils, broad beans and possibly peas have been recovered in the exceptionally well-preserved context of S'Urachi (van Dommelen et al. 2019: 153; see also Chapter 5). This general absence is also likely due to contextual and environmental conditions. Much of the palaeobotanical data available for Sardinia is from amphoras recovered in lagoons, and "waterlogging does not favour preservation" of legumes (Sabato et al. 2018: 11). At this stage of research, the proportion and relevance of legumes in Phoenician and Punic Sardinia can only be hypothesised by combining data from Bronze Age and Iron Age settlements (Bakels 2002; Ucchesu et al. 2014b), limited data from Phoenician and Punic contexts on the island (Acquaro et al. 2001), and other data from extra-Sardinian Phoenician contexts (e.g. Ibiza and Iberian Peninsula, Vendrell Betì 2016: 58). No major changes between the Late Bronze and Iron Age have been identified in Sardinia (Bakels 2002) and the available data do not contradict data from other Phoenician and Punic sites outside the island.

Available evidence indicates that the most common legumes in the Phoenician and Punic West (as in Sardinia) were broad beans (*Vicia faba*), chickpeas (*Cicer arietum*), lentils (*Lens culinaris*) and green peas (*Pisum sativum*). Chickpeas represent the only change compared to the previous period. Indeed, broad beans, lentils and green peas constitute the main legumes in Bronze Age Sardinia (Ucchesu et al. 2014b: 353) whilst chickpeas are common during the Phoenician and Punic period. Although no precise proportion is available, they are mentioned as the second largest group of legumes by Campanella (2008: 62) and Vendrell Betì (2016: 57). This is unsurprising as, according to ancient authors (Moscati 1972: 23), they were probably introduced to the West by Phoenician people (Vendrell Betì 2016: 57). Furthermore, Cato (*De Agri Cultura;* Vendrell Betì 2016: 58) records a variety of chickpea named "Punic chickpea". Palaeobotanical data appear to confirm the Phoenician origin of chickpeas; the most ancient chickpea remains in the western Mediterranean are from 8th century BCE layers at Castillo de Doña Blanca in Southern Spain and Lixus in Morocco (Vendrell Betì 2016: 57-58; fig.1).

Broad beans seem to have been the most common legume based on the limited data, attested both in Punic settlements at Puig d'en Valls (Pardo 2015: 133-134) and pre-Phoenician settlements in Sardinia (Ucchesu et al. 2014b). Lentils, often found archaeologically (Vendrell Betì 2016: 58-59), are also recorded in a relevant source: Pliny's *Naturalis Historiae* (XVIII, 98; see below) explains how to roast and grind lentils, quoting the opinion of the Punic Mago (Campanella 2008: 62). Green peas seem to have been less common according to the palaeobotanical record. However, a variety of pea named *Punicum* is mentioned in Columella (*De Re Rustica* II, 10, 20; IX, 1, 8).

Regarding the consumption, preparation and processing of legumes, several practices have been hypothesised based on the available written sources. Legumes can generally be preserved for long periods of time once dried, and they could have been consumed dried or boiled in soups; if ground to make flour, they could be consumed in breads (Campanella 2008: 62). The previous quote by Mago discussing lentil and chickling (a specific type of pea) processing suggests legumes were used in a similar way to cereals (Pliny, Natural History, XVIII, 98; trans. W. H. S. Jones): "As to the actual method of pounding corn, we will put forward the opinion of Mago: he says that wheat should be steeped in a quantity of water beforehand, and afterwards shelled of husk and then dried in the sun and well pounded in a mortar; and barley should be treated in a similar way; of the latter, he says, 20 sixteenths should be wetted with two sixteenths of water. Lentils must be roasted first and then mixed with bran and lightly pounded, or with a fragment of unbaked brick and half a peck of sand added to each 20 sixteenths. Chickling to be treated in the same ways as lentils. Sesame to be steeped in warm water and spread out, and then rubbed well and dipped in cold water so that the chaff may float to the top, and again spread out in the sun on a linen sheet; and if this is not done very quickly it turns musty with a livid colour".

There is little else that can be stated about the consumption and preparation of legumes, since archaeology has not recognised practices, spaces or objects specifically linked to these activities. Legumes were probably processed together with cereals. To the best of my knowledge, no seeds have been found and examined in contexts clearly connected with cereal or legume processing.

2.2.2.3 Vegetables and fruits

Both vegetables and fruits undoubtedly played a fundamental role in Phoenician and Punic diet; however, they have been recovered at different rates. While fruits are often depicted in artworks and models (fig. 8), and, more importantly, preserved as charred seeds, vegetables cannot be easily recovered archaeologically (Campanella 2008: 63). References to vegetables are extremely limited and identifications are only tentative (e.g. Acquaro et al. 2001: 49). As a result, our knowledge about vegetables in the Phoenician and Punic world is primarily based on a limited number of written sources, while far more conclusions can be drawn about fruits. Notably, organic residue analysis can occasionally enable identification of vegetables and plants, as will be explained in Chapter 4 (Roffet-Salque et al. 2016; Dunne et al. 2016).

Known vegetables are limited to: garlic, known to have been often used in Carthaginian recipes (Pliny, *Historia Naturalis,* XIX, 112; Columella, *De Re Rustica,* XI, 3, 20; Vendrell Betì 2016: 115); artichokes (Pliny, HN, XIX, 43, 152); leeks (Pliny, HN, XIX, 112); and cabbages (Campanella 2008: 65). Moreover, combining data from the Roman world and assuming continuity, other vegetables have been attributed to the Phoenician and Punic diet (Vendrell Betì 2016: 115), such as onions, turnip, lettuce, and cardoon (Spanò Giammellaro 2007). It is not clear how many of these products were part of the Sardinian diet as written sources mentioning vegetables in the Punic world often focus on Carthage (Vendrell Betì 2016: 115).

Knowledge about fruit is broader. Written, iconographical and archaeological sources have enabled some scholars to outline which fruits constituted part of the diet in the Phoenician and Punic world in general (Spanò Giammellaro 2007; Campanella 2008: 65). With specific focus on Sardinia, several recent papers have broadened our knowledge about fruit consumption, cultivation, use and trade on the island (e.g. Del Vais and Sanna 2009; Buosi et al. 2016; Sabato et al. 2018). Fruits could have been consumed in several different ways, but they were also used to preserve or flavour meat traded inside amphoras (Del Vais and Sanna 2009; Portas et al. 2015; Sabato et al. 2018; see section 2.2.2.4 below).

In pre-Phoenician Sardinia, wild fruits such as grapes, figs, berries, and plums were the most relevant produce (Ucchesu et al. 2014b: 353). This list differs slightly from fruits recorded for the Phoenician and Punic period. According to Vendrell Betì's synthesis (2016: 117-146) based on literary, iconographic and archaeobotanical evidence, the main fruits consumed in the Phoenician and Punic Mediterranean were figs, pomegranates, plums, apples, pears, dates, grapes and olives. The latter two fruits are connected with relevant products such as wine and oil. Equally important were nuts: acorns, chestnuts, pine nuts, almonds, walnuts, hazelnuts and pistachios. Several of these fruits come from the eastern Mediterranean or had been domesticated in the East earlier than on Sardinia. At the present stage of research it is not easy to establish which cultivations were introduced on the island by the Phoenicians and which appeared between the end of the Bronze Age and the Iron Age, becoming more common in the following centuries. Significant data exists only for domestic grapes (attested on the island since the Bronze Age) and domestic plums, attested for the first time in the Punic Age. Current data are shown below.

Figure 8. Clay models of fruit from Carthaginian tombs (4th-3rd centuries BCE?). Ph. by the author, "Carthago" exhibition in Rome, Colosseum, December 2019.

Pomegranates, called *Malum punicum* by Cato and *Punicum granatum* by Columella, had many symbolic and evocative features in antiquity as "a major symbol of fertility, abundance, perfection and sanctity" (Nigro and Spagnoli 2018: 49). For this reason, they are often illustrated in iconographical figurines and stelae, recovered from tombs and cultivated in the Phoenician West from an early period (Nigro and Spagnoli 2018). This symbolism comes to the Phoenician and Punic world mediated by Greek traditions. It seems that the fruit did not enjoy the same fortune in Sardinia that it did in other Mediterranean areas, such as Sicily. It is rarely seen in Sardinian iconography and no paleobotanical remains have been detected so far (Nigro and Spagnoli 2018: 62-63). Columella, citing Mago (*De Re Rustica* XII, 56, 5-6), records two different ways to preserve and consume pomegranates used by Punic people: clay and sea water (Campanella 2008: 65). Pomegranates are considered an essential part of the Punic landscape (Moscati 1972: 24-25), despite rarely being found as part of the archaeobotanical record (Nigro and Spagnoli 2018; Vendrell Betì 2016: 120).

According to written sources, figs were common in Mediterranean diets and were traded from Carthage to Rome and Greece (Campanella 2008: 64). They were probably widely consumed as they are present in the archaeobotanical evidence both in Sardinia (Buosi et al. 2016; Ucchesu et al. 2015; van Dommelen et al. 2018) and in Phoenician and Punic settlements around the western Mediterranean (Vendrell Betì 2016: 119). As with pomegranates, figs were often thought to have been introduced to the western Mediterranean by the Phoenicians due to their eastern origin

(Campanella 2008: 63), but this has been proven false. Figs have been part of the Sardinian diet at least since the Late Bronze Age (Sabato et al. 2015; Ugas 2015: 191).

Plums (*Prunus domestica*) are often recovered in the archaeological record (Vendrell Betì 2016: 121). A recent report on the recovery of the earliest *Prunus domestica* in Italy in Punic Sardinia (Ucchesu et al. 2017) suggests this fruit also was possibly introduced in the region by the Phoenicians. Plums also are found in amphoras containing animal bones and dried fruits (Sabato et al. 2018; see below).

Grapes (*Vitis vinifera*) were used to produce wine (see section 2.2.2.7 below) and, like plums, they appear to have been used to preserve and enrich meat stocks as they are often recovered from amphoras (Portas et al. 2015; Sabato et al. 2018). Their cultivation was widespread in Sardinia (Di Rita and Melis 2013; Buosi et al. 2016; Miola et al. 2009; van Dommelen et al. 2018: 153). Contrary to what was thought for decades, grape cultivation was not introduced to Sardinia and the western Mediterranean by the Phoenicians (Ucchesu et al. 2014a); grape cultivation was already established in Bronze Age Sardinia.

According to Pliny, who mentions Mago, apples (*Malus domestica*) and pears (*Pyrus communis)* were widely cultivated in Carthaginian orchards (Vendrell Betì 2016: 120). They are rarely mentioned in texts, but several ceramic reproductions of these fruits are attested in the funerary record (Vendrell Betì 2016: 121).

Due to their oriental origin, dates (*Phoenix dactylifera*) have been commonly considered a staple in the diet of Phoenician populations (Spanò Giammellaro 2007) and they are represented on coins, razors and stelae from Carthage (Campanella 2008: 64). However, to my knowledge dates are still not palaeobotanically attested in the Phoenician western Mediterranean.

Olives and olive oil have raised wider research interest compared to other fruits and fruit products, due to their relevance in the Mediterranean diet (see Chapter 1; 1.1.1.2). Olive (*Olea europaea*) is a common fruit in the Mediterranean. In the western Mediterranean, domesticated olive trees are evident from the Bronze Age (Di Rita and Melis 2013: 4281). Its major product, olive oil, is often mentioned in written sources referring to the Phoenician and Punic world, both in the eastern (Campanella 2008: 93) and western Mediterranean (Vendrell Betì 2016: 125). In the Biblical quote regarding the woman from Zarephath (see 2.2.2.1), oil has a central role as one of the objects of Elijah's miracle: "*The jar of flour will not be used up and the jug of oil will not run dry until the day the Lord sends rain on the land*" says the prophet to the widow (1Kings, 17, 13), indicating the importance of both commodities in her diet. Even today, olive oil plays a central role in Mediterranean diets: it is used as a dressing, as an ingredient of doughs and bread, or as a non-stick agent. It is tempting to presuppose the use and role of olive oil in the Phoenician and Punic Mediterranean and Sardinia as similar to the modern function it fulfils in the same geographical areas. However, this should not be assumed. Olive cultivation has been common in some western Mediterranean areas since the Bronze Age (Di Rita and Melis 2013: 4281), but, from archaeobotanical evidence, not in Sardinia, as highlighted by several authors (Bakels 2002; Sabato et al. 2018). The most relevant findings referring to olive oil production in the Phoenician and Punic world are from North Africa (Lixus, Carthage) and Andalusia (Campanella 2008: 91-93). Olive oil took much longer than wine to spread across the western Mediterranean (Broodbank 2013: 516). This does not mean that olives and olive oil did not play a role in Phoenician and Punic Sardinia; they are often recovered from archaeological sites (Acquaro et al. 2001; Di Rita and Melis 2013; van Dommelen et al. 2019: 153). However, according to the available data, it should be considered that "a widespread use of Olea fruits is a recent practice in many parts of Sardinia" (Di Rita and Melis 2013: 4281). This can separate the historical reality on the island from that of common imagination.

Nuts were no less important than other fruit, as they contributed vital calories. They were also traded, being often found in amphoras packed with other food such as meat (Del Vais and Sanna 2009). They have also been occasionally attested in archaeological settlements (Sabato et al. 2018; Di Rita and Melis 2013; Miola et al. 2009). Almonds, walnuts and pinecones/nuts are the most common nuts in written sources (Vendrell Betì 2016: 131), and they are often recovered archaeologically. Nuts and pinecones have also been recovered as funerary offerings (Campanella 2008: 65; Vendrell Betì 2016: 130), but their meaning is still unclear. Due to the lack of available evidence, it is not yet possible to establish if walnuts, hazelnuts and pine nuts were introduced to Sardinia by Carthage (Sabato et al. 2018).

To conclude this section, a relevant issue raised by a quote from Pseudo-Aristotle is discussed (*De mirabilibus auscultationibus,* 100). The unknown author, most likely writing in the first half of the 3rd century BCE, asserts that Carthage forced the cutting down of every fruit tree on the island of Sardinia. This quote has been interpreted by scholars in a variety of ways (Manfredi 1993) but, on the basis of the available data, it is possible to consider it as an *ex-post* argument (Campanella 2008: 22): Pseudo-Aristotle is likely assuming this to be the case based on his observation of the contemporary 3rd century environment, and with an evidently anti-Carthaginian purpose or source (Vanotti 2007: 181). It is known from the paleoenvironmental evidence that arboreal vegetation was widespread on the island in the Late Bronze Age and Iron Age. The availability of wild plant products seems to have been greater than in following periods (Ugas 2015: 191). Palaeobotanical data also leads to the contradiction of Pseudo-Aristotle's claim (Acquaro et al. 2001: 50). Although data are still very limited, based on recovered pollens it seems clear that fruit trees did not disappear after the 5th century BCE. Plant cultivation was varied, at least in the targeted area of Tharros (Acquaro et al. 2001; Di Rita and Melis 2013). Nevertheless, the same data show a reduction of arboreal species and environmental change between the 5th and the 4th centuries BCE "probably in favor of agricultural practices" in the area of Santa Gilla (Cagliari) lagoon (Buosi et al. 2016; see also Miola et al. 2009; Di Rita and Melis 2013). This could suggest a change in the economy, perhaps slowly moving to a monoculture, which was accomplished in the Roman period, especially in the Campidano and Sinis plains (Acquaro et al. 2001), and to a more integrated economy, based on joint agriculture and livestock rearing, in other areas (Di Rita and Melis 2013; Miola et al. 2009).

2.2.2.4 Meat

Meat is thought to have been an unusual commodity in the Phoenician and Punic world, and considered a food consumed on special occasions and at events such as feasts (Delgado and Ferrer 2011b: 193). Since the existing evidence shows development in livestock-rearing techniques (Fariselli 2017: 312; Campanella 2008: 65-66; Vendrell Betì 2016: 62; Spanò Giammellaro 1999), it has been suggested that meat became more common in the late Punic period. The belief in meat as a rare food product has been considered uncontroversial due to the strong link between the Phoenician and Punic culture and cereals, as conveyed by all available sources. The picture illustrated by written sources, especially the Bible, likewise shows meat as a commodity for special occasions. So far archaeology seems to confirm this statement (Delgado and Ferrer 2011b: 193). Isolated findings, such as a pit found in archaic Uthica (North Africa), providing evidence of a large amount of consumed meat (Cardoso et al. 2016), cannot modify this general picture due to their very likely relation with occasional feastings.

As with other commodities, it is challenging to establish the reliability of these general statements in Phoenician and Punic Sardinia. A well-established livestock-rearing economy based on cows, goats, and sheep is attested for the indigenous culture on the island, based on faunal evidence (Manconi 2000). Domestication techniques, however, do not seem to have been developed until the Iron Age, as suggested by the widespread pathologies recorded on bovines from across the island during the Bronze and first Iron Age (Wilkens et al. 2015: 88-89).

Meat was widely traded among Phoenician and Punic settlements as indicated by butchered animal bones recovered in amphoras (Portas et al. 2015; Cassien 2014). It could have been stored and traded dried, smoked, or salted, or preserved in olive oil or in brine (Campanella 2008: 67). It was probably consumed in many different ways (e.g. roasted, grilled), but more often boiled to get the greatest amount of meat even from older animals (Campanella 2008: 67). The limited faunal analyses seem to confirm this general view, as traces of burning, typical of grilled or roasted faunal remains, are not common (Cardoso et al. 2016: 320). This lack of burning evidence can potentially be consistent with the boiling processes, although it is not possible to exclude alternatives such as deboning before grilling or roasting.

In Sardinia, as in many other regions of the western Mediterranean, the Phoenician and Punic period is characterised by the introduction of new animal species not related to diet, such as donkeys and mongoose (Wilkens et al. 2015), and the widespread diffusion of species introduced at the end of the Bronze Age: dormouse, hare and horse (Wilkens et al. 2015: 84). The introduction of dormouse and hare, as will be outlined below, was possibly related to diet. Compared to the previous period, "significant differences are observed: among them, a decrease in caprines and an increase in deer hunting" during the Punic period (Wilkens 2012: 94; transl. by the author). New domestication techniques were likely introduced or developed during the period that resulted in an increase in livestock size (Wilkens 2012: 94).

In Phoenician and Punic settlements in general, as well as in Sardinia in particular, the most commonly recovered animal bones include cattle (*Bos taurus*), pigs (*Sus domesticus*), sheep (*Ovis aries*) and goats (*Capra hircus*). Due to similarities in their bone structure, sheep and goats cannot easily be distinguished; they are often recorded as ovicaprines in archaeozoological reports.

Ovicaprines were the most widely reared and consumed species across the entirety of the Phoenician-Punic world and in Sardinia (Campanella 2008: 67; Cruz-Folch and Valenzuela-Lamas 2018). They were reared for both meat and milk production, as confirmed by slaughtering age and butchering traces (Wilkens 2008: 257; Perez Jordà et al. 2010: 297). It is unclear if they were involved in wool production (Wilkens 2012: 46; Manconi 2000). As shown in tables 1 and 2, sheep always outnumber goats when identification is possible, so at present it appears that sheep were more prevalent than goats in Phoenician and Punic Sardinia. Ovicaprines are often represented in artworks and models (Campanella 2008: 66), and they were also involved in sacrifices (Amadasi Guzzo 1988).

Bovines are found as the second largest domestic group (Farello 2000). As shown in tables 1 and 2, bovine bones are often less than the half than ovicaprine bones, but proportion largely varies per site. Since bovines are bigger than other animals and meat is more abundant, they could be a more important element of diet than the number of bones suggests. In Phoenician and Punic Sardinia, however, it is unclear if they were reared primarily for working or consumption needs. They were also involved in sacrifices (Amadasi Guzzo 1988). Bovines were usually slaughtered when adult, both in Phoenician and Punic Sardinia (e.g Nora (Sorrentino 1992); Sant'Antioco (Wilkens 2008)), in Late Bronze Age and Iron Age Sardinia (Perra 2018: 55-56) and in other Phoenician and Punic settlements such as Carthage (Lancel et al. 1982).

Pigs are the most debated animals in the Phoenician and Punic scholarship because some late sources (e.g. the historian Herodian, ca. 170-250 CE, and the philosopher Porphyry, ca. 234-305 CE) stated that pigs were not consumed by the Phoenicians (D'Andrea 2019; Campanella and Zamora 2010: 49). The archaeological evidence, however, suggests that pigs were consumed, both in the Phoenician West and the East. In the Phoenician motherland pigs appear to have been eaten sporadically (Lev-Tov and McGeough 2007: 97) and rarely or never involved in sacrifices (Campanella and Zamora 2010: 51-52). This low pig consumption and rearing in the Phoenician motherland seems to be connected to economic and environmental reasons (Vila Dalix 2004; Hesse and Wapnish 1997). In the Phoenician and Punic West, in contrast, pigs are one of the most commonly reared and consumed animals, serving as the third most common domestic species after bovines and ovicaprines. They have also been recovered from ritual contexts (D'Andrea 2019; Cardoso et al. 2016: 321; Vendrell Betì 2016: 232).

Pigs are always found at Sardinian sites, but usually in fewer quantities than domestic ruminants (see table 1). They undoubtedly constituted a relevant part of the economy and the diet (Wilkens 2012: 145; Campanella-Zamora 2010: 54). When investigated, a slaughtering age between 1 and 3 years, aimed to maximise meat, confirms the dietary purpose of pig rearing (Farello 2000; Masala 2017). The limited data available (Sorrentino 1992; 2009) suggest a higher consumption of pig at inland sites compared to coastal ones (Wilkens 2012: 145; Perez Jordà 2010: 297). Interpretation for this evidence is lacking. It could be linked to a limited interest by Phoenician people in pig consumption, at least in the archaic phases, but this is only a possibility. Sardinian data are insufficient to maintain that pig presence or absence was linked to the ethnic origin of the people inhabiting the settlement. Non-Sardinian data do not offer definitive answers. Pigs were rare in the archaic settlements of Carthage and Mogador, but common from the earliest layers at Uthica and Anthiburos (Cruz-Folch and Valenzuela-Lamas 2018: 184). Finally, it appears that amphoras were not used to trade pork on Sardinia (Portas et al. 2015), and that pork was in general excluded from trade in the Phoenician and Punic Mediterranean (Campanella and Zamora 2010; Cruz-Folch and Valenzuela-Lamas 2018: 184).

At present, it is difficult to detect discontinuity in the presence or absence of domesticated species between the pre-Phoenician and Phoenician period, although there is a detectable decrease in the number of caprines (Wilkens 2012: 94). Research also suggests a change between the Iron Age and the Punic Age in the ovicaprine-bovine ratio. At some

Iron Age sites, bovines were the most numerous group (Manconi 2000: 274), and at S'Urachi, an indigenous site near Oristano inhabited until the Roman era, bovines are found far more often in the earlier layers, while ovicaprines are dominant in the Punic age (van Dommelen et al. 2019: 152), as they are in Punic Tharros, Sulky (table 1), Cagliari (table 2), and Pani Loriga (D. Ramìs, *pers.comm.*). They are not, however, prevalent at Nora (table 2). The evidence base is too limited to enable any definitive conclusions, but the trend appears to be significant.

Table 1 Animal bones from settlement sites in Phoenician and Punic Sardinia (reworked from Wilkens 2012: 96).

Animals	Sulky Area IIF 7th-6th	M. Sirai Late 7th-6th	Nuraghe Sirai Late 7th	Sulky (dump) Late 6th	Tharros 5th-4th	Sulky Area IIF 3rd-1st ?	Santu Pedru 4th-3rd?	Olbia 4th-3rd
Mollusca	198	1233	1085	20	160	779		
Pisces	340	7	1	1	13	385	1	
Reptilia								
Aves	19	7	13		9	100	1	
Micromammals	12					42		
Prolagus sardus	2	5						
Glis glis						1		
Canis familiaris	1	3	1	5	5	4		
Sus scrofa domesticus	20	600	185	58	84	76	279	1
Sus scrofa meridionalis		12	1					
Cervus							50	
Cervus elaphus		538	426	36	17		203	2
Bos/cervus		68						
Ovis/capra	21	157	176	79		186	203	7
Capra hircus			4	18		3	5	
Ovis musimon		6	17	29	254	26	7	1
Ovis aries		10		5				
Bos taurus	10	269	70	82	276	39	201	6
Equus asinus				1	2			
Equus caballus								2
Other mammals		2	2	1				

A smaller number of other animals were reared for cooking purposes. Chickens (*Gallus gallus*) were probably introduced to the western Mediterranean by the Phoenicians, due to their eastern origin (Campanella 2008: 68). They appear in Sardinia in the Punic period (Carenti and Wilkens 2006). At Sant'Antioco, the only context where bird bones have been accurately investigated and published, they represent 28% of the whole bird assemblage, despite being only found in the late period (3rd century BCE, Carenti 2016). Chickens are also attested in other domestic assemblages on the island (e.g. Sorrentino 1992; 2009) and outside it (e.g. Carthage, Poulain 1982), but they are notably absent in Tharros (5th–4th centuries BCE, Farello 2000). Their breeding for culinary purposes is confirmed by bone selection and burning traces (Carenti 2016: 208). At present, it is challenging to understand how prevalent chickens were in the diet because, in general, the percentage of recorded bones is limited. This may be the result of collection methods (see section 2.1.2 above).

Horses, also represented on Punic coinage in the 4th and 3rd centuries BCE (Fariselli 2019), and donkeys, introduced by the Phoenicians, as mentioned above, are recovered in low numbers. They were probably used for movement, and were unlikely to have been consumed (Wilkens 2012: 152), unlike modern-day practices in Sardinia and many areas of the western Mediterranean.

Dogs, however, were occasionally consumed, as indicated by traces of butchering (Campanella 2008: 70, 249; Cardoso et al. 2016). They were not reared for that purpose, so probably consumed during special times as food shortages (D'Andrea 2018).

Table 2 Animal bones from settlements in Phoenician and Punic Sardinia, selected publications.

Animals	**Cagliari** 5th-2nd Sorrentino 1992	**Nora** 5th-2nd? Sorrentino 2009	**Nora** 7th-early 5th ? Sorrentino 2009	**S'Urachi Area D** 5th-2nd Ramìs et al. 2020a	**S'Urachi Area E** 6th-4th Ramìs et al. 2020a	**S'Urachi** 7th Ramìs et al. 2020b	**Truncu 'e Molas** 4th-3rd Pérez et al. 2010
Mollusca		18	190				n.g.
Pisces	102		2	26	1	1	466
Reptilia	9						
Testudinae				15		1	
Aves	6			161	18	29	
Prolagus sardus				1	3	2	
Vulpes vulpes				1	2		
Lepus				8		1	
Canis familiaris	3		3	12	15	15	
Gallus gallus			2	41	4		
Sus scrofa	110		46	3	3	2	76
Sus scrofa domestica				301	648	715	
Cervus		4	26				13
Cervus elaphus	17			167	882	748	
Ovis/capra	185	15	150	1018	1884	835	118
Capra hircus				10	9	3	
Ovis aries				107	251	199	27
Ovis musimon				2	4		
Bos taurus	78	39	194	286	1420	818	7
Equus	22			10	19		
Equus asinus			1		2		
Equus caballus			1	2	1		
Other mammals				1		6	

According to written sources, other domestic animals likely reared for consumption purposes were rabbits and hares (Vendrell Betì 2016: 74). There is little archaeological evidence to support this due to the previously mentioned inadequate collection methods (Campanella 2008: 69; Cardoso 2000). Dormice (*Glis glis*) were likely consumed as well, as occurred later in the Roman world; this is also suggested by faunal records in Sant'Antioco (Campanella 2008: 71).

Moreover, a small proportion of meat came from wild animals, although this seems to have always been limited around the Phoenician and Punic Mediterranean (Vendrell Betì 2016: 80; Cruz-Folch and Valenzuela-Lamas 2018). It is unlikely that Sardinia would be an exception since hunting on the island had a marginal role in the previous period (Wilkens et al. 2015; Ugas 2015). Red deer seem to have been the most hunted and consumed wild animal, outnumbering bovine remains at some sites (Perez Jordà et al. 2010: 297). Red deer bones appear to be significantly less numerous at coastal sites that are evidently "Phoenician and Punic", i.e. inhabited by people having an Eastern Semitic culture, such as the case of Sulky, Nora, Tharros or Cagliari (tables 1 and 2). Deer bones are more common than any other wild animal, as shown in tables 1 and 2, but it is not possible to suggest a precise proportion due to the unavailability of a minimum number of individuals and the lack of specific hunting-related data (e.g. butchering traces; type of bones recovered), as already noted in section 3.2.1. An increasing interest in deer is recorded throughout the Phoenician and Punic world (Wilkens 2012: 89), and deer are found at nearly every site in Phoenician and Punic Sardinia (see tables 1 and 2). In addition to meat, they were likely hunted for antlers, as confirmed by the fact that animals were killed when adult (3-5 years old; Campanella 2008: 24). Several tools made with deer antlers have been recovered on the island (Wilkens 2012: 28), and both annually shed antlers those obtained through hunting are attested in the archaeozoological record (Wilkens 2012: 94).

Boar were hunted, but limited information about them is recorded (Farello 2000; Carenti and Wilkens 2006). In Sardinia boar remains are indistinguishable from pigs (Albarella 2017). Finally, wild birds are known from written sources to have fulfilled a role in sacrifices (Amadasi Guzzo 1988); they were also consumed, but their role was marginal in the diet (Farello 2000; Carenti 2016). In Punic Sant'Antioco (Carenti 2016), the most common wild bird was the mallard (*Anas platyrhynchos*), and birds represent around the 2% of the faunal assemblage, with domestic birds being predominant among them (Carenti 2016). In Tharros, birds represent 1.5% of the assemblage, with *Aythyae* (diving ducks) being the most common (five individuals; Farello 2000: 297). In general, bird remains are rare in the Sardinian archaeozoological records. This, as explained above (see 2.1.2), is possibly due to biases in collection methodology and the hollowness and fragility of bird bones, not preserved or detected in absence of wet-screening (Farello 2000: 297; Wilkens 2012: 14).

2.2.2.5 Secondary products: eggs, milk, dairy products and honey

Milk and dairy products, eggs and honey were the most important animal derivatives in the Phoenician and Punic diet, as suggested by the available archaeological and written evidence. However, available information about these products and their role in the Sardinian diet has been limited so far.

Chicken eggs played a role in the Punic diet, as stated by their presence in the most famous Punic recipe, *puls punica* (see section 2.2.2.1; Cato, *De Agri Cultura,* 85), but it is not possible to establish how prevalent they were in general and in Sardinia specifically. Archaeologically, chicken eggs are often found in funerary contexts (Campanella 2008: 69) but not domestic sites. Available data suggest chicken was widespread on the island only in the late Punic and early Roman period (Carenti 2016; see also section 2.2.2.4).

There is even less direct evidence for milk and dairy products because they are only directly detectable through archaeological evidence, if organic residue analyses are applied (Evershed et al. 2002). All available indirect sources, however, suggest that they were widely consumed, and especially three pieces of evidence. First, the widespread rearing of sheep, the milking animal par excellence in antiquity (Wilkens 2012: 24). Second, the slaughtering of animals mainly when very young, so that the ewes can become pregnant again, and less often when adult to allow them to reproduce and be milked rather than killed for meat (Perez Jordà et al. 2010: 296; Portas et al. 2015). Finally written sources, which highlight the role of dairy products in Phoenician and Punic culinary culture both in the East and West (see also 7.1.1.2). Until now the identification of milk through organic residue analysis in Phoenician and Punic contexts have been hypothetical and weak (Oggiano and Botto 2012; Pecci 2008), since the biomarkers used are not unambiguously connected with dairy products (Evershed et al. 2002). For this reason, those past analyses cannot be considered as an evidence for milk processing. Analyses carried out for this project, investigating the isotope ratio of selected animal fats, constitute a step forward in this respect (see Chapters 6 and 7).

It is likely that fresh milk was rarely consumed due to the hot weather, as was usual in the ancient Mediterranean. In the Bible, for example, it is a luxury food, often associated with honey. Milk was probably more often consumed as sour milk or yogurt, which are frequently mentioned in written ancient sources, especially biblical ones (several examples are provided in Campanella 2008: 85). It was obtained by adopting a fermentation technique that is still very common in the Middle East and warm regions of the Mediterranean. On the base of available evidence, cheese was surely produced, as indicated by the sources and the presence of fresh cheese in the *puls punica* recipe (Campanella 2008: 85). Butter can be also hypothesised as a consumed dairy product (Vendrell Betì 2016: 82). However, it is unclear how common cheese and butter were in the diet: no vessels interpreted as connected with their production have been identified in the Phoenician and Punic world, and written sources are distant in time and space.

The only vessels traditionally associated with milk are the *vasi a biberon* ("baby bottle jug"). They are so called due to their shape, with a hole or a strainer to introduce a liquid, similar to a modern-day baby bottle (fig. 9). The same interpretation has been proposed for zoomorphous *askoi* often uncovered in infant burials (Campanella 2008: 86-87; Fariselli 2017: 313). The interpretation of these vessels as being used for milk consumption has been widely accepted. Recent organic residue analyses undertaken on similar "baby bottle jugs" from Bronze and Iron Age Central Europe have detected dairy fats, which appears to confirm this interpretation (Dunne et al. 2019b). Unfortunately, no organic residue analysis has yet been undertaken on zoomorphous *askoi*, in the Phoenician and Punic world and in general.

Figure 9. Biberon jugs and zoomorphous askoi, from Tharros (A; 4th century BCE); Sant'Antioco, tophet (B; 7th century BCE); Tharros (C; 4th century BCE?). Images from Guirguis (ed.) 2017: fig.458 (A); 406 (B); 396 (C).

The role of honey in the Phoenician and Punic diet is less known. Although it is mentioned in every discussion dealing with Phoenician and Punic foodways (Spanò Giammellaro 2007; Campanella 2008; Vendrell Betì 2016), there has been no detailed study and analysis. The available information about it is likewise limited. It is known to have been used in Punic cuisine because of its presence in the *puls punica* recipe (see section 2.2.2.1). Beekeeping was a relevant activity in Punic North Africa, according to Roman sources mentioning Mago the Carthaginian (Bortolin 2008: 45), as also confirmed by designs representing bees on 2nd-1st century BCE coins (Campanella 2008: 84; Bortolin 2008: 50). The environmental conditions, fundamental for beekeeping, suggest the Mediterranean area and the Tyhrrenian islands as being involved in honey production from prehistoric times (Bortolin 2008: 37-40). Honey production is also attested in nearby contemporary ancient cultures such as the Greeks and Egyptians (Giuman 2008). In Sardinia beehive products were certainly known and beekeeping practised. However, specific archaeological and historical evidence is limited (Bortolin 2008: 48): no beehive or structure connected with honey production and processing has ever been identified, probably because they were made with perishable materials. One bronze figurine dated to the Iron Age represents a figure with bees who is interpreted as Aristaeus; it was found in the 19th century near Oliena in the middle of the island and described by G. Spano (Spano 1855). One late tradition, reported by Solinus in the 3rd century AD, tells the history of the hero Aristaeus who introduced cheese, oil and apiculture on the island and founded the city of Cagliari (Nicosia 1994). However, these elements do not provide enough evidence to establish the role or importance of honey and beehive products on the island. Despite being limited to beeswax detection (see Chapter 4; 4.3.3), organic residue analysis is providing new data. Before the current research, beeswax had been detected in one Punic cooking pot in Sant'Antioco (Pecci 2008) and in several amphoras (Botto et al. 2005; Oggiano and Botto 2012). However, not much has been determined about honey production and consumption in pre-Roman Sardinia, which is one of the aims of my project (see Chapter 6).

2.2.2.6 Fish and aquatic products

Fish and aquatic resources such as shellfish seem to have played a pivotal role in the Phoenician and Punic diet, with the research community unanimously suggesting these products were consumed more than meat and were more important to the diet as a whole (e.g. Spanò Giammellaro 2007: 66; Campanella 2008: 236; Vendrell Betì 2016: 89; Aubet and Buxò 1999: 339). Fish and other aquatic animals are widely represented in iconography, mentioned in written sources and recorded archaeologically. Some sites, as outlined below, have been linked with fish processing and production. Some archaeological vessels have been connected to fish consumption (Campanella 2008: 78). The state of current research and discussion surrounding aquatic consumption is presented here, but unfortunately, most of the data has not been recorded in Sardinia. Several Spanish researchers have focused on fish production and consumption during the Phoenician and Punic period (e.g. Costa and Fernandez 2012), and this data will be often mentioned.

Phoenicians are considered as having an important relationship with the sea for geographical reasons, and, consequently, an interest in sea products. Indeed, some scholars hypothesise hunting for fish, primarily tuna, as the primary reason for Phoenician migration and settlement locations (Bartoloni 1991; Bartoloni-Guirguis 2017). Although this theory lacks support, it is certain that Phoenicians had knowledge and interest in fishing and sea exploitation. Indeed, they founded salting factories, where fish was processed to create fish sauces or other products, across the central and western Mediterranean from the first decades of colonisation (Campanella and Niveau de Villedary 2005; see below). Evidence of this apparently widespread knowledge originates from the terracotta matrixes representing fish and sea products produced in the 4th century BCE in Punic Sardinia, North Africa and Ibiza (Marras 1993: 94). The most interesting and significant of these comes from Sant'Antioco (fig. 10, private collection) and is described in Marras 1993. This object not only represents sea animals with great accuracy, but each animal seems to have been positioned following specific logic, i.e. the gilthead bream is pointing to a clam, the octopus is pointing to a crab and the animal interpreted as a moray seems to threaten the octopus itself. This reflects real predator-prey relationships.

Fish played an important role in the economy and society: some scholars believe it was an everyday food in Phoenician cities and colonies (Delgado and Ferrer 2011b: 193), but it clearly had functions beyond mere food for subsistence and diet (Martinez 2012). Fish was traded, as it has been recovered in amphoras (Nuñez 2011; Wilkens 2000). Fish were also sacrificed (Zamora 2004; Corrado et al. 2004), and they are often recovered in tombs as funerary offerings (Campanella 2008: 75). These aspects are not discussed here since they are not directly related to common foodways.

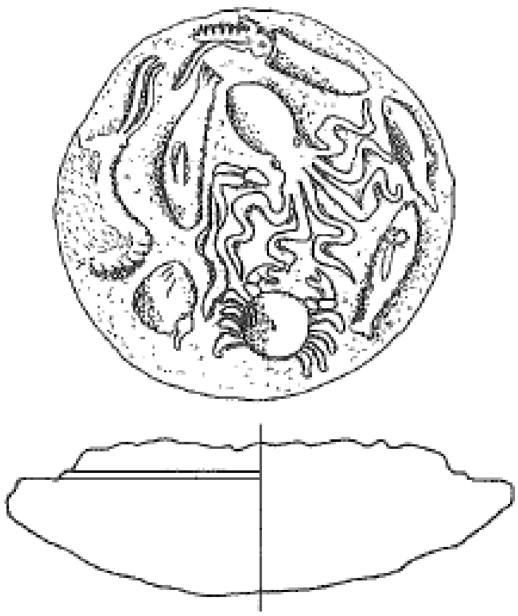


Figure 10. Clay matrix from Sant'Antioco, Marras 1993.

According to Antonella Spanò Giammellaro's interpretation, based on written sources (2007: 66), the most widely consumed fish in the Phoenician and Punic West were gilthead bream, goatfish, mackerel, sturgeon, moray, sole and tuna. To this list, small fish such as sardines, anchovies, mullets *(Mugil cephalus)* and picarels (*Spicara maena*) should be added (Campanella 2008: 74). As highlighted by researchers, the usual lack of sifting hinders the detection of several potentially common species (e.g. Farello 2000: 297).

Archaeological data show that the role of shellfish in the diet of Phoenician and Punic people was undoubtedly relevant (Campanella and Niveau de Villedary 2005: 40), although written sources have less to say about it. From the available records, gastropods such as *Patellae* and bivalves like *Mylitus edulis* seem to have been the most common commodity at several sites (Farello 2000; 297; Miola et al. 2009: 913; Carrasco 2005; Oller and Nebot 1999; a list is provided by Vendrell Betì (2016: 106-114)). These are shellfish with a common dietary role and are clearly exploited for culinary uses (Farello 2000; Masala 2017). The presence of these shellfish across every archaeological context on contemporary Sardinia suggests they were broadly used for culinary purposes (Wilkens 2012: 94; Chilardi and Carannante 2019: 118-119). According to the available iconography (Campanella 2008: 71) and archaeozoological data (Wilkens 2008: 249), octopuses and cuttlefish must also be considered as part of the diet, at least in Sant'Antioco. To the best of my knowledge, they have not been commonly found elsewhere.

Other sea life deserving attention are crabs, turtles and dolphins. Although they have not received much interest from researchers, sea turtles and dolphins were occasionally hunted and consumed in Sardinia according to the available zooarchaeological record (Vendrell Betì 2016: 97-100). Crabs are often represented on supports, such as plaques, matrixes (see fig. 10 above) and plates found in tombs. Crab remains have rarely been recovered archaeologically, so their role in diet is unclear (Vendrell Betì 2016: 97). Finally, a brief mention should be made of the *nāhiru*, a kind of sea animal described by the written sources as extremely difficult to catch, but often captured by skilled Phoenician fishermen; it has never been clearly identified by scholars (Campanella 2008: 25). Recent research is indicating it may refer to a whale (Bernal and Monclova 2012), according to the origin of the term (Wapnish 1995).

Fish could have been consumed in several different ways (Campanella 2008: 78). They could have been roasted, grilled or heated in the typical cylindric ovens (called *tannurs,* see 3.3.5), but the best known fish products are salted raw fish slices and fish sauces. Both products are mentioned in several late sources (Campanella 2008: 72), and they were probably produced from an early date in the salting facilities spread across the western Mediterranean. These salting facilities for fish processing constitute a core part of the economy around Cadiz and Gibraltar, in the so-called *circuito del Estrecho* (Martinez 2012), and they are also attested in Sicily (Sarà 2015). Currently, none have been found in Sardinia for the Phoenician and Punic period, but the location of some of the first Phoenician settlements seem to be connected with the availability of areas suitable for salting facilities (Martìn Hernàndez et al. 2017). Fish sauces such as *garum* are well known in the Roman period, and their Phoenician origin has never been seriously called into question, even if evidence is still limited (Campanella 2008: 72). More evidence is available for salted raw fish slices (*salsamenta,* τάριχοι); the quality of these salted fish slices is outlined in different sources. In a famous quote by Atheneus of Naucratis (IV, 135a in Campanella 2008: 71), dated to the middle of the 4th century BCE, salt-cured raw fish is defined as "just a salty side dish (ωμοτάριχος) for Phoenicians", confirming that the product had to be relatively common. These *salsamenta* have also been found in amphoras (Wilkens 2012: 89).

Fish were also potentially processed to obtain flours, as suggested by scholars basing themselves on the existing data (Oggiano and Botto 2012: 162; Campanella and Niveau de Villedary 2005: 57). Written sources (Arrian, *Indica,* XXIX, 12; Strabo, XV, 2, 2) suggest the existence of such peculiar flours, obtained by drying out and then grinding large fish in mortars. Vessels suitable for grinding are well known from Phoenician contexts (see 3.3), and despite these vessels being traditionally connected to cereal processing (Campanella 2008: 79), usage for grinding fish cannot be excluded.

Figure 11. Example of dishes from Phoenician and Punic Sardinia. A: Tharros, 6th century BCE; B: Monte Sirai, first half 4th century BCE; C: Gesico (Cagliari), 3rd century BCE. Images from Guriguis (eds.) 2017: 358-360.

The presentation and consumption of fish in the Phoenician world has also sparked debate. The so-called "fish plate", a Hellenistic dish with a small, deep cavity in the middle and an extended rim, often depicting illustrations of fish, was also adopted in the Punic world. It is often recorded in late tombs (4th–2nd centuries BCE) containing fish offerings (Campanella 2008: 78; Tronchetti 2010: 33). The controversial question is whether it was used to consume fish? In Phoenician and Punic ceramic culture, this vessel can be defined as just a dish, evolving from the archaic dish with a small rim and a large cavity. Some scholars suggest a change in food presentation and consumption can be postulated based on a shift in dish shape (Campanella 2008: 80), but evidence for this is limited. Therefore, it seems unjustified at this stage to discuss or hypothesise about a possible shift in diet, or a specific shift in fish consumption, solely on the change in dish shape.

Focusing specifically on Sardinia, faunal data for potential aquatic food products is unfortunately not robust. Fishing and sea exploitation were not relevant activities in pre-Phoenician Sardinia, according to the available archaeozoological evidence (Wilkens et al. 2015). Moreover, non-coastal fishing seems to have been introduced on the island only in the Late Bronze Age (Depalmas et al. 2015). It was stated that the foundation of Levantine settlements led to "a rising interest in environmental resources, made evident by the increase of shellfish gathering and fishing activities and, in the Punic phase, in conservation and trade of fishing products" (Wilkens 2012: 94; transl. by the author). However, this statement has been rejected by other scholars, who state that no increase is recorded (Chilardi and Carannante 2019: 118). This deep difference in scholars' opinions confirms the need for a comprehensive synthesis which is still lacking. Despite fish biomarkers being targeted, this project will not be resolutive in this sense, as will be explained in Chapters 7 and 8.

Regarding shellfish, available malacological data are too limited to enable a wider discussion because those from different sites (Sorrentino 1992; 2009; Wilkens 2008; Wilkens 2012: 96) have not been collected by specialists. This has provided a limited and unrepresentative sample. Following the most recent synthesis (Chilardi and Carannante 2019: 118-119), in the Phoenician and Punic period, as in the Sardinian Iron Age, the most common species were *Cerastoderma glaucum* (lagoon cockle), oysters and *Tapes decussatus* (bivalve). The authors suggest a preferential exploitation of lagoon environments for culinary reasons, recording no discontinuity with the previous period, but, as mentioned above, this opinion is not unanimously accepted by scholarship (Wilkens 2012: 94).

The data for Sardinian fish is stronger but still limited. Although remains have been recovered (Miola et al. 2009: 913; Portas et al. 2015; see table 1 and 2) they are often not published, of undetermined species (Sorrentino 1992) or the published sample sizes are too small (Wilkens 2008). For this reason, the results of robust studies will be briefly outlined to offer an example of Sardinian records.

In a study by Wilkens (2000), the contents of amphoras from a storage room in Olbia dated to the 4th–3rd century BCE were analysed. In one amphora, fragments of 321 *Centracanthus cirrus* (curled picarel) and 7 *Spicara smaris* (picarel) were found; the second amphora contained at least 46 *Mugil auratus* (golden grey mullet). Species including *Paracentrotus lividus* (sea urchin), *Sparus aurata* (gilthead breams) and undetermined *sparidae* were also present in the storage room. This context has been interpreted as a storage room for products to be sold; the room was later burnt and abandoned.

The fauna from 5th–4th centuries BCE layers in the Punic settlement of Tharros have been analysed (Farello 2000) and shown to include fish and shellfish. Mullet is the most common fish, while the greater amberjack (*Seriola dumerii*) appears in the 4th century. The author states that with the introduction of wet-screening in the 1997 excavation, other species started to be detected, namely gilthead seabreams and one unidentified fish. Shellfish is represented by gastropods and bivalves with evident culinary uses, the only exception being the *Pinna nobilis,* fished to produce byssus filaments.

Fish and fishery resources from the Cronicario area in Sant'Antioco have been fully studied and published (Carenti 2013), revealing that gilthead seabreams from the lagoon and Mediterranean mussels (*Mytilus galloprovincialis)* seem to have been the most important resource in the earlier phase (8th-7th centuries BCE). The faunal remains suggest that "presumably, fishing was practiced in shallow waters. Deep-sea fishing, however, was also practiced" occasionally (Carenti 2013: 48). The author concludes that "the rooms examined provided evidence on food consumption typical of a household unit and on small-scale exploitation of fishing as a subsistence activity among family groups within the town. Fishing was probably carried out on the margins of more complex commercial fishery and international fish trade" (Carenti 2013: 48).

Analysing the record of a Punic farm dated to the 4th and the 3rd centuries BCE (Truncu 'e Molas, Oristano), Pérez Jordà et al. (2010: 298) conclude that "fish consumption seems to have been a usual practice in the settlement". This is supported by the recovery of *Sparidae* (20 fragments), *Mugellidae* (13), *Moronidae* (6) and *Anguillidae* (6), which are the most represented species. Most of the remains come from a lagoon close to the site, and a minority from the sea, but none of them from the hinterland. At this stage it is not possible to know if similar trends can be recorded in other contemporary Sardinian sites.

In general, what seems new for the Punic period in Sardinia is a structured fish storage, processing and production system, testified by contexts such as the one at Olbia mentioned above and typical of Phoenician and Punic areas in the Mediterranean (Chilardi and Carannante 2019: 120).

To conclude this brief overview of the available information regarding aquatic products in Phoenician and Punic Sardinia, it is necessary to focus on an often neglected aspect: isotope analysis. It is known that fish and fish products were commonly eaten, probably providing a wider contribution to the diet than meat. But this has been established from a limited number of sites, and we do not know how many people had access to such resources. Isotope analysis conducted on human remains from Punic Ibiza (Fuller et al. 2010: 517) and Bronze Age Sardinia (Lai et al. 2013) suggest a limited contribution of fish to the diet. These data must be considered, because the archaeozoological evidence suggest fishery resources were less relevant in Sardinia before the establishment of Phoenician and Punic settlements. According to Barbara Wilkens (2012:20), fish and shellfish exploitation was "widespread in many coastal sites as a secondary activity", used to integrate diet, but it never fulfilled a primary role. This is unsurprising, considering that the Mediterranean has always been poor in fish (Braudel 1976: 148), and only within the past century has fish become a common food in the area (Salamon et al. 2007).

2.2.2.7 Drinks

Alcoholic drinks, due to their widespread social and nutritional implications, deserve the greatest attention (Wilson 2015; Dietler 2006; 2010). As already mentioned in section 2.1.1, wine has received the most interest from research thus far. Non-alcoholic drinks such as water and fruit juices were obviously drunk, but no direct insights can be found in relevant resources (in Vendrell Betì 2016: 147, the author deals with water, but her environmental considerations are only slightly related to diet).

A similar lack of knowledge and interest is evident for alcoholic drinks such as cider and mead. They have never been broadly considered in previous references because they seem to have had no widespread circulation in the past. They are supposed to have been consumed in the Phoenician and Punic world only in some areas of the Iberian Peninsula and Sicily, continuing indigenous traditions (Campanella 2008: 85; Albanese Procelli 1996). Beer is on the contrary mentioned in several papers regarding Phoenician foodways (e.g. Spanò Giammellaro 2007; Campanella 2008: 90-91; Vendrell Betì 2016: 55-56), probably because, unlike cider and mead, it is common in modern Sardinia. Beer, obtained from barley, has been produced in areas of the Near East close to Phoenicia and occasionally in Phoenicia itself since the Bronze Age. In the Phoenician and Punic West, however, it seems to have just been consumed in some Iberic areas (Vives Ferrandìz 2008), depending on local indigenous customs. No evidence of beer consumption has been identified in Phoenician and Punic Sardinia. No real evidence exists for other spirits, such as *grappa.* It is supposed to have been distilled in Sardinia from the Bronze Age (Ugas 2015), but this is probably based on modern comparisons.

The consumption of wine seems to have been common but related to special occasions and not to everyday life (Campanella 2009: 87). Wine, as recently proven through archaeobotanical analyses, had been produced in Sardinia from the Middle Bronze Age (Ucchesu et al. 2014a). This differentiates the island from other western Mediterranean areas where wine was introduced by Eastern incomers during the Iron Age (e.g. southern France, Dietler 2015). The quick spead of wine use across the western Mediterranean between the Bronze and Iron Ages, and its success among local people (Broodbank 2013: 516), were probably connected with its role as a drink used for meetings or rituals, a role which has clearly been established by a variety of archaeological sources and modern comparisons. This success is attested even in places such as southern Spain where the consumption of other drinks was very common (Vives Ferrandìz 2008).

Due to the recent detection of domesticated wine grapes in Bronze Age Sardinia, attesting local production before the foundation of Phoenician settlements (Ucchesu et al. 2014a), it is difficult to comprehend how Sardinian productions relate to the eastern Phoenician wines mentioned and celebrated in the Graeco-Roman sources (Campanella 2008: 89). This detection has lead to a revision of wine history because the drink has been traditionally connected with Greek and Phoenician migrations at the beginning of the Iron Age (Ramos 1998; Campanella 2008: 40). Nevertheless, wine was a well-established product on the island in my target period, recorded at many sites (e.g. Di Rita and Melis 2013; Perez

Jordà 2010: 299; Buosi et al. 2016) and widely consumed. Ancient wine was drunk in a different way to contemporary usage, due to its different taste. Pliny reports (*Naturalis Historia,* XXXVI, 166) that in Carthage it was common to add lime plaster to temper the must (new wine); moreover, honey, spices or grated cheese were used to aromatise the drink. This is commonly accepted and confirmed by the recovery of cheese graters in tombs (Campanella 2008: 88).

Some vessels in Phoenician and Punic Sardinia have been interpreted as being used for serving and pouring wine. These include the "pilgrim flask", originating in the East, and the local *brocca askoide* (askos jug), which is also represented in bronze figurines (Bartoloni 2017; fig. 12). However, as stated by other scholars (Botto 2016: 90), it is not clear, whether these vessels were exclusively related to wine. Ceramic categories possibly related to wine processing and preparation, i.e. *mortaria*, basins and especially tripod-bowls, will be discussed in Chapter 3. Vessels known as cups were also but not exclusively used for wine drinking (Bartoloni 2017; Botto 2000; see also Chapter 3, section 3.3.2). Moreover, wine has been connected to several other vessels through organic residue analysis (Botto-Garnier 2018; Botto et al. *in press*), but, as explained in Chapter 4 (4.3.5), these identifications are not particularly reliable due to the ubiquity of the compounds used as biomarkers.

Figure 12. Bronze figurine of a person pouring from an askos jug, from Monte Sirai (Fariselli 2017: 315).

Greek vessels related to wine consumption and symposia also are common in Sardinia, but the archaeological evidence suggests there was a specific Punic Sardinian way to consume the beverage. For example, after the 5th century BCE, only vessels related to wine drinking, and not to wine serving or making, are imported and imitated. Wine rituals in funerary practices do not appear relevant. These elements suggest that approaches to wine consumption and its rituals were deeply embedded in the local Punic culture and drinking customs despite involving "exotic" Greek vessels. Due to the lack of written sources, it is challenging to precisely outline these customs, as previous literature has pointed out (e.g. Bernardini 2005; Tronchetti 2010).

Literary sources mention other features related to wine production in Carthaginian territories. For example, straw wine (*passum*; wine obtained from grapes that have been dried) was produced and celebrated for its quality (Campanella 2008: 89). The most interesting reference, however, which concludes this chapter, is contained in Plato's *Laws* (674a-b; transl. by R. Gregg Bury, 1869), and dated to the 4th century BCE:

> [I will refer] to the Carthaginian law, which ordains that no soldier on the march should ever taste of this potion, but confine himself for the whole of the time to water-drinking only, I would add this, that in the city also no bondsman or bondsmaid should ever taste of it; and that magistrates during their year of office, and pilots and judges while on duty, should taste no wine at all; nor should any councillor, while attending any important council; nor should anyone whatever taste of it at all, except for reasons of bodily training or health, in the day-time; nor should anyone do so by night—be he man or woman—when proposing to procreate children.

If the law did exist, and due to the nature of the text there is no reason to suppose it was an invention, its necessity would confirm that wine consumption was very common in Carthaginian society.

2.3.2.8 Summary

The picture of foodways illustrated for Phoenician and Punic Sardinia is relatively defined. The diet was mainly based on cereals and legumes, consumed in breads and porridges. Meat was an occasional commodity; fish and fishery resources were apparently more broadly consumed, at least on the coast. The role of other commodities, such as vegetables, eggs, dairy products, honey or oil, despite being undoubtedly relevant, is still unclear, because they are rarely archaeologically detected. Some of them (dairy fats; leafy plants; honey; oil) are targeted within the current research (Chapter 4).

It is now well-established that no radical discontinuity existed with the pre-Phoenician period. Many of the novelties introduced from the East (wine, horses, apples) appeared on the island centuries before the foundation of Phoenician settlements, while others, such as chickens, started to be widespread only in the 3rd century BCE. However, some changes in the diet are recorded with the arrival of the Phoenicians: the introduction of chickpeas and plum cultivation, and the spread of shellfish consumption. The development of rearing techniques and the introduction of animals as donkey and mongoose suggest a change in lifestyle which is also confirmed by the spread of farms in the Punic period (see 3.1.3). But many gaps and doubts in the understanding of foodways on the island still exist, as evidence is sparse and insufficient. Lack of focus on social organisation and the availability of commodities to the community is a second relevant problem. For example, it is not clear how many people consumed products such as shellfish whose exploitation increased with the foundation of Phoenician settlements.

One last major gap in our current knowledge, as this chapter has made clear, is the lack of focus on local and cultural differences. Variations in diet and foodways are likely to have existed on the island, changing over space and centuries, but these have not been identified, since the data collected are too sparsely distributed. Cereals and legumes, as an example, were probably consumed in several different ways by the Levantine or North African migrants and the local communities. But evidence to define these customs is lacking, since most of the written sources refer to Eastern Phoenicians or Carthaginians in the Roman period.

The current research aims to fill part of these gaps. To do so, the archaeological and historical context is needed, as a first step, to obtain a more defined picture. This context is described in the next chapter.

Chapter 3
Historical and archaeological context

3.1 Historical context, words and events

3.1.1 Phoenician and Punic people: lexical and theoretical issues

"Io nacqui Veneziano ai 18 ottobre del 1775 […]; e morrò per la grazia di Dio Italiano […]."

"I was born Venetian on October 18th,1775 […]; and I will die thanks to God Italian […]."
(Ippolito Nievo, *Le confessioni di un Italiano,* 1867)

In the contemporary archaeological and historical record, the land known as Phoenicia during the 12th to 4th centuries BCE corresponds to modern Lebanon and the Carmel coast of Israel down to Tel Dor; it was represented by the cities of Tyre, Byblos, Sidon, Arwad, Saraepta and Berytus. Its inhabitants are known as "Phoenicians" (Moscati 1989; Krings 1994; fig. 1). Since at least the 9th century BCE (Cardoso et al. 2016), Phoenicians founded new settlements in the central and western Mediterranean, establishing a permanent presence in western lands, including Sardinia. From the end of the 6th century BCE, Carthage, a Phoenician city situated in modern-day Tunisia, started to dominate the western Phoenician world and Sardinia. The period and the people were then defined as "Punic". Both terms are modern archaeological labels applied to past people: widely accepted but needing additional explanation to avoid misleading interpretations (e.g. Quinn 2018).

In the area under investigation, i.e. pre-Roman Sardinia, the terms "Phoenician" and "Punic" started to be consistently used based on the work of Sabatino Moscati and his pupils (Moscati 1963; Garbini 1992; Moscati et al. 1997) throughout the 1960s and 1970s (Xella 2014: 17; Quinn and Vella 2014). These decades saw the emergence of "Phoenician-Punic archaeology" as an independent archaeological field: archaeological and literary evidence indicated that these Levantine people were migrating from approximately the same geographic area and primarily writing the same Semitic language (Xella 2014: 38). There are, however, limitations to these terms. Recent research has outlined two main issues.

The first is lexical. "Phoenicia" and "Phoenicians" are Greek words used in ancient times to define a land and a people (or, more precisely, just people) with no clear borders, but not corresponding to the territories outlined above (Ercolani 2015). No equivalent for the word "Phoenician" exists in the Phoenician language (Xella 2014: 28; Quinn 2018: 25-43) because they defined themselves based on their urban identity (Sidonian, Tyrian etc.) and lineage. Similar issues exist for the word "Punic", from Latin *Poenus*, simply a Latin translation of the Greek word for "Phoenician" (*Phoenix;* Prag 2014).

The second issue is theoretical. Scholarship discusses the possible lack of a Phoenician *identity* (Edrey 2016; Lopez-Bertran 2011; Garbati and Pedrazzi 2016) or even an *ethnicity* (Hodos 2010; Woolmer 2017: 4). At this stage of research, it is not clear if Phoenicians ever consciously chose or knew to belong to “a people” and act accordingly (Xella 2014; Garbati and Pedrazzi 2015; 2016; Quinn and Vella 2014).

This relevant contemporary debate is ongoing, and widely discussed in several recent publications (e.g. Quinn and Vella 2014; Garbati and Pedrazzi 2015; 2016; Quinn 2018), but it is only partially related to the aims of my project, which is focused on only one island with clear historical developments (see below, 3.1.2; 3.1.3). This debate illustrates how these terms are used throughout this thesis, and why they need to be used in this current research about foodways in Phoenician and Punic Sardinia. There are two reasons their use is required.

The first is related to the history of archaeological studies. As recognised by Paolo Xella, one of the contemporary scholars criticising the narrative presenting Phoenicians as “a people”, the term “Phoenician” has been established over the decades as a useful heuristic tool in the central and western Mediterranean (Xella 2014: 40). This is due to the combination of a well-established academic tradition and the archaeological evidence.

The archaeological evidence is the second reason for using the terms “Phoenician” and “Punic”. Material culture in the western Mediterranean suggests that these migrants, speaking or at least using the same written language (Hackett 2004: 367) and moving from the same geographical area (Xella 2014; Delgado and Ferrer 2011b: 187), established settlements, burials and a network of trade links and settlements. It is possible to detect shared customs developing over time in the archaeological record (for example, in funerary culture: Ramos 1990; Bison 2015). The pantheon of deities was also partially shared among cities and settlements, but the lack of literature makes difficult to comprehend the degree of consistence of Phoenician religion over the Mediterranean (Bonnet 2020). Nevertheless, there is clearly a degree of coherence among Phoenician settlements, despite local variation (Van Dommelen and Gomez Bellard 2008; Quinn and Vella 2014). Over the centuries, “Phoenicians” in the West seem to have built shared traditions (Quinn 2018: 91-131), potentially as a way to strengthen a common identity (Delgado and Ferrer 2011a); at times, they also reproduced and recreated ways of doing and thinking as was indigenous to the eastern Phoenician centres (Delgado and Ferrer 2011b: 187). Sharing a common language, a common origin and common deities likely played a role in these developments; this is a common practice in migrant communities, and probably also favoured by Carthage, a Phoenician city aiming a hegemonic power over the “Western Phoenician” world (see below, 3.1.3).

In Sardinia, the “Phoenician” material culture is clearly distinguished from other archaeological cultures and connected with Eastern Mediterranean examples during the Archaic period. Since the end of the 6th century BCE, due to historical developments exposed below (see section 3.1.3), this material culture starts to be called “Punic”, and it is more connected with North African remains. It is relevant, and perhaps surprising, that this coexistence in the West and increasing material homogeneity did not establish any common ethnonym and never replaced local identities (Garbati 2016). However, an archaeological label is needed to define this culture and to discuss these people collectively, also representing diversity of practices within and between individual settlements. “Phoenician” and “Punic” are well established labels, so that I will speak about Phoenician and Punic people, cuisine and culture. But I will do so being aware that these terms do not imply necessarily that these past communities were conscious of being part of the same people; in other words, being aware of the potential, the origin and the limits of these terms (Xella 2014: 40).

3.1.2 The "Phoenician colonisation" of Sardinia (8^{th}–6^{th} centuries BCE)

The picture of the Phoenician era in Sardinia, i.e. of the centuries when Levantine people founded new, self-governing settlements on the island before the Carthaginian intervention, is evolving. Until recently, the archaeological interpretation of the period was linked to views depicting Phoenician incomers as establishing a new settlement on an island apparently depopulated and weakened after centuries of crises (see, for example, Stiglitz et al. 2015; Bernardini 2015; Bernardini and Perra 2012). The contribution of new archaeological evidence and research are helping to overcome this view (Van Dommelen and Roppa 2014; Tronchetti 2014; Guirguis 2019a; see Zucca 2017: 45 for a brief synthesis), but the available information is still limited.

Phoenician people started to establish autonomous settlements on the island of Sardinia from the beginning of the 8^{th} century BCE. At this time, Sardinia was an island already inhabited by communities actively involved in intercultural exchanges and trade. These indigenous people are named Nuragic by archaeologists basing on the Sardinian word *nuraghe,* which is the name of the thousands of towers built during Bronze and Iron Age and characterising the landscape of Sardinia. In Sant'Imbenia, a Nuragic village in the northeast of the island, local people cohabited with Phoenicians and probably Euboic people from the end of the 10^{th} century BCE. Here these people developed local culture and traded across the Mediterranean, as established by the widespread Sant'Imbenia amphoras attested in Southern Iberia, Carthage and Etruria (Zucca 2017: 46). Sant'Imbenia was not an isolated case as a multicultural settlement. Phoenician products and hybrid Phoenician-Nuragic materials are widely attested on the island from the beginning of the Iron Age (Usai 2012; Van Dommelen and Roppa 2014).

The first Phoenician settlements on the island were established in this socio-cultural context, some decades after the foundation of the first settlements in the Mediterranean West (Guirguis 2017: 55). Notably, I prefer to use the word "settlement" instead of "colony" because the connotation of "colony" can be considered misleading. A colony, in the standard English meaning of the word (e.g. Cambridge Dictionary), is "a country or area controlled politically by a more powerful country", or state power in the ancient world. However, nothing similar seems to have existed for the Phoenician settlements in the West. The role of the Tyrian monarchy in this process is still unclear (for a broader analysis, see Aubet 2009; Delgado 2017; Quinn 2018). However, the process of migration and colonisation was possibly supported by the state, but it was clearly not ruled by it.

In the first stage of this migratory settling or "colonisation", as commonly defined in English, the most important settlement in Phoenician Sardinia was Sant'Antioco (Sulky). Founded in the 8^{th} century BCE on an island near the southwestern corner of Sardinia that was previously inhabited by indigenous people, it seems to have been the only settlement with urban status in this period according to the archaeological evidence. In the 8^{th} and the 7^{th} centuries BCE, other smaller settlements were founded along the coast, with the most important being Nora, Bithia and Cagliari in the south; Tharros, Othoca and Neapolis in the mid-west; Cuccureddus di Villasimius in the southeast and Olbia in the northeast (Guirguis 2017: 56). Olbia, a unique case in Sardinia, was Phoenician only until the end of the 7^{th} century, when it was occupied by Greeks until the end of the 6^{th} century (see section 3.2.4).

Except for Sant'Antioco, these settlements were inhabited by a few families, and they appear to have functioned as trading posts. In this phase of Phoenician migration, the location of the settlements exclusively on islands and peninsulas appears to confirm that local communities were still in control of the land and the island. An agreement with the local communities can be hypothesised using modern comparisons (Ruiz-Galvéz 2013) and is also suggested by material culture and toponyms (Zucca 2017). It is likely that indigenous people cooperated in the birth of these outposts, not only trading with them but also living there (Zucca 2017: 50-53; see also Delgado 2017, Guirguis 2019b, and Hodos 2010 for a Mediterranean overview).

Figure 13. Map of Sardinia with an indication of the main settlements and regions of Phoenician and Punic colonisation. Reworked from Bartoloni 2017: 260. Squares indicate settlements involved in this project.

From the 8th to the 6th century BCE, Phoenician settlements were founded mainly by the coast, while some Phoenician people and small groups were also apparently living in Nuragic villages (Secci 2017: 260). A different model for interacting and settling has been outlined for the area of Sulcis in the southwest of the island (Botto et al. 2013). There, the previously mentioned urban settlement of Sulky/Sant'Antioco and other smaller and less investigated settlements of Inosim and Portoscuso were founded on islands along the coast in the 8th century BCE. Around the 7th century, Phoenician people likely moving from Sant'Antioco settled in indigenous villages (e.g. Nuraghe Sirai (Perra 2019)) and, cooperating with local people, established new settlements on hills in the hinterland (Monte Sirai and Pani Loriga), obtaining control of the routes from the sea to the centre of the island and of the territory around the hill. The nature of the Phoenician presence in this area is different from what the evidence suggests for the other regions of the island; in no other area does inland penetration occur so early. This difference is likely connected to different degrees of interaction and the relationship among the local communities; in this region a "mixed" Sulcitan community seems to have developed, whose peculiar nature will be confirmed by later events (see section 3.1.3).

During these first centuries of stable Phoenician presence Levantine materials are attested around the island, locally reinvented and reused (Van Dommelen and Roppa 2014). Phoenician settlements were certainly also inhabited by indigenous people, and potentially by people from other parts of the Mediterranean (Rendeli 2017; Guirguis 2019a). Cultural variety existed in and among both the settlements. Funerary culture in this sense is revealing. Three different "Phoenician" incineration rites are found on the island between the 8th and the 6th centuries BCE (Bartoloni 2005; Bison 2015). Not all of them are attested in the motherland, where funerary practices are also varied (Sader 2005), suggesting that local elaborations of Levantine funerary practices existed on Sardinia. Moreover, in several burials generally definable as "Phoenician" basing on funerary rite, indigenous or southern and central Italian vessels are located among grave goods directly connected to the ritual, suggesting the existence of "hybrid" practices (Guirguis 2010: 26). In the same Phoenician period, animals and food commodities are also introduced in the island, as it is explained above (see section 2.2), while no major environmental change is recorded, confirming the limited impact of the initial Phoenician presence on the island.

During the first half of the 6th century BCE, no major changes are attested on the island, but the archaeological evidence, especially from funerary contexts, suggests the arrival of a small number of people moving from Carthaginian North Africa in the beginning of the century (Bartoloni 2005; Botto 2008). Due to contemporary and subsequent events, which show a direct intervention by Carthage in the affairs of the island, the nature and aims of this new, limited migration are still debated. According to written sources (Justin, XVIII, 7, 1-2), Carthage won several battles against indigenous tribes in North Africa in the first half of the 6th century BCE. In this way, they probably established a new balance of power and freedom of movement on the continent, thus making a new phase of overseas expansion possible.

The first military intervention by Carthage in Sicily is recorded by the sources (Justin, XVIII, 7) and dated around 545-540 BCE. In approximately 541-535 BCE, the sea battle known as battle of Alalia occurred in the Tyrrhenian Sea, signaling a new level of Carthaginian involvement in overseas affairs. The war was caused by an increasing Phocaean interest in the central Tyrrhenian Sea, made clear by the establishment of a new Massalian colony in Alalia (Corsica) in 565-563 BCE. A coalition of Etruscan cities and Carthage confronted a Phocaean army in a naval battle along the Sardinian and Corsican coasts, which caused great losses on both sides, despite Greek sources reporting the Phocaeans as the winners. Carthaginian expansion plans were only slowed by this outcome, which, on the opposing side, caused the Greek expansion in the central Mediterranean to stop, the partial Greek abandonment of Corsica, and a new balance in the western Mediterranean where Carthage played a central role (Bernardini et al. 2000).

3.1.3 The Carthaginian period (509-238 BC)

Everything suddenly changed on the island from the end of the 6th century BCE. In the second half of the century, Carthaginian interest and involvement in Sardinian events increased rapidly, following the military events outlined above. Written sources report two consecutive military campaigns by Carthage in Sardinia. The first, led by general Malchus around 540 BCE, is reported to have been a failure (some scholars identify it as the naval combat against the Phocaeans, e.g. Gras 2000), while the second one, led by Amilcar and Asdrubal around 520-510 BCE, led to the control of a large section of the island (Bartoloni 2017: 79; details below). Both campaigns are reported in late sources (especially Justin, 2nd century AD; XVIII, 7; XIX, 1), and the details are highly debatable. However, archaeological evidence seems to confirm some kind of military intervention against Phoenician settlements in Sardinia: fires are documented in Cuccureddus di Villasimius (Bartoloni 2017: 81; Guirguis 2019b), and disruptive changes (see below) are recorded in the island's Phoenician settlements around the end of the 6th century.

In the first Romano-Carthaginian treaty, signed in 509 BCE, the control of the island is taken as an accomplished fact: Sardinia is compared to Libya (the Carthaginian part of North Africa), and, according to the treaty, no trade or sale was allowed on the island without a Carthaginian officer present (Bondì 2017: 101). It is known, thanks to epigraphic sources, that similar treaties were stipulated in the same historical period between Carthage and other Tyrrhenian cities (e.g. Pyrgi; Bellelli and Xella 2016). This makes clear both Carthaginian political choices and the new geopolitical balance which followed the battle of Alalia. The treaty between Rome and Carthage establishes that, from the Carthaginian point of view, Sardinia had the same status as North African territories under Carthaginian control. This control was mainly commercial and aimed at protecting Carthaginian interests and removing commercial competitors. In the first phase of the Carthaginian presence in the island, interventions to control and penetrate the island's hinterland appeared to have been limited. The first consequence of the new power balance was the fall and abandonment, or radical reduction, of the Phoenician settlements on the east coast of the island. This was due to the stoppage of trade routes to Etruria imposed by Carthage to safeguard its relationship with Athens. Materials from Etruria become rare at the end of the 6th century BCE and stop in the following century (Botto 2017a:77; Bartoloni 2017: 80). The military intervention in Cuccureddus di Villasimius (southeast of the island) could be related to a resistance to this new imposition, if not related to the previous Greek-Carthaginian battle as suggested by recent evidence (Guirguis 2019b).

Several events characterise this first Punic phase. A major change in the funerary record occurs, with incineration typical of Phoenician Sardinia giving way to inhumation, typical in Carthaginian North Africa. The material culture is considered more "North African", i.e. related to Carthaginian examples, and these materials will be referred to as "Punic" in this dissertation. The foundation or re-foundation of a major new "national" sanctuary in Antas takes place, and there are several additional changes in settlement location and diffusion, with the fall of the eastern settlements being one such example.

The main settlement in this new phase was Cagliari, which was probably chosen by the Carthaginian power as a sort of administrative centre of the island. The extension of the Punic necropolis began at this time. The necropolis is characterised by shaft chamber tombs and the rite of inhumation, following the Carthaginian custom and not the cremation ritual of Phoenician Sardinia. The richness of grave goods and the creation of the *tophet* sanctuary testify this new status as an urban centre (Bartoloni 2017: 82). Major urban renovation works are also recorded for the 5th century BCE in Nora (Bonetto 2009), while similar inhumation necropolises were developed in several pre-existing settlements such as Nora, Tharros, Sant'Antioco and, later, Monte Sirai, Pani Loriga and Olbia (Bartoloni 2005). *Tophet* sanctuaries, usually considered an indication of urban status for Punic settlements (Aubet 2009: 264-266), were launched in the same period in Nora, Tharros, Cagliari and, a few decades later at the end of the 5th century, in Monte Sirai.

This interest is not only conveyed through investments in the previous Phoenician settlements, but also through the establishment of new settlements. During the 5th century, agricultural settlements were founded or revitalised in the Campidano plain and in the nearby areas of Marmilla and Trexenta (Bartoloni 2017: 86; see fig. 13). This establishes the Carthaginian desire to control the routes connecting the sea and the plateau to the island's hinterland, and the beginning of a new wave of Punic penetration into rural areas. Other indigenous settlements in the hinterland appear to have been re-invigorated from the end of the 5th century BCE (Bartoloni 2017: 86). During the 4th century BCE, marking the peak of Carthaginian power and success in Sardinia, some of the settlements that were facing a decline in the 5th century were renovated with new structures, investments and potentially inhabitants; this was the case of Bithia, Othoca, Sant'Antioco and Monte Sirai (Bartoloni 2017: 96). These major changes were likely made possible due also to migration of small groups moving from Carthage itself and Punic North Africa, as suggested by written sources (Moscati et al. 1997). This appears to be confirmed by the presence of Sardinian material culture with North African examples that are not typically found in Carthage (Bison 2015).

The military aspect of this presence should not be ignored. The existence of fortified outposts suggests the allocation of small military contingents in some areas on the south of the island (Bartoloni 2017: 84). In the 4th century BCE, several pre-existing settlements are provided with fortified walls, among them Olbia, Cagliari, Bithia, Nora, Sant'Antioco, Monte Sirai and Inosim (Bartoloni 2017); these walls could have both an ideological and functional meaning, and they convey a renewed interest by the North African capital in controlling and safeguarding these towns.

Other changes and new developments refer to the religious sphere. Around the end of the 6th century BCE, a temple dedicated to the god Sid Addir Bab(a)i (a syncretism of a Punic and a Nuragic deity, both related to hunting [Bartoloni 2017: 88]) was created in Antas, in the area of Sulcis. Other religious structures were created in the same area around the 4th century BCE; these sanctuaries are not connected to a settlement, but they are located in the middle of a mining basin and, notably, in the area where the Phoenicians were better integrated with the local people and culture. Sid-Babi in Antas was the most important religious structure, as indicated by the "national" success of the temple and the fact that the structure was renovated several times from the 4th century BCE until the 3rd century AD. In the Roman period, the god was known as Sardus Pater. The precise role of Carthage in the creation and development of this cult is still unclear, but the African city clearly used it for its hegemonic purposes to promote a coherent Sardinian-Punic identity (Quinn 2018: 126).

In general, through the evidence outlined here and other additional elements (see especially Van Dommelen 1998; Van Dommelen and Gomez Bellard 2008), it is possible to recognise in Sardinia a second phase of the Carthaginian hegemony commencing at the beginning of the 4th century and ending with the Roman conquest. This phase is characterised by a rural penetration of the Carthaginian power and culture, through the foundation of farms, settlements, rural sanctuaries and the already mentioned military forts; this effort is recorded not only in Sardinia, but also in western Sicily and North Africa (Bartoloni 2017: 95). The rise of several small rural settlements especially characterises the Campidanese plain, the Sulcitan area, the peninsula of Sinis and the area around Olbia, which worked as a central place, possibly with urban status (Secci 2017; fig. 13). Apparently, no Punic settlement, despite the attested diffusion of Punic material culture, was founded in the northwest of the island. The penetration of the Carthaginian culture in rural Sardinia is also testified by the diffusion of Punic toponyms in the hinterland of the island (Secci 2017: 261).

This process of rural penetration proceeds throughout the whole of the 4th and 3rd centuries BCE, apparently without break despite the political situation suddenly changing in the middle of the 3rd century (Secci 2017). After the loss of the first Punic War in 241 BCE, Carthage started a war against its rioting mercenary troops in Sardinia and, at the end of the war in 238 BCE, it was forced by Rome to leave the island, which was consequently occupied by Roman troops (Bartoloni 2017: 100). Sardinia did not readily accept the new power, and riots and wars characterised the first decades of Roman occupation, as testified by the six triumphs against the Sardinian people celebrated in Rome over 120 years. The hero of these riots, a Sardinian nobleman, had a Semitic name, Ampsicora, highlighting the embedded Punic-indigenous culture of the island at this stage. The Punic written language and political titles continued to be used at least until the 2nd century AD. Until the 2nd century BCE, material culture is still "Punic", and no break is recorded; this explains the inclusion of sherds from the 3rd and 2nd centuries in this research (see section 3.3).

3.2 Sites involved in the project

Sites selected for analysis of pottery are described in this section (fig. 39). The six targeted sites are different in location, chronology and nature (rural/urban; indigenous/Phoenician foundation). This information is illustrated per each site following the current debate and available literature, in which pottery and burials play a relevant role in culturally defining a site. Regional developments will be briefly mentioned in each site description, to better contextualise the site in the general picture of Phoenician and Punic Sardinia (see above, 3.1.2; 3.1.3). Selecting different sites is part of the sampling process, as described in Chapter 5 (5.1), aiming to obtain a wide dataset about Phoenician and Punic Sardinia. Faunal and environmental data available per each site, are exposed in Chapter 6 (6.1), as they are directly useful to compare and interpret results of the analyses.

3.2.1 S'Urachi

The Nuragic complex of S'Urachi (San Vero Milis, Oristano) is located on the alluvial plateau of Campidano di Milis, the extreme northern edge of the Campidano plain, in the hinterland of the Gulf of Oristano (Stiglitz et al. 2015: 194; fig.14). The region lies on the middle-western coast of Sardinia. It is a relevant area for the study and comprehension of colonial, cultural and commercial encounters (Stiglitz et al. 2015: 192). Between the 8th and 7th centuries BCE, Phoenician settlements of Tharros, Othoca and Neapolis are founded around the gulf, leading to the wide spread of Levantine materials in the area and to cultural and social changes in the indigenous communities (Usai 2012; Bernardini 2015).

Figure 14. The location of nuraghe S'Urachi (and the surrounding settlement) and the other main archaeological settlements around the Gulf of Oristano (from Stiglitz et al. 2015). Temple: Phoenician settlement; cross: ritual (indigenous) site; point: nuraghe.

The Nuragic complex of S'Urachi is composed of a *nuraghe* with multiple central towers and an external enclosure wall characterised by ten towers. It has been excavated at several different periods since 1947 (Stiglitz et al. 2015). Precise date of the Bronze Age *nuraghe* is unclear due to the lack of detailed stratigraphy. In the Phoenician period, a settlement was located outside of the external enclosure. This settlement and the external area of the nuraghe are the targets of an archaeological excavation and project aimed to investigate it (*S'Urachi: cultural exchange and daily life around a nuraghe in the historical period*). The project has been ongoing since 2013 and is run by the Joukowsky Institute for Archaeology and the Ancient World (Brown University, USA) and the Museum of San Vero Milis (Sardinia). Excavation is in progress, and only preliminary reports have been published: the history and life of the settlement up to this point can be only partially depicted. The material culture (pottery, settlement position, structures) suggests continuity with the indigenous Sardinian world. Up to this stage, the settlement proved to be in use and vital from at least the 8th century BCE until the early Roman era (Van Dommelen et al. 2018). Selected sherds from S'Urachi come from this present-day excavation (for more information see 6.1.1).

3.2.2 Pani Loriga

The archaeological area of Pani Loriga is located on a modest hill by the Riu Mannu river in the southwestern region of Sulcis, in the territory of modern Santadi (Carbonia-Iglesias). It was discovered in 1965 and has been excavated at several different points in time from then until the present (Botto 2016: 7).

The site is 20km from the Phoenician city of Sulky/Sant'Antioco (fig. 15), which was founded in the 8th century and was well-connected with Pani Loriga in ancient times. The Phoenicians from Sant'Antioco likely had a role in the foundation

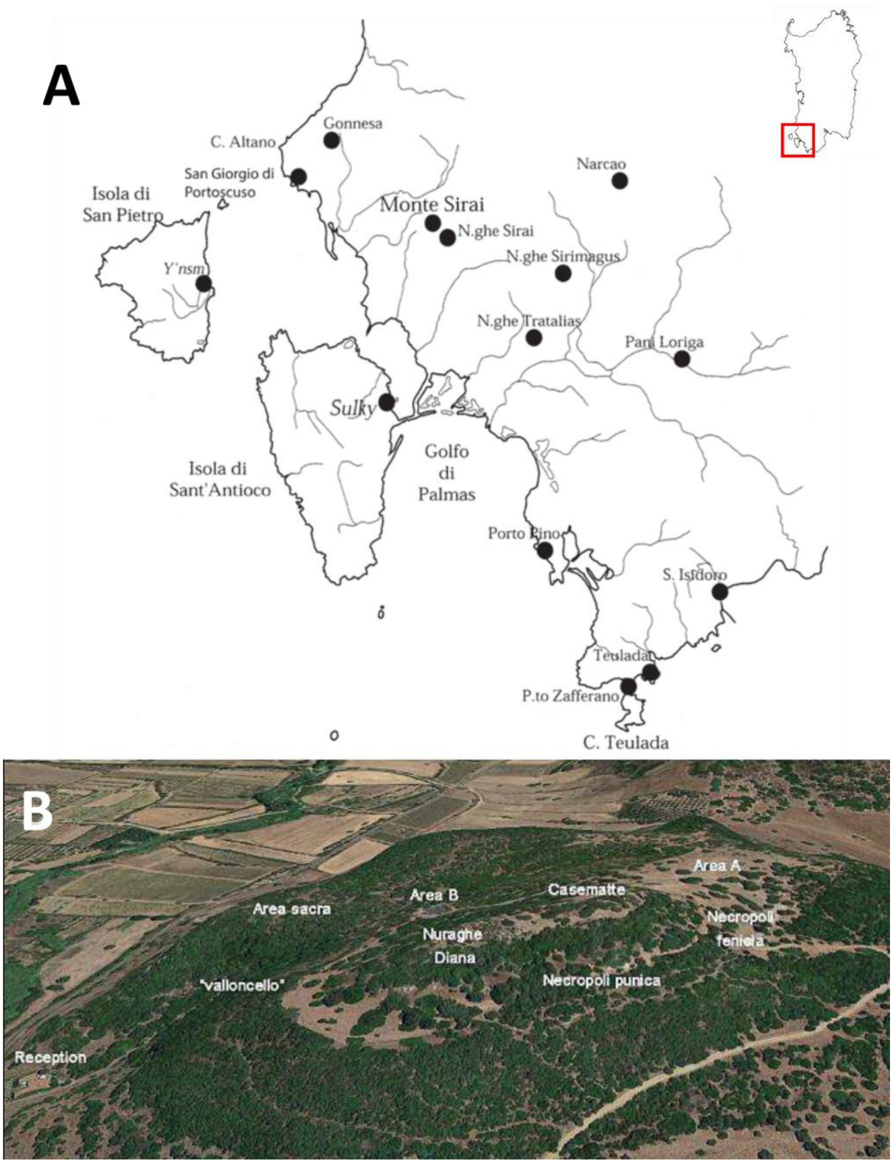


Figure 15. Location of Pani Loriga and other archaeological settlements in southwest Sardinia (A), and photo of the Pani Loriga hill with indication of Area B and other archaeological features (B), from Botto 2016.

of Pani Loriga in the 7th century BCE, as suggested by material evidence. Other settlements were founded in the Sulcis region at the same time (see 3.1.2). These settlements seem to have been established to control the coast of Sulcis, its hinterland and its agropastoral and mineral resources in a renewed cooperation between the Phoenician and indigenous communities, which is unique in this phase. This cooperation led to the creation of heterogenous communities. Pani Loriga, based on pottery and settlement position and structure, appears to have been one of these mixed communities (Botto 2016: 12).

This successful model of cohabitation and cooperation did not disappear during the Carthaginian hegemony. It was more probably transformed: in Pani Loriga, differently from other sites (see 3.1.2), major developments between the end of the 6th and the 5th centuries BCE have been discovered, with the creation of a fortified settlement on the site's hillside slope. The settlement was rapidly abandoned for unknown reasons around the middle of the 4th century BCE. It is still not known if it moved to a different part of the hill or another location within the region (Botto 2016: 13).

3.2.3 Nora

The ancient Phoenician, Punic and Roman settlement of Nora is located on a peninsula on the eastern side of the Gulf of Cagliari by a natural inlet that was used as a harbour. It was connected to a small (50km²) and fertile plateau surrounded by mountains, with limited ways to reach other parts of the island. As the location of the settlement suggests, Nora was created with a clear maritime and trading purpose (Finocchi 2002). The peninsula is characterised by three hills (two capes, Punta del Coltellazzo and Sa Punta 'e su Coloru, and a central elevation now known as Colle di

Tanit); the Phoenician and Punic settlement appears to have been located in the southwestern part of this peninsula (Bondì 2017a: 233; fig. 16).

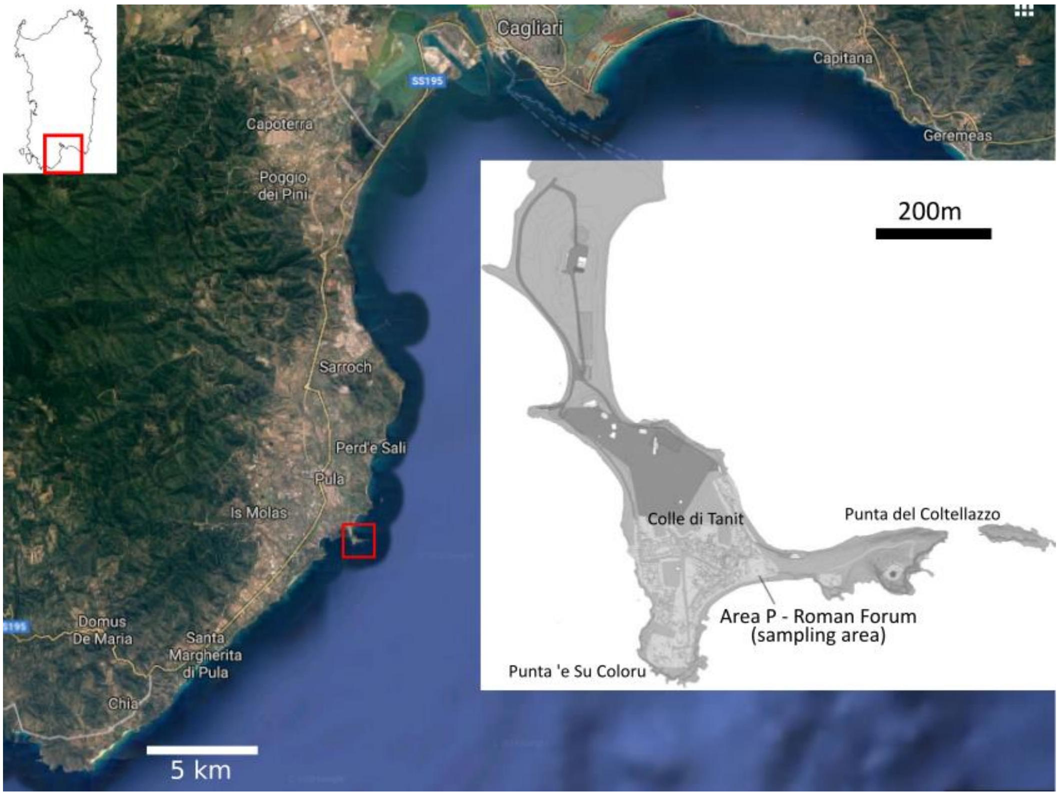


Figure 16. Location of the Nora Peninsula in the Cagliari Gulf, and map of the peninsula (reworked from Bonetto 2009).

Ancient sources defined Nora, which was inhabited as a city until the end of the Roman era, as the most ancient Phoenician city in Sardinia (Pausanias, 10, 17; Solinus, 4, 2). However, excavations undertaken since 1990 by the Universities of Genoa, Milan, Padua, Pisa and Viterbo (Bondì 2017a: 234) have contradicted this possibility. No evidence suggesting urban status was detected in the Phoenician phase. A clearer picture of the settlement's historical developments was obtained as a result of new archaeological data. According to the evidence available from the Roman Forum excavation (Bonetto 2009) and other more recent data (Berto et al. 2012; Bonetto et al. in press), it is now established that Nora was a small settlement from at least the 7th to the 6th centuries BCE. It was likely used as a commercial outpost as there are no evident urban features (Bonetto 2009: 69-78) and it lacked territorial control (Finocchi 2002): it is defined as a "Phoenician" settlement in archaeological literature based especially on pottery and features of the burials, characterised by cremation rites (e.g. Bondì 2017a). Only in the Carthaginian period, from the end of the 6th century BCE, was Nora converted into a more relevant settlement, probably reaching urban status. Major changes are attested, as suggested by the use of non-perishable materials, the creation of new specialised buildings and housing blocks (Bonetto 2009: 175), the occupation of new areas (Finocchi 2013: 162) and the creation of the *tophet* sanctuary in the 5th century (Bondì 2017a: 238). The Phoenician and Punic necropolis of Nora begins from at least the end of the 7th century and remains in use in the same area, despite changing funerary customs, until at least the 3rd century BCE (Bonetto et al. 2017). No further major changes are recorded in the urban area until the 2nd century BCE, while the Punic occupation of the hinterland highly develops in the 5th and 4th centuries BCE (Finocchi 2013: 171).

3.2.4 Olbia

The city of Olbia is located on its eponymous gulf in the northeastern corner of the island, isolated from the other Phoenician and Punic settlements on the island and from the Mediterranean (D'Oriano 2017: 252, fig. 1; 13). The settlement was located by a natural spring, on a well-protected gulf that served as an ideal harbour for Tyrrhenian routes; it was also close to fertile plains and suitable areas for fish breeding and salt extraction (D'Oriano 2017: 251; fig. 17).

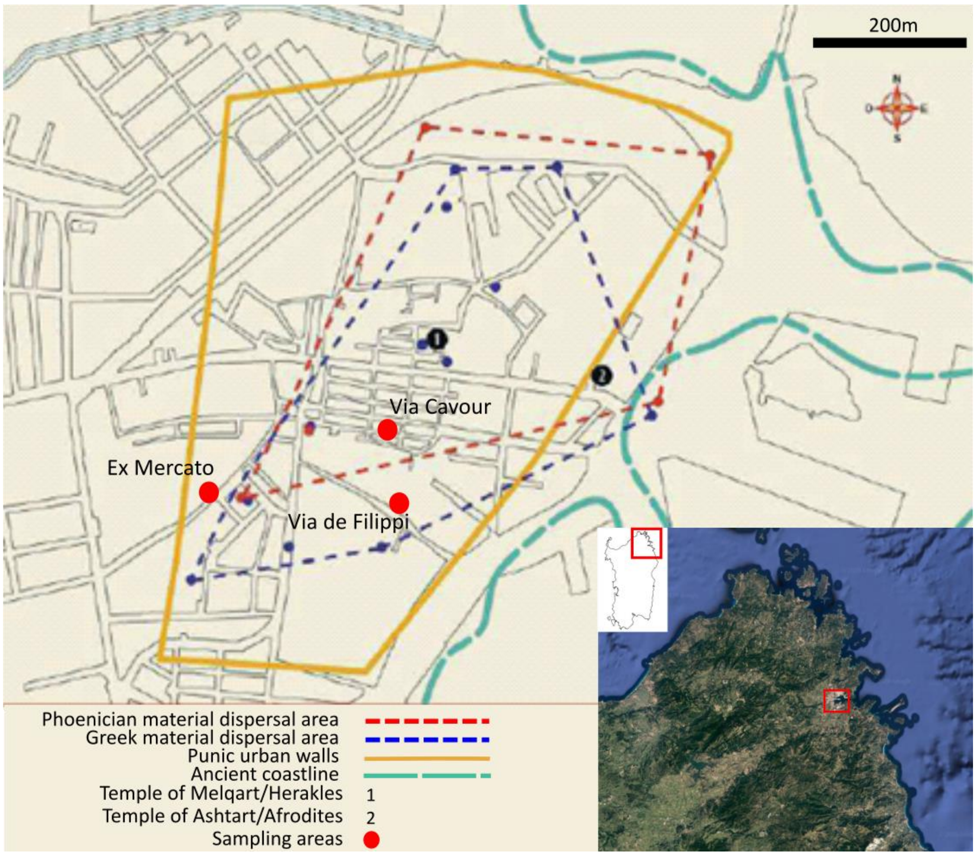


Figure 17. Map of the ancient settlement of Olbia showing the main archaeological features and the ancient coast line, reworked from D'Oriano 2017, with indication of sampled contexts. On the right, map of the region of Gallura, with the location of Olbia.

Around the middle of the 8th century BCE, Phoenician people founded a settlement here, but, uniquely in Sardinia, the settlement was abandoned around 630 BCE and occupied by Greeks from Phocaea (D'Oriano 2017). Based on changes in material culture, especially pottery, and settling, it appears the Greeks left the settlement when Carthage took control of Sardinia at the end of the 6th century BCE, but this phase is archaeologically unclear. The whole area of the archaic settlement was extensively rebuilt in the 4th century, impacting the lower layers. Around 330 BCE, Olbia became a more relevant settlement, probably reaching urban status. The city wall, a new orthogonal settlement and a new necropolis were created at this time (D'Oriano 2017: 254; fig. 17). This change was likely due to the deliberate intervention of Carthage and the arrival of people from other Punic areas, such as North Africa and possibly the island's hinterland (Cavaliere 2010a). No major change is recorded after the 4th century until the Roman phase. These actions of settlement rebuilding extensively removed lower layers and previous buildings. For this reason, well-dated archaeological contexts and materials in Olbia are mostly dated between the 4th and the 2nd centuries BCE, i.e. from the Punic phase. More than the 90% of the sherds involved in this project come from this phase (see 6.4).

3.2.5 Sant'Antioco

Sant'Antioco (SLK in the Phoenician language), often named *Sulky* in Phoenician and Punic archaeological literature (Unali 2017) was, as presently accepted, the most important settlement of pre-Carthaginian Sardinia. It is commonly considered by scholarship as the only settlement with urban status in Phoenician Sardinia (Unali 2017; Guiguis 2019a; Tronchetti 1991). It was founded by Phoenician people around the middle of the 8th century BCE on the Sant'Antioco island on the southwestern coast of Sardinia (see fig. 15; Guirguis 2019a: 113). Sant'Antioco island itself was previously inhabited by indigenous people who likely cooperated with the new group, as suggested by local pottery attested both in the settlement and in the sanctuaries (Unali 2017: 129). The position of the settlement enabled both to control the sea routes between the south and the west of the island, and the mineral resources of the hinterland (Unali 2017: 129). As explained above (3.1.2; 3.2.2) the area of Sulcis was characterised by a deeper cooperation and cohabitation of Phoenician and indigenous people between the 8th and the 6th century BCE, and Sant'Antioco/Sulky worked as a central place for the region.

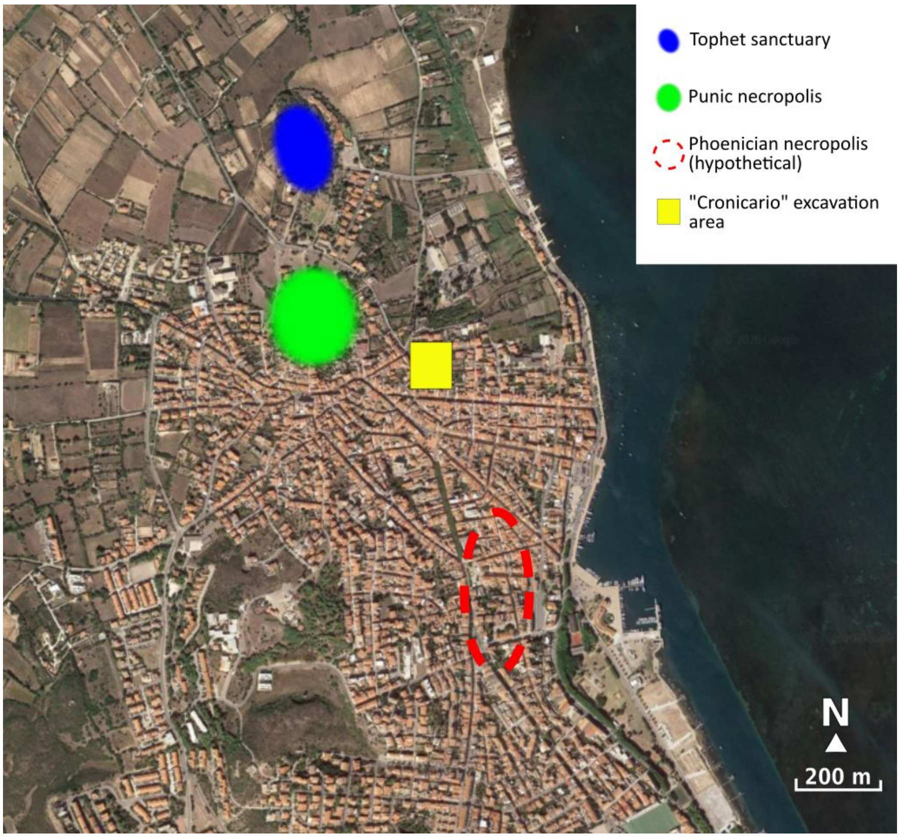


Figure 18 Map of present-day Sant'Antioco with indication of the main archaeological features of the Phoenician and Punic site.

Despite its relevance, the history of Phoenician and Punic Sant'Antioco is poorly understood, since the modern settlement is located exactly on the ancient one and habitation continued from the ancient times through the present day (fig. 18). The *tophet* sanctuary and the Punic necropolis, located on an upper area at the north of the settlement, are among the most studied parts of the site. The *tophet* sanctuary was in function between the 8th and the 1st centuries BCE, being the only *tophet* of Phoenician Sardinia (see 3.1.2). The hypogeal necropolis was founded in the 5th century BCE and, as typical in the Punic phase, was characterised by chamber tombs (Unali 2017: 136). The Phoenician necropolis, characterised by the rite of cremation, has never been identified and only some burials are known. Both the *tophet* and the necropolis suggest a sort of specificity and vitality in the material culture of Sant'Antioco: both the stelae of the *tophet* and the chamber tombs do not follow directly Carthaginian models.

The most excavated and studied settlement area is the one known as “Cronicario”. It has been targeted by archaeological excavations by the University of Sassari in different points in time since 1983, under the direction of Paolo Bartoloni and now Michele Guirguis. The area had an artisanal function in the Punic age. A dump found here, which was used between the 5th and the 3rd century BCE, offers a good overview of the life of the settlement (Campanella 2008). Sherds involved in this project come from this dump. Less is known about the Phoenician phase of the settlement. Only recent excavations are targeting the lowest layers, suggesting the existence of a complex trade network and of a multicultural settlement since the 8th century BCE (Guirguis 2019a).

3.2.6 Genuri – San Marco

The *nuraghe* San Marco is located in the territory of modern Genuri in the region of Marmilla at the foot of the upland (*altipiano*) della Giara, (Atzeni et al. 2012; 2016; fig. 19). The *nuraghe* is constituted by one central tower and three surrounding towers. It was located in an area characterised at the end of the Bronze Age by the presence of several other *nuraghi* (Atzeni et al. 2012).

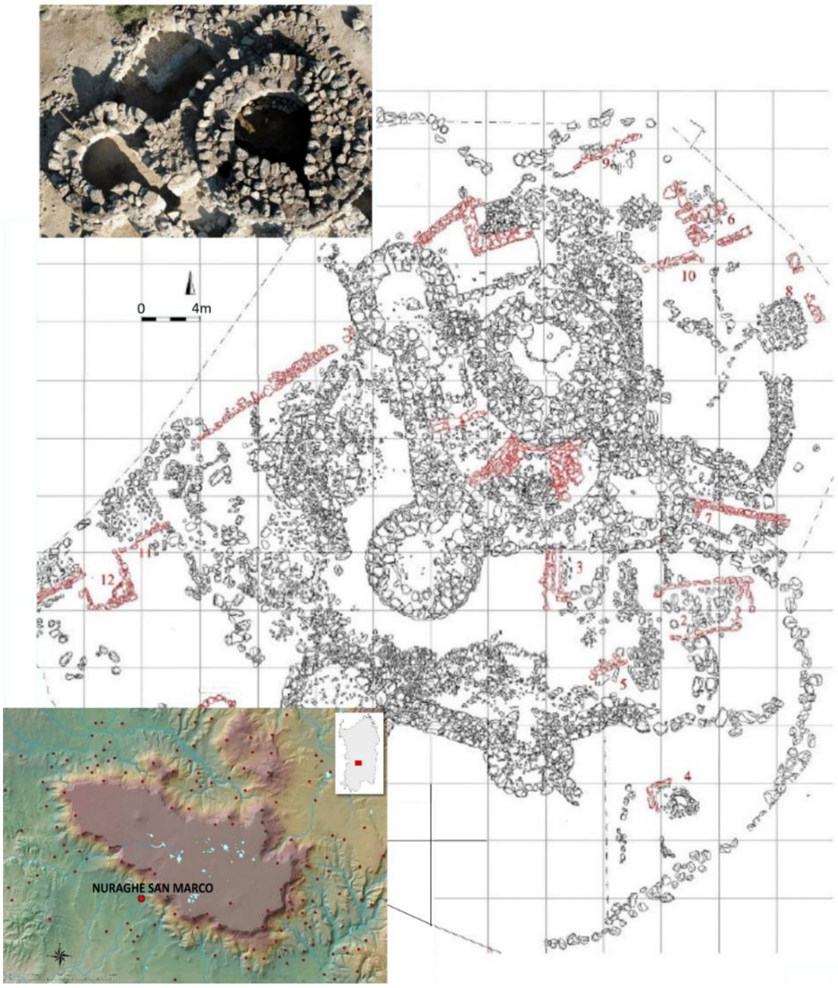


Figure 19. Map of the Nuraghe San Marco. Post-nuragic structures highlighted in red. In the photo: room 22 (Punic phase) located in the surrounding area, north to the nuraghe. From Atzeni et al. 2016 (tav.1). On the left, location of nuraghe San Marco and other nuraghi surrounding the altipiano della Giara, reworked from Atzeni et al. (2016).

This complex has been recently investigated, between 2001 and 2013, revealing a domestic reoccupation around the *nuraghe* in the late Punic period (4th–3rd centuries BCE) and then following settlements until the Medieval age (Atzeni et al 2016). The Punic age settlement, targeted within the current research, is one of the many settlements founded in the hinterland of Sardinia during the rural expansion of Carthage (see 3.1.3). The settlement, however, appears to have been likely inhabited by indigenous people who adopted Punic pottery, as in S'Urachi: the settlement position and structure does not show discontinuity with the Sardinian indigenous world. The 4th-3rd centuries BCE settlement is well dated and excavated, but unfortunately little has been published, the only paper being Atzeni et al. 2016. The excavators, basing on stratigraphy, hypothesise a consistent settlement living for an extended period of time between the two centuries. Material culture suggests that the settlement, despite being peripheric, was inserted in a rich network of trade inside and outside the island (Atzeni et al. 2016: 177).

3.3 Ceramic categories involved in the project

The main ceramic categories believed to be involved in food preparation and cooking have been included in the analysis, based on current archaeological literature. In this section, ceramic categories analysed in the project will be briefly described, outlining the shape, function and other key features of each vessel category. The section is a synthesis of the present state-of-art of knowledge, rather than a comprehensive catalogue of types and subtypes. This choice is determined by constraining available information, posing limits to the current research and interpretation of results.

The most comprehensive ceramic catalogues for Phoenician and Punic Sardinia are site-based (Campanella 2008; Campanella 2009a, b, c). A Sardinian catalogue on an island level does not exist. This means that every paper and catalogue classifies their ceramic assemblage differently, and often inconsistently. As explained in the introduction, a single site-based project was not undertaken on the insistence of the *Soprintendenza*, although sampling from a number of sites still enables the first major organic residue analysis dataset to be generated for Phoenician and Punic Sardinia. Since ceramic categories adopted in the Phoenician and Punic period are similar all over the island, the current state of research on common wares in Phoenician and Punic Sardinia makes it possible to undertake general comparisons and highlight trends on an island level. Since many local variations exist, however, more detailed ceramic definitions on an island-wide basis are not yet available. These local variations have never been systematically classified. This is particularly true for common cooking ware, as the one analysed in this project, because it was often locally produced and used, causing a plethora of small variations in shape/form between sites, although a general level of comparability remains (Roppa et al 2013).

For these reasons, the synthesis presented in this section adopts the following criteria. Ceramic catalogues of Nora (Campanella 2009 a; b; c; Botto 2009) are used as a base for definitions and an anchor for island-level comparisons. This is because these catalogues represent the most comprehensive ones for Phoenician and Punic Sardinia, since they include strata and pottery from the 8th century BCE to Roman times. Types and vessel categories in this section are described combining data from Nora with data available in other published ceramic catalogues from other sites (e.g. Chessa 1992; Bartoloni-Campanella 2000; Campisi 2000; Cavaliere 2007), updated through discussions with pottery specialists. Shape names and definitions are based on English translations of the common definitions adopted by

Sardinian scholars, especially Lorenza Campanella, who has published the most comprehensive catalogues available about Phoenician and Punic cookware (Campanella 2008; 2009a, b, c).

It has been decided to not describe fabrics and subtypes in detail, since this information is not available for every site in this study. For example, fabric information is lacking for four of the analysed sites: Pani Loriga; Sant'Antioco, Olbia, and Genuri San Marco. Furthermore, fabrics and subtypes of pottery widely vary between sites, and no agreed classification system exists, making comparisons on an island-wide level inconsistent. This decision to avoid greater detail and comprehensive lists therefore avoids overrepresentations of single site assemblages and consequent misunderstandings. Attention is given to those subtypes which are recorded all over the island, and thus reflect general (island-wide) trends. Other subtypes are shown in the figures (figs.21, 23, 24, 26) to offer an idea of the existing variety. Other extra-Sardinian areas of the Phoenician and Punic world will be mentioned when necessary, for example to indicate the origin or the diffusion of a specific type. Additional descriptions and details, limited to targeted sherds and sites, will be discussed in the discussion (Chapter 7). Connecting lipid preservation to fabrics could be a relevant path for future research (see 8.3).

3.3.1 Cooking pots

In Phoenician and Punic Sardinia, cooking pots are characterised by a wide, curved body and a narrow mouth. Their use can be hypothesised based on existing statuettes (fig. 20) and adopting general assumptions on shape. It has been argued that, "a cooking pot that is at least as deep as it is wide […] reduces the relative surface area so that liquid evaporates more slowly and is thus useful for food with a high liquid content – such as porridges, stews and broths" (Spataro-Villing 2015: 6).

Only potsherds recovered from settlements have been analysed for this project, thought to be involved in daily life. But in the Phoenician and Punic world cooking pots had also a ritual use, which needs to be underlined. Indeed, these pots, apparently used for cooking and daily life, were also regularly used as urns in *tophet* sanctuaries and occasionally in necropolises on the island (Bartoloni 1996). This is not a feature specific to Phoenician and Punic Sardinia. Cooking pots are more often used as urns at other Phoenician settlements outside of Sardinia (Delgado-Ferrer 2011a; Orsingher 2015). These pots are also often found in tombs as containers for food offerings, both in Sardinia and in other Phoenician necropolises (Bartoloni 2005). Therefore, the cultural role and

Figure 20. "Phoenician" terracotta figurine showing a person cooking with a globular pot, Musée du Louvre, provenance unknown (Spataro-Villing 2015: 3).

meaning of cooking pots in the society under investigation was probably different to the modern Western one. This element will be considered during the interpretations and discussions in Chapter 7.

Two pot-making traditions are attested on the island during my target period, following parallel and interconnected developments.

3.3.1.1 Wheelmade pots

Wheelmade cooking pots on Sardinia are defined in literature as "Phoenician and Punic pots" (e.g. Campanella 2008; 2009a; Roppa 2015) because these shapes were brought to Sardinia by Levantine migrants. However, the fabrics suggest that these pots in Sardinia are primarily produced locally, indicating the ceramic traditions develop on the island following local patterns. Over 15 subtypes of wheelmade cooking pots have been distinguished by archaeologists. Twelve subtypes have been found in Nora, used here as a base dataset. Subtypes date span from the 8th to the 2nd centuries BCE (Campanella 2009a). A selection of these subtypes is shown in figure 21. Some are attested only occasionally and locally. Other subtypes are widespread across the island and are described here.

At Nora, the most common type of wheelmade pot is the globular pot called P2 by Campanella (2009a) (fig. 21 a, b, c). This shape is represented in more than 80% of fragments in the Roman Forum. The same type is found at all target sites in this project. These pots are characterised by a globular shape, one handle (P2 pots with two handles are attested outside Sardinia), a distinct everted rim that is internally thickened and has a pointed lip. They represent the most typical cooking vessel for the Phoenician phase (8th to 6th century BCE) in the western Mediterranean, and they originated directly from Eastern traditions (Spagnoli 2010). The shape evolved from smaller, ovoid pots to become bigger and more globular (Campanella 2009a: 300). The base appears to have been partially flattened to fit on a small stand (Campanella 2009a: 313-314). They are often defined in Spanish and Italian literature as "cooking pots" (e.g. Campanella 2008; Roppa 2015), but I will always define them as P2 pots, following Campanella's typological definition, to avoid any misunderstandings.

In other areas of the island, the most common subtype is different, but a full-scale picture of the island is too complex to be described due to the limited number of published and investigated contexts. For example, during the 6th and 5th centuries BCE, the most common type of cooking pot in the region of S'Urachi is a globular pot with an outward curving "Greek style" rim (this is distinguished as P3 by Campanella 2009a; Campisi 2000: 162; Manca di Mores 1991; fig. 21d). In the same period around Sant'Antioco and Pani Loriga (Campanella 2008; Castiglione 2018), however, the most common type was the pot with straight and vertical rim (defined as P5 by Campanella 2009a; fig. 21e).

Cooking pots varied over the centuries, but since research about these types is recent and no comprehensive investigation has been undertaken on the island, it is not possible to identify any trends at present. Most of the changes detected refer to the shapes of the rim, as seriation for other parts of the pot is far more complex. Without a recognised functional use, these changes have only limited relevance to this project. Fig. 21 illustrates some of these pot shapes. Among the changes, it is important to highlight the appearance of "lid-seating grooves" that appear in some pots from the 5th century BCE. These grooves imply that lids were introduced. This may be a reflection of the adoption of a Greek tradition. Lids possibly substituted multifunctional dishes previously used (Campanella 2009a). P2 pots, no longer produced in the 5th century, seem to be replaced by a shape called P6 by Campanella (2009a: 328), which features this "lid-seating groove" (fig. 21 f, g). This shape is attested across the western Punic world from the 5th century BCE, first appearing in Sicily (Campanella 2009a: 328) where links with Greek culture were more developed.

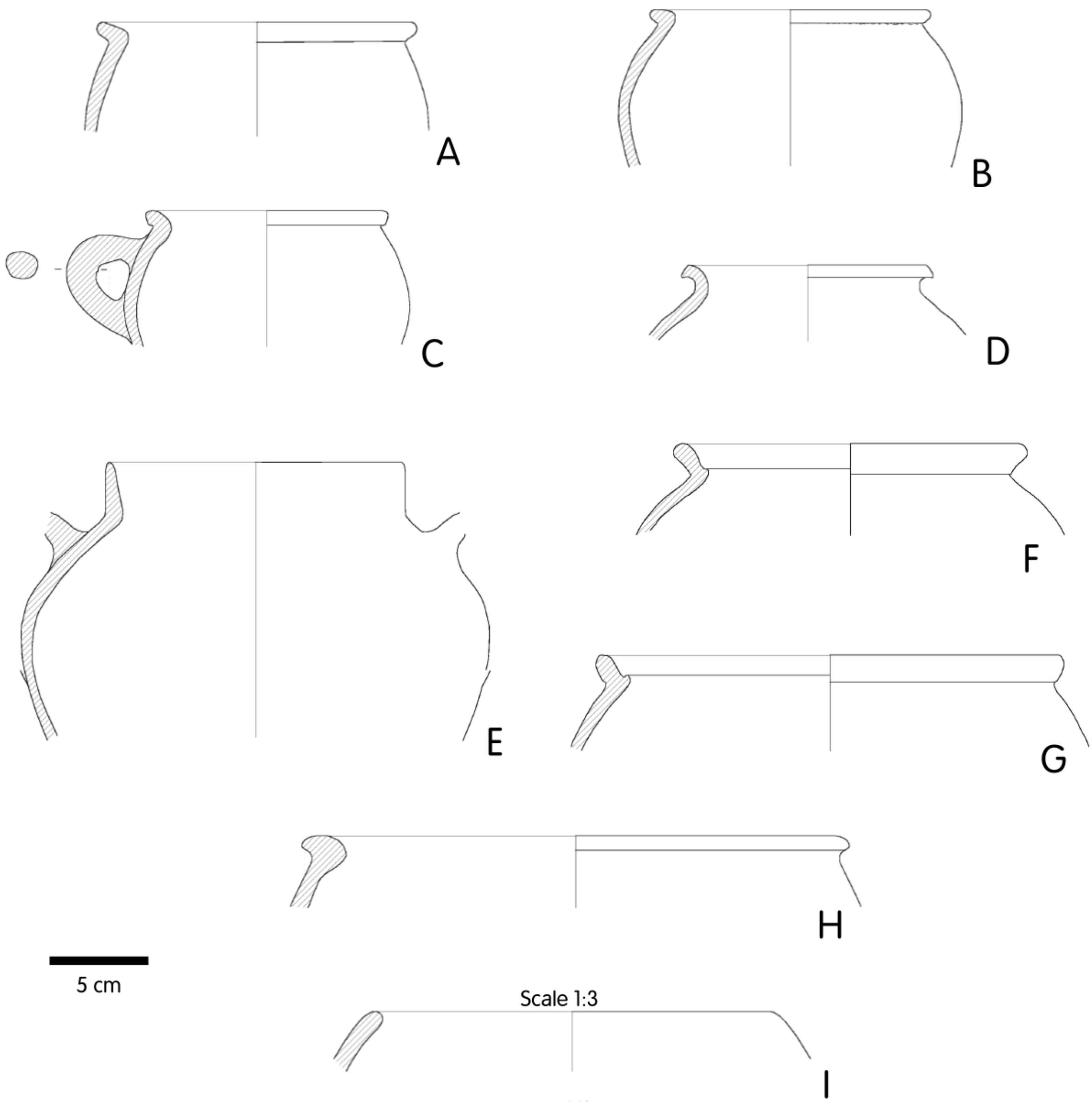


Figure 21. Wheelmade cooking pots from the site of Nora (Campanella 2009b). Types: A. P2, subtype A (7th century BCE); B. P2, subtype B (first half 6th century BCE); C. P2, subtype C (second half 6th century BCE); D. P3 (5th century); E. P5 (5th century BCE); F. P6, subtype A (3rd–2nd centuries); G. P6, subtype C (3rd century BCE); H. P8 (4th–2nd centuries); I. P10 (3rd–2nd centuries BCE).

At the present stage of research, it is not possible to distinguish or hypothesise differences in use between these types of cooking pots: the shape is always quite similar, handles are often attested, and fabrics confirm the primary purpose was cooking due to the abundance of large inclusions used to increase fire-resistance (Campanella 2009a: 295).

3.3.1.2 Handmade pots

Handmade cooking pots, and handmade pottery in general in Phoenician and Punic Sardinia, has been traditionally connected with the indigenous world and manufacture. These shapes have variously been defined as "nuragic" (in Nuragic settlements, e.g. Van Dommelen et al. 2018) or prehistoric (Campanella 2008: 96). However, it has recently been demonstrated that these definitions can be misleading. On the one hand, it is now clear that not all the handmade material in Sardinia is dated to pre-Phoenician times. For example, these vessels were in use during the Punic period (Castiglione 2018), at least until the 3rd century BCE in Olbia (Cavaliere 2008; Perra 2016). These elements indicate that the chronology of handmade pots needs to be revised. For this reason handmade cooking pots are dated by context in tables I-VI (Appendix); when context is not available, chronology is proposed followed by a question mark. On the other hand, it is also clear that handmade materials in Sardinia cannot be always linked directly to indigenous makers. Fabrics of handmade materials, in Phoenician times and sites, are sometimes non-indigenous in texture and inclusions (Perra 2016). Moreover, similar cooking pots are found across the Phoenician Mediterranean. In Carthage, for example, "cooking in the eighth century was almost exclusively done in handmade cooking pots" (Mansel 2011: 358).

Figure 22. Handmade pot with "reverse elbow handle" from the Phoenician necropolis of San Giorgio di Portoscuso, late 8th century BCE (Guirguis 2017: 361).

These recently highlighted elements push to refuse the systemic equation "handmade=indigenous", which was often assumed until a few decades ago. Ongoing research is providing new data each year. However, up to this stage, on Sardinia handmade pots can still be regarded as generally linked with indigenous traditions and manufacture. Research on single cases is needed to better highlight the possible cultural origin of each vessel. Moreover, elements attested in some handmade cooking pots are clearly derived from indigenous Sardinian traditions, as in the case of "reverse elbow handles" (*anse a gomito rovescio;* fig. 22) and "ear handles" (*anse ad orecchia* (Cavaliere 2010a)).

Standardisation in handmade pots is limited, but some types can be distinguished. The most recognizable shapes are the "S profile" pot and the globular pot. "S profile" pots (fig. 23a, b) are found across the Phoenician West and in Sardinia, but not in the Levant (Botto 2009: 359). They have a distinctive rim with an "S" shape and a flat base. These productions and shapes derive from the interaction of different ceramic and cultural traditions. In the case of Sardinia, these pots can be interpreted as local Sardinian productions appearing in colonial contexts. The second shape to be described is the globular handmade pot (fig. 23d). On Sardinia, these cooking pots are especially known from Sant'Antioco (e.g. Campanella 2008: 194-196). They are linked with the typical Phoenician wheelmade pot named P2 (described above) because it has the same shape. It is difficult to establish why some globular pots were wheelmade and others were not, not only in Sardinia, but also in locations such as Carthage (Mansel 2011). Both types used to be dated between the 8th to the 6th centuries BCE, but recent research is overturning this chronology (Castiglione 2018; E. Madrigali and Andrea Roppa, *pers. comm*.), showing that these cooking pots were in use at least until the 5th century BCE.

Other handmade cooking pots present bulges, a spout and the already mentioned "reverse elbow handles" and "ear handles" (fig. 23e, f), or no specific features (these are defined as handmade pots in tables I-VI, Appendix). Their fabric is usually darker (reddish brown to brownish black) than that of wheelmade cooking pots, and inclusions are abundant and large. However, more "Phoenician and Punic" fabrics, with a finer texture and lighter colours, are also attested (see Perra 2016).

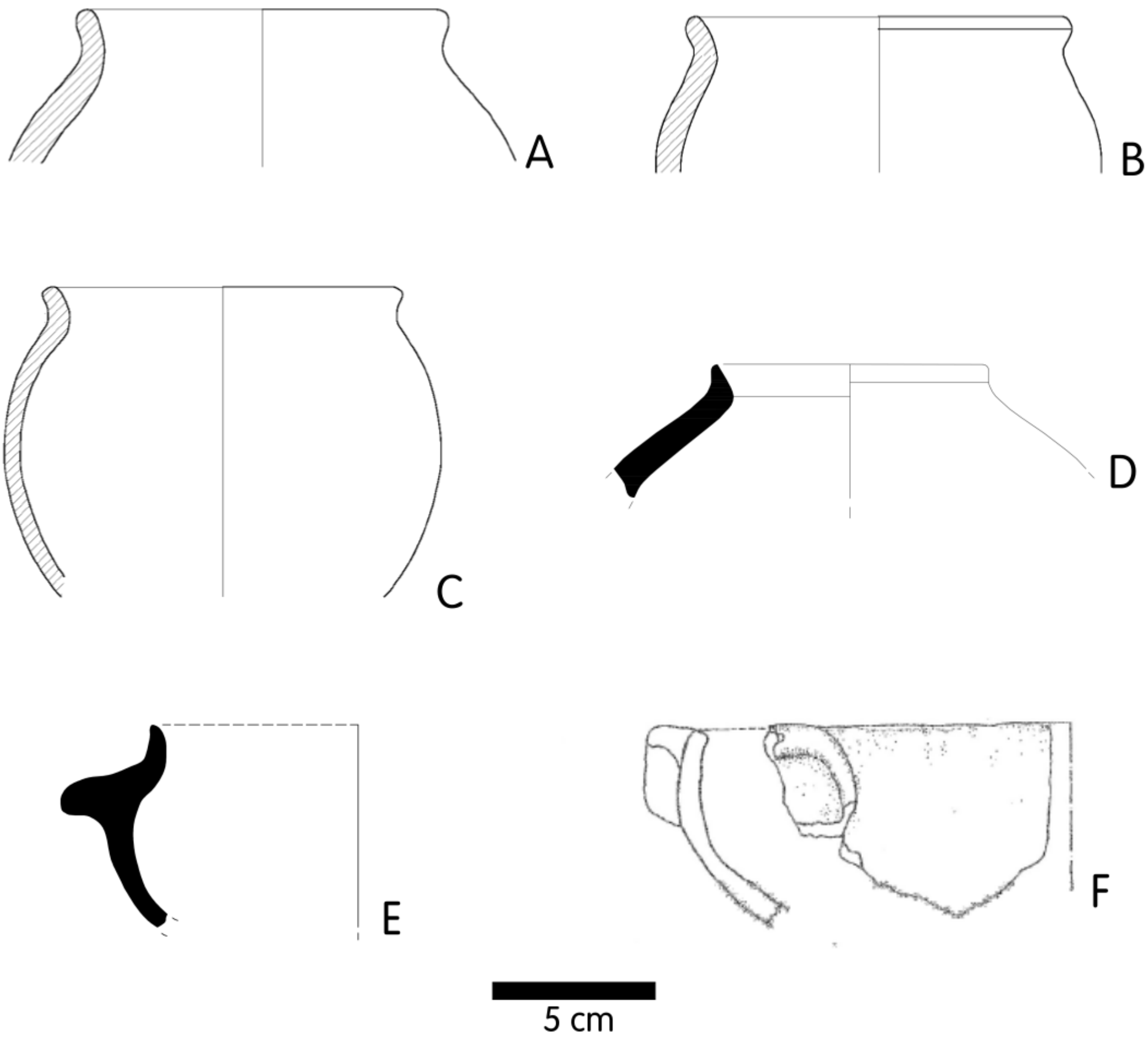


Figure 23. Examples of handmade cooking pots from Phoenician and Punic sites. A, B: "S profile" pots, Nora (Botto 2009); C: globular pot, Nora (Botto 2009); D: globular pot, Pani Loriga (E. Madrigali, unpublished); E: Pot with "falso versatoio", Pani Loriga (E. Madrigali, unpublished; F: "ear pot" (pentola ad orecchia), Olbia (Cavaliere 2010).

To sum up, the outlined picture is defective and rich in open questions, as it reflects the present state of research. The lack of standardisation, the fact that similar handmade globular pots were produced in other parts of the Mediterranean and the chronology of Sardinian handmade pots currently under revision make it difficult to offer more precise general trends for handmade pots. For the aim of this project, however, only handmade cooking pots found in Phoenician and Punic contexts have been analysed: these pots can be dated by context and regarded as generally connected with the indigenous world, especially when elements as the “S profile” and the “ear handles” are attested (see tables I-III, Appendix).

3.3.2 Basins and tripod bowls

The definition of basins and tripod bowls is problematic. In Phoenician and Punic archaeology, vessels called “basins” (*bacini* or *bacili* in Italian; *cuencos* or *morteros* in Spanish) are a large majority of wheelmade open shape vessels with a wide diameter (ca. 20–50 cm) and a relatively shallow and concave basin (*vasca*). It is a broad definition, often expressed by scholars through relative comparisons with other categories. L. Campanella (2009b: 247), who proposed the actual grouping, included in the category “not only solid and robust vessels, characterized by thick walls and bottom, concave and voluminous basin, but also open shapes with less thick walls and less depth profile” (transl. by the author). I. Chessa (1992: 104), used the definition “open shape vessel with not very deep concave basin” (transl. by the author). Despite this definition depth, depending on the shape, can reach 20cm.

For this reason, I prefer to use the neutral word “basins” for this category, equivalent to the Italian word *bacini*. It is preferred to the term “bowls”, which is occasionally used in literature to define the same category (e.g. Jamieson 2011). Despite these vessels being generally classified as “food preparation pottery”, basin subtypes are extremely varied in rim or foot shape, thickness, fabric, colour and presence of decorations, handles or spouts (see Chessa 1992; Campanella 2008; 2009b). A total of 16 subtypes are identified in Nora alone, spanning from the 8th to the 2nd centuries BCE (Campanella 2009b; fig. 24). But variation inside the category is so broad that a diachronic synthesis is extremely complex even on a site base, and for this reason never tried before. This variation is likely due to the fact that the macrocategory of basins include shapes having different uses. Examples of uses suggested for specific subtypes are food presentation (Campanella 2009b: 274; Campisi 2000), perfume burning (Campanella 2009b: 253), or even as a slug container in metallurgy (Campanella 2009b: 280). Some “basins” were probably used as proper bowls (Campanella 2009b: 263) or mortars (Cavaliere 2007; Campanella 2008: 147). Some basins were likely used for cooking, based on traces of burning (Campanella 2009b: 251; 271), in a way similar to the latter casseroles or as *testi*[3] or cooking bells (Campanella 2008: 144; Campanella 2009b: 267).

Some major developments can be broadly outlined here, leaving single-site bibliography for more detailed information (see also 6.1 and 7.2.2). In the Phoenician period (8th-6th centuries BCE) most of the basins are characterised by solid and thick walls and bottom, less shallow and more concave basin and a hard fabric with small inclusions (BA1, BA3 in

[3] A traditional central Italian vessel used to heat bread on embers, similar to a pizza stone.

figure 24). These types can be linked to Cypriot-Phoenician models. Similarly to tripod-bowls (see below), their use seem to be connected with food handling and preparation, or grinding of soft products as spices (Botto 2000). But once more, variations exist. The type BA2 (fig. 24), widely attested in the 8th and 6th century, has thinner walls and a suggested use as perfume burner or cooking bell (Campanella 2009b: 254). Other less common subtypes have different fabrics, shapes and suggested uses (e.g. BA6, fig. 24).

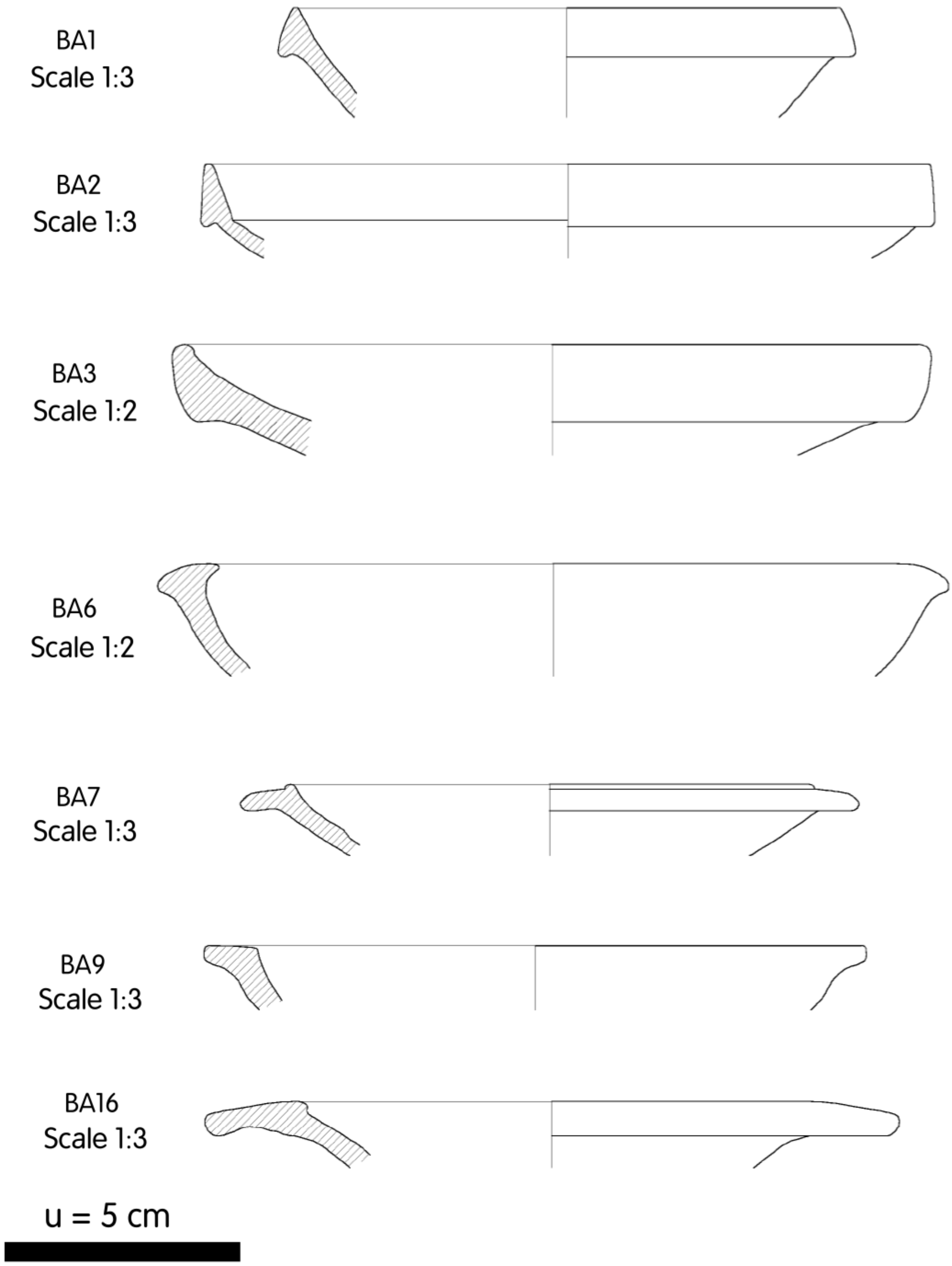


Figure 24. Examples of Phoenician and Punic basins (Campanella 2009a). BA1 7th–6th centuries BCE; BA2 7th century; BA3 second half 7th–6th centuries; BA6 8th–7th centuries; BA7 4th century; BA9 3rd–2nd centuries; BA16 3rd–2nd centuries BCE.

With the Punic phase and the introduction of casseroles (6th-5th centuries) there is a decrease in the number of basins in the archaeological record, but also an increase in the variety of types (Campanella 2009b: 247). Some of the more decorated types, connected with food serving and presentation (e.g. Campanella 2008: 145) are limitedly connected with this research. Several types introduced in the Punic phase (BA7, 9, 16 in figure 24), and possibly connected with food preparation, are characterised by outstretched and more or less flattened rims (Campisi 2000; Campanella 2008: 240). There rims could work as handles or, in presence of charring traces on the rim, as cooking bells or *testi* (Campanella 2008: 141). A difference in use is suggested by the introduction of this novel shapes but, once more, detailed interpretation is hindered by the existing variations, especially relating to fabrics. In the macrocategory of basins, the fabric can vary from coarse fabrics to fine ones within the same site and subtype, suggesting different uses to be investigated (e.g. Campanella 2009b: 268). Differences between fabrics can include colour, hardness, material, and the number and size of inclusions, suggesting different uses, not all of which are connected with food processing. More information about subtypes which offered interesting insights during this research is outlined in the discussion (Chapter 7).

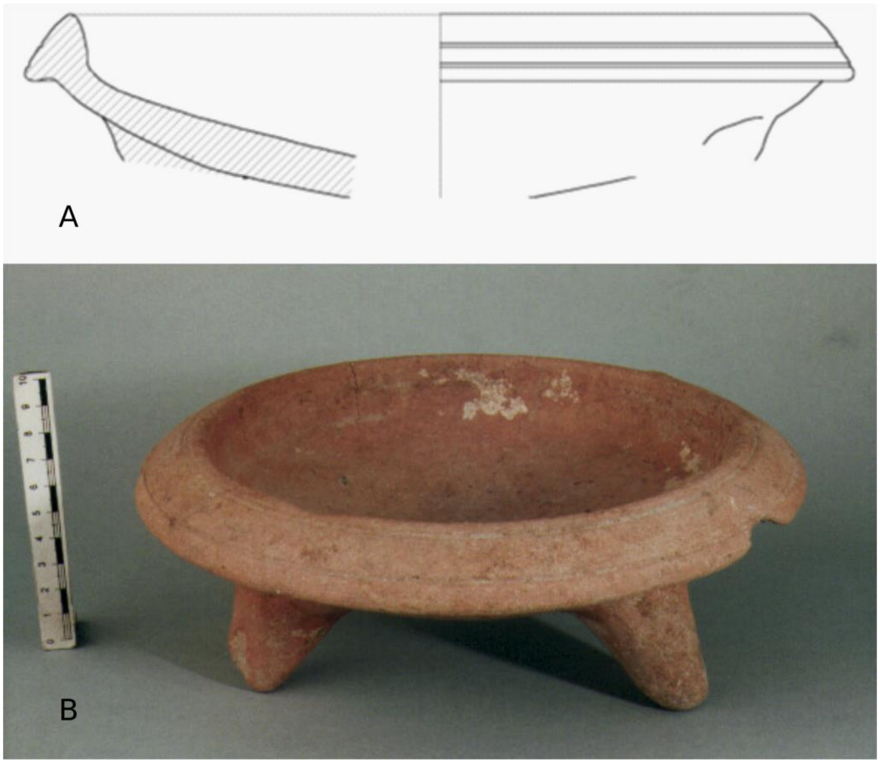


Figure 25. Example of Phoenician tripod bowls from Nora (A, Campanella 2009a: 289) and Sant'Antioco (ICCD catalogue, provenance unknown).

Tripod bowls (fig. 25) are known in Italian literature as *coppe tripodi* (literally "tripod cups", e.g. Botto 2000), a misleading definition. Campanella (2009b: 286) originally suggested adopting the label of *tripod bowls* (in English) for tripod vessels with clearly different fabric, thickness and shape from tripods likely to have been used as cups (*coppe tripodi*) or as mortars to grind cereals (*mortai tripodi*). The label is a useful tool to distinguish the three categories on the basis of their probable use, and it has been adopted by several scholars and in this dissertation. Unlike basins, which evolve throughout the Phoenician and Punic period, tripod bowls only occur the archaic period (7th–6th centuries BCE) and their function is more consistent (Campanella 2009b). Due to their thickness, fabric (hard and with abundant inclusions) and consumption traces (Campanella 2009b: 288), it has been convincingly established that they were primarily used as mortars to grind non-tough commodities such as spices or vegetables (Botto 2000: 84). However, this interpretation is not unanimous as some scholars still hypothesise they had multiple functions (Campanella 2009b: 287).

Tripod bowls are always categorised separately from basins in ceramic catalogues. But both basins and tripod bowls are always categorised as “vessels for food preparation” (Campanella 2008; 2009b; Botto 2000; Cavaliere 2010b). The division between the two categories can be ambiguous, due to the not always clear border between the two. A tripod base/foot cannot be excluded for some of the basins (e.g. Campanella 2009b: 253; 263). The use of some basins could have been similar to the one of tripod bowls, unclear due to the broadness of the category of basins. For these reasons, both ceramic categories are treated together in this project (only 6 tripod bowls sherds have been analysed, see Chapter 6). Future research will enable the reorganisation of these ceramic categories in the future.

3.3.3 Casseroles

In Punic contexts, casseroles (*tegami* in Italian, *cazuelas* in Spanish and defined as pans or saucepans in other English-language literature) are wheelmade open vessels characterised by a convex bottom, shallow basin and a “lid-seating groove”. Casseroles, along with lids, are dated from the middle of the 5th century BCE until the end of the Punic era.

Campanella (2009a) distinguished five different subtypes at Nora (fig. 26). The most ancient type (referred to as *Teg1*) is characterised by a rounded base and no discontinuity between the rim and the base. Casseroles later become deeper and their walls straighter, and the passage between the base and the walls became angled (fig. 26e). There is variety in this ceramic category, as shown in fig. 26, but this appears to be a general trend.

Their fabric is generally fine textured, and the abundant inclusions are well-sorted and smaller than in cooking pots (Campisi 2000: 168; Roppa et al. 2013: 129). Based on the literature, however, fabric seems to vary among sites: in Nora and Sant’Antioco inclusions are generally rare and small (Campanella 2008: 98; 2009a: 348) while in Cagliari they are described as larger and their frequency is not mentioned (Chessa 1992: 119). It is not possible, up to this stage, to establish how these statements can be extrapolated and compared, given the subjective nature of pottery recording generally in archaeology. The inner basin is usually burnished or slipped (Campanella 2009a: 348-351), and previous organic residue analysis suggests the existence of a waterproof covering made with *Pinaceae* resin (Pecci 2008). This burnishing or slipping could have had an impact on lipid absorption, as discussed below (Chapter 7).

In general, “wide open vessels with shallow bottoms are suitable for roasting, sautéing, frying, or baking [food products]” (Spataro-Villing 2015: 6), and this is what Punic casseroles were probably used for. It is not clear what commodities were cooked in them, but they are likely to have been used to process a variety of foods. The suggestion that casseroles were used to quickly cook foods using oil (e.g. Campanella 2009a: 348) is plausible, although this is an assumption based on modern Italian and Sardinian comparisons.

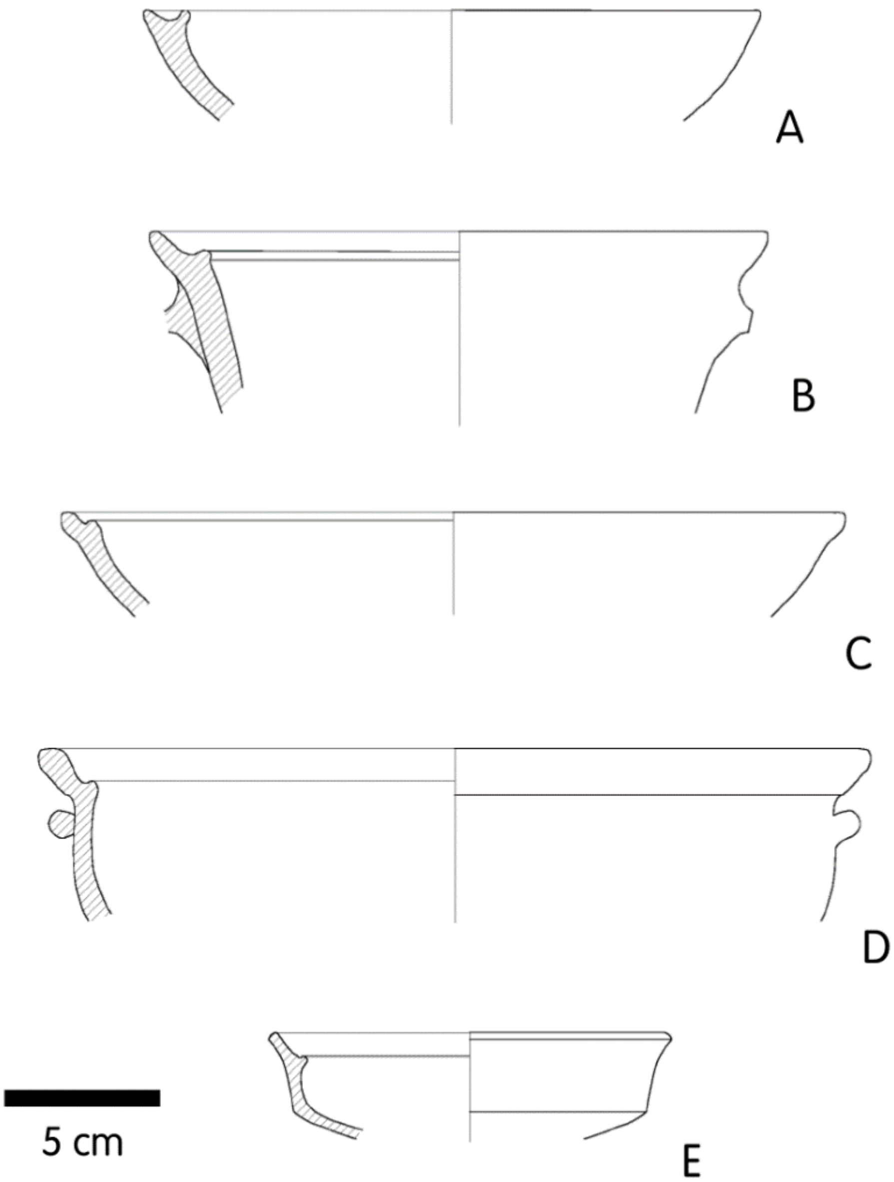


Figure 26. Examples of Punic casseroles from Nora (Campanella 2009b). A: subtype 1, (5th century BCE); B: subtype 2 (5th–4th centuries); C: subtype 3 (4th–3rd centuries); D: subtype 4 (4th–3rd centuries); E: subtype 5 (3rd–2nd centuries BCE).

3.3.4 Baking trays

Baking trays (named *teglie* in Italian[4]) are handmade open vessels characterised by a flat base, shallow basin and thick walls (fig. 27). A rough fabric with large inclusions, together with burning traces, indicate their use as cooking vessels (e.g. Campanella 2008: 195-196; Botto 2009). In Sardinia, baking trays attested in the Phoenician and Punic period derive from a ceramic tradition and shape originating in the Nuragic era (Campus-Leonelli 2000).

[4] In literature about prehistoric Sardinia, they are defined as *spiane* or *tegami* (Campus-Leonelli 2000). This definition has gradually been abandoned in Phoenician and Punic literature to avoid confusion with the vessels referred to as "casseroles".

Approximately a decade ago Rubens D'Oriano (2012) offered new relevant insights to update the knowledge about this ceramic shape, attested also in North Africa and Southern Iberia. Revising the existing archaeological evidence, the scholar claimed that it was possible to argue that baking trays were culturally linked with Sardinian customs and people, also when found outside the island. This theory is based on the fact that the ceramic shape in Sardinia originated centuries before and last centuries after it is attested in other contexts. Moreover, baking trays found outside Sardinia seem always easily comparable to the ones produced on the island. When D'Oriano was writing, a low number of baking trays was found outside Sardinia, making possible that Sardinian people were producing them (D'Oriano 2012: 260).

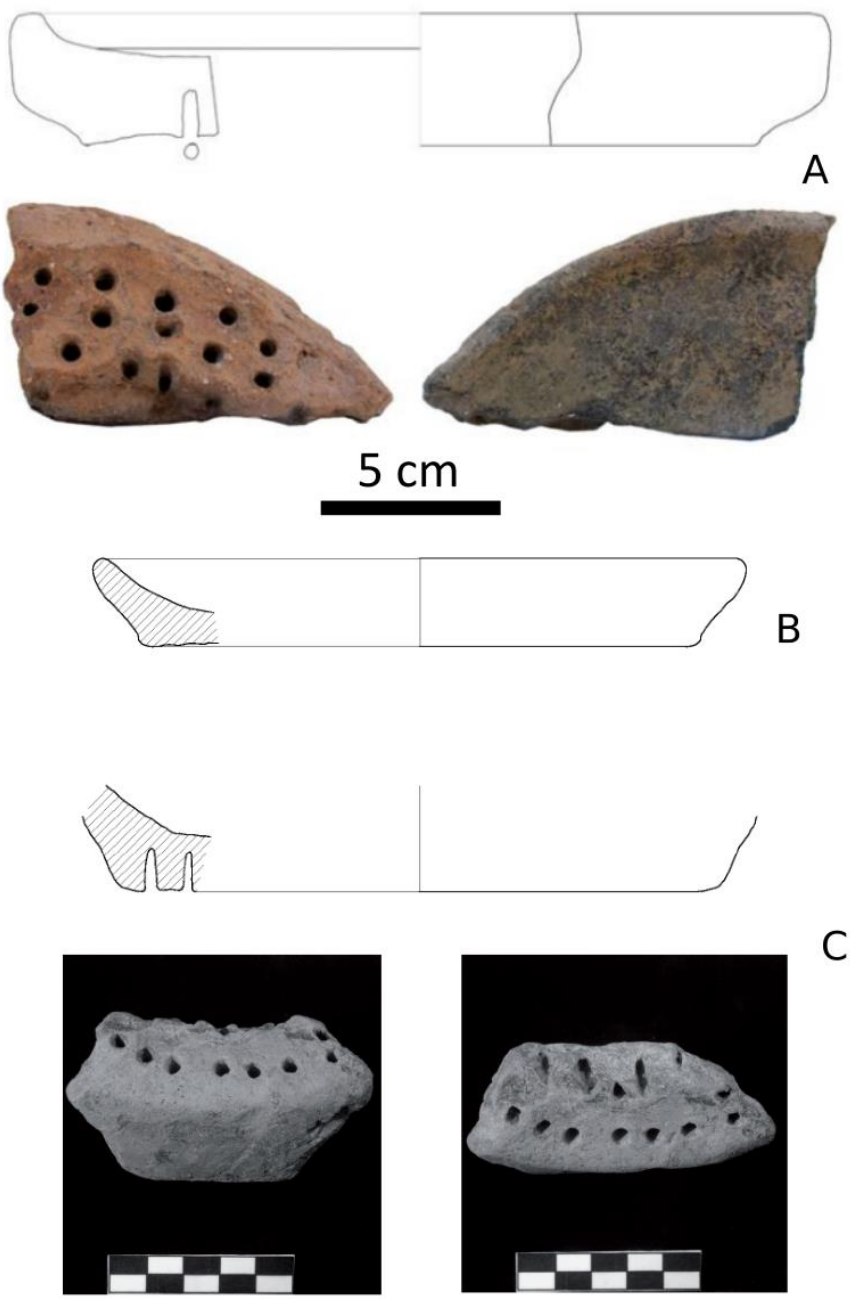


Figure 27. Examples of baking trays from S'Urachi (A, Roppa et al. 2013) and Nora (B, C, Botto 2009).

More recent research and findings, however, push to partially revise the theory. A large number of baking trays was found in Punic North Africa, especially in 4th–3rd century layers at Anthiburos (Sghaier 2017), hugely increasing the number of baking trays known outside Sardinia. In light of this recent evidence, Michele Guirguis (e.g. Guirguis 2019a: 118) interprets baking trays as indicative of a developing material *koiné* in the central Mediterranean during the first millennium BCE. The Sardinian origin of the vessel is, however, not denied by this most recent interpretation, since baking trays are widely used in the island throughout the Iron Age, and they are attested in Phoenician and Punic contexts until the 4th–3rd centuries BCE (Cavaliere 2008).

Two main types of baking trays are found on the island during my target period: the "typical" Nuragic tray, with a flat, plain base, and the perforated baking tray (see fig. 27a, c). The latter first appears around the 8th century BCE, and it has been convincingly interpreted as a variation of the previous tray design: a hybrid production derived from the application of a Levantine element (the non-bypassing holes) to a local vessel (Botto 2008: 362) (fig. 27b). Some scholars suggest they were used in baking bread and cooking, especially in the case of perforated trays (Botto 2008: 362), while other scholars interpreted them as multifunctional pans (Mansel 2011: 357; Campanella 2008: 197, Pecci 2008). Evidence is insufficient to exclude one of the two possibilities. Organic residue analyses will provide extremely relevant additional evidence (see 7.2.4).

3.3.5 Ovens

In the Phoenician and Punic world, ovens were subcylindrical structures, 80-100cm in height. They were constructed with a base of 3-4 curved ceramic panels welded together that were placed on the ground, and sometimes stabilised with rocks. A circular, open-top ceramic structure of was placed on top of the ceramic panel base to form the walls of the oven and provide access from the top (Campanella 2009c: 470; fig. 28; 29).

They are called *tannur* or *tabouna,* applying the Arabic word used today for similar ovens still in use in some areas of North Africa and the Middle East (Sghaier 2017; Pérez Jordà et al. 2010: 300). These ovens are widespread in Phoenician and Punic Sardinia and across the central Mediterranean region, but they are very rarely recovered in Morocco, Iberia and Ibiza (Marin-Aguilera 2016: 206; Pérez Jordà et al. 2010: 300). This suggests different bread making procedures and a different social role of bread in Sardinia and the central Mediterranean compared to other areas of Phoenician presence, as mentioned in Chapter 2 (2.2.2.1).

Figure 28. Terracotta figurine from Carthage showing a woman placing breads on a tannur wall (Fariselli 2017: 311).

These ovens are characterised by a bulging rim, their wall thickness (2-3 cm) and abundant lithic and vegetal inclusions in the fabric. Panels are handmade and often decorated with fingerprints (fig. 29); other simple decorative motifs are also attested (Campanella 2001: 233). Their specific usage is indicated by ceramic figurines (see fig. 28) and modern comparisons. They seem to have been predominantly used for bread baking, with fire and fuel situated at the bottom to heat the walls. When the fire was weaker and the walls warm enough, flat breads were stuck to the walls to bake; they were removed after a few minutes when cooked (Campanella 2001).

This ceramic structure is evidently bread-related. However, a use of *tannurs* to also bake or cook commodities rich in lipids was not excluded by the scholars. For example, L. Campanella (2008: 79) suggest a use to cook fish. Moreover, in Sardinian modern cuisine breads made by mixing cereals and lard, cheese or honey (lipid-based commodities) are attested. Part of the scholarship (e.g. Ugas 2015) suggest that these traditions possibly persist since the Bronze Age, but the evidence to state that is lacking. It has been chosen to include this shape in the project to test if lipids can be detected in *tannur* walls to corroborate these hypotheses.

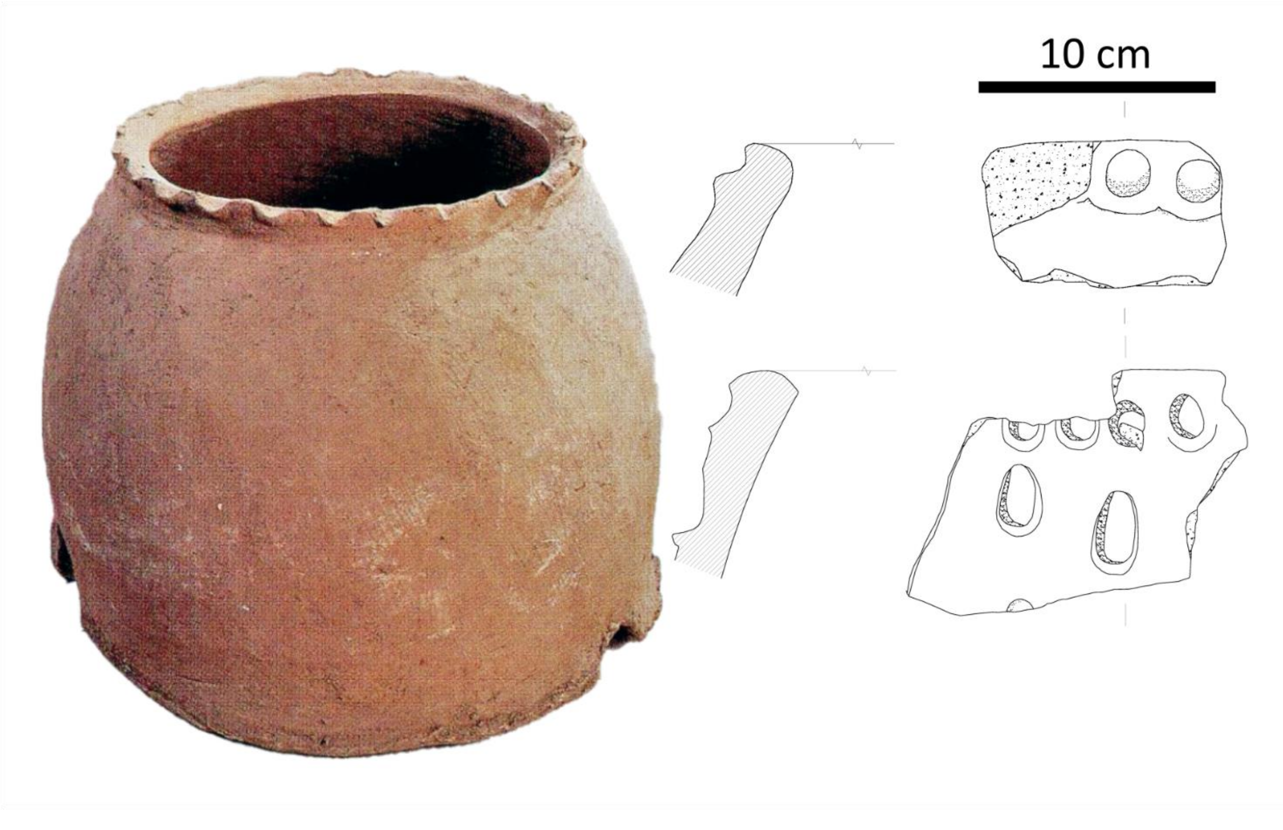


Figure 29. Contemporary tabouna (Tunis, late 20th century, Sghaier 2017) and examples of Punic tabouna decorated with fingerprints (Nora, Campanella 2009c).

3.3.6 Ceramic categories and research questions

The following research questions were stated in the introduction (1.2):

1) What commodities were processed in the main ceramic categories involved in cooking and food preparation practices?
2) What do the detected commodities suggest about vessel use and specialisation?
3) What do the detected commodities suggest about changes in cuisine and diet over time?

4) Are intra-site and inter-site spatial patterns identified through ORA? What do they suggest?

All of them, directly or indirectly, refer to pottery, since pottery is the target of the analyses undertaken for this project. This section made clear why those questions are particularly interesting in the context of Phoenician and Punic Sardinia. Investigation on cooking ware is ongoing and, despite general broad trends are well-established, biases and gaps persist. Local variations are particularly poorly understood, hindering by consequence the definition of detailed trends on an island level (question 4). Vessel use is also often debated, especially for ceramic categories as basins or baking trays (question 2). Changes in use of vessels over time, on the contrary, have been poorly debated (question 3). However, archaeologists also suggested what commodities could have been processed in some vessel categories (e.g. porridges in cooking pots, multiple foods in casseroles…): hypotheses have never been tested through analyses of residues (question 1). To sum up, this research aims to collate, through organic residue analyses on pottery, the information about diet and Phoenician and Punic foodways discussed in Chapter 2 with specific pottery and sites in 8^{th}-2^{nd} centuries BCE Sardinia. Indeed organic residue analyses, the only direct method for determining the use of individual vessels, can connect food and ingredients with specific vessel categories and sites, as it is illustrated in the next chapter. The evidence obtained will allow a more precise comprehension of foodways and vessel use, offering insights about their social implications.

Chapter 4
Principles and applications of organic residue analysis on archaeological pottery

4.1 What is organic residue analysis?

Organic residue analysis encompasses a range of different analytical techniques to detect organic residues associated with material remains. In an archaeological post-Neolithic context, these remains typically include pottery, since, differently from perishable materials, it is preserved over centuries and millennia. At times, these residues can be superficially detectable: visible and immediately recognisable by the human eye or, more commonly, carbonised and encrusted (Evershed 2008a: 903). However, due to the nature of the archaeological record, the majority of the surviving residues are absorbed by the vessel wall. These are the focus of this research project.

The analytical approaches are targeted to the detection of *archaeological biomarkers*, defined as "substances occurring in organic residues that provide information relating to human activity in the past" (Evershed 2008a: 897), i.e. preserved compounds or suites of compounds unambiguously related to a defined organic source (see below, section 4.3). Recognising biomarkers through organic residue analysis, it is possible to address what food products and commodities were processed or stored in ancient vessels, keeping in mind the limitations discussed in section 4.2. Over recent decades, many archaeological questions have been addressed through organic residue analysis: the use of the vessels (Carrié-Duhaut et al. 2007; Eerkens 2005; Poulain et al. 2016; Cramp et al. 2011); cooking practices (Baeten et al. 2013); cultural and subsistence changes (Cramp et al. 2014; Evershed et al. 2008a); subsistence practices and dietary reconstruction (Lucquin et al. 2016); ancient trading of goods (Rageot et al. 2015); *longue durée* processes (Carrer et al. 2016). A good overview of the contemporary state of the discipline can be found in Roffet-Salque et al. 2016, with references.

Whilst a range of analytical techniques are employed to characterize organic residues (for an extended review, see Pollard et al. 2007), one widely used approach (and the one used in this study) is high temperature GC-MS. High Temperature Gas chromatography (HTGC) allows separation and quantification of individual compounds. Combined with mass spectrometry (GC-MS; HTGC-MS), it enables identification of individual compounds basing on their ion fragmentation patterns. Stable carbon isotope ratios of individual fatty acids recovered from organic residues (GC-C-IRMS) is also necessary for identification of some commodities (Mottram et al. 1999; Copley et al. 2003), as discussed below in section 4.3. These three techniques – HTGC, GC-MS and GC-C-IRMS – are among the most sensitive and widely used techniques and are used in my research; experimental protocols will be outlined in detail in chapter 5.

4.2 Principles of lipid analysis

Lipids such as fats, waxes and resins are detectable in ceramic vessels. When food products are processed in a pot (e.g. cooked or stored), organic molecules are generally absorbed into the fabric of the vessel, and some of them may be preserved for millennia (Evershed 2008a; 2008b). The surviving molecules can be extracted and used as "chemical fingerprints" to reconstruct the original lipid content of the vessel; this is the basic principle of organic residue analysis.

Not all organic residues or compounds are readily preserved over the centuries or, indeed, millennia. Organic compounds such as proteins, carbohydrates, nucleic acids and amino acids are among the possible classes of archaeological biomarkers. However, lipids (fats, waxes and resins in the natural world) are normally better preserved and more prevalent in organic residue analysis due to their hydrophobic nature. For this reason, lipids constitute the main target of organic residue analysis on pottery, and a bias against the recovery of biomarkers from the processing of lipid-poor commodities such as cereals or legumes exist (Hammann and Cramp 2018).

4.2.1 Lipid absorption and preservation

Several factors can determine how many lipids are absorbed and preserved in the vessel. First of all, the kind of commodities processed in the pot: it was experimentally established that boiling meat five times deposits the same amount of lipid as boiling of vegetable leaves approximately 150 times (Charters et al. 1997). In general, the processing of commodities through the addition of water and prolonged heating often produce the transfer of fats into the ceramic walls. This leads to vessels involved in cooking and boiling as the ones that contain high concentrations of lipid rather than those used for serving or dry storage (Correa Ascencio and Evershed 2014). Due to the nature of vessel use, lipid distributions arising from the use of pots are unlikely to be homogeneously distributed in the vessels. Depending on the cooking or heating technique, they are more likely to be concentrated in some areas of the vessel (e.g. close to the rim for closed shapes used for boiling, due to the migration of lipids during cooking processes (Charters et al. 1993)). Therefore, the location of the sampled piece must be considered when quantitatively interpreting the results; in this research, the large majority of the analysed vessels have been sampled on the rim, with a few exceptions indicated in the Appendix (tables I-VI).

Results of past studies suggest that absorbed organic residues survive in >80% of domestic cooking pottery assemblages worldwide (Evershed 2008a: 904). Other categories of vessels, such as burnished, slipped or glazed vessels, generally present lower lipid preservation, but organic residue analysis has been successfully applied to these vessels as well (Frére et al. 2012; Pecci et al. 2015). In cases of poor lipid concentration, different protocols can extract more lipids. Namely, the acidified methanol extraction method enables us to extract 4 times more organic residue compared to the chloroform–methanol extraction method used in the majority of earlier organic residue analyses and this project. Acidified methanol, however, causes a loss of information due to the hydrolysis of complex lipids as triacylglycerols and wax esters (Correa Ascencio and Evershed 2014).

Features of the vessel, especially the fabric, are highly relevant for both lipid absorption and preservation. Non-visible residues are often absorbed in the vessel and preserved. It is generally assumed, that lipids are better preserved in vessels with porous fabrics, whilst very hard fabrics often yield low lipid concentrations (Correa Ascencio and Evershed 2014). But the precise link between the fabric of the vessels and lipid absorption and preservation is poorly understood. Recently, through the use of secondary ion mass spectrometry (SIMS) imaging on sections potsherds, Hammann et al. established that also macroscopic structures in the ceramics are involved in lipid preservation, and not only individual pores. The authors also suggested precipitation of fatty acids as calcium salts as an important aspect of lipid preservation in archaeological sherds (Hammann et al. 2020). Further research is needed to clarify this fabric-preservation relationship more precisely.

4.2.2 Lipid survival and degradation

Different factors determine the survival of lipid biomarkers. First of all, by the biochemical properties of different compounds, such as stability and solubility in water. Almost all lipid residues are affected by hydrolysis and oxidation processes, but in different ways depending on their biochemical properties. For example, triacylglycerols (TAGs) are more likely to contribute to lipids recovered from pottery compared to other lipids, because they constitute 95% of the human diet. TAGs, however, are rarely recovered since they readily degrade to release their free fatty acid components. Therefore, these fatty acids originating from the hydrolysis of TAGs are the most common compound to be recovered from archaeological residues (Gregg and Slater, 2010; Pollard et al. 2007: 151).

Moreover, environmental factors such as temperature, light exposure, the degree of waterlogging, and redox conditions influence lipid preservation (Eglinton and Logan 1991). It has been stated that "while extremes of waterlogging and desiccation are unquestionably conducive to the survival of organic residues, alternating wetting and drying in climate zones where seasons of high rainfall are followed by hot dry periods appears to be detrimental to residue survival" (Evershed 2008a: 911). Sardinia is an area of very low rainfall, especially in the south where five out of six of the targeted sites are located. As a result, it is promising for lipid preservation.

Notably, the lipid extracts recovered are an integrated mixture from multiple uses of the pot (fig. 30). Generally speaking, it cannot be determined whether the commodities identified were prepared together, or arise from different, successive uses of the pots. Recent experiments by Miller and colleagues (2020) demonstrated that superficial charred macro remains represent the last foodstuff cooked in the vessel, while absorbed lipid residues are developed over a number of cooking events and are replaced slowly over time. For this reason, every hypothesis about recipes or combination of ingredients made based on analysis of absorbed residues is highly tentative. Such hypotheses need to be substantiated through other available data, such as the environmental, zooarchaeological, archaeological and historical information (Oggiano and Botto 2012: 164; Baeten et al. 2013: 1167).

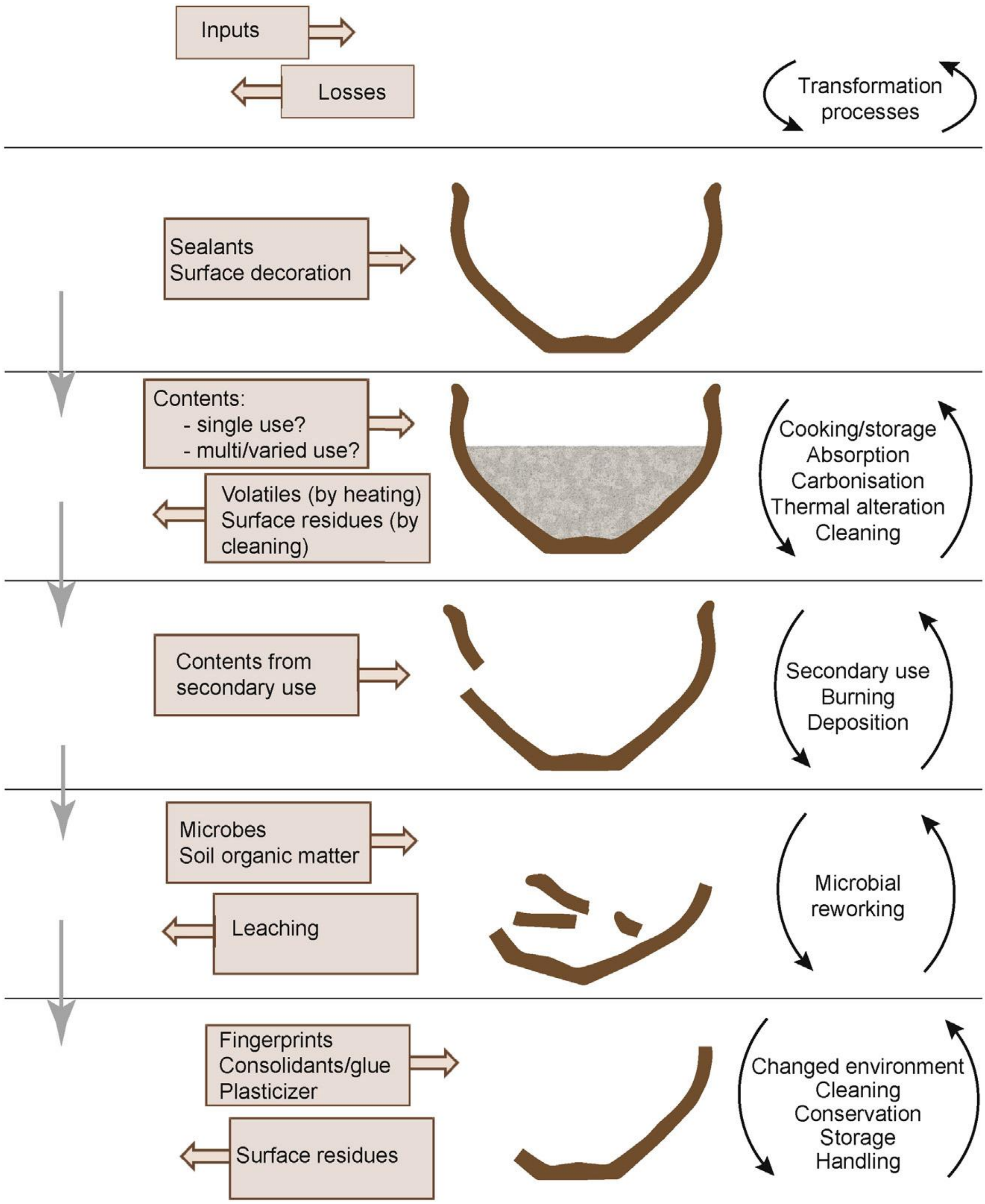


Figure 30. Main inputs, losses and transformation processes affecting the survival and composition organic residues in archaeological pottery. From Roffet-Salque et al 2016, fig. 2; adapted from Stacey 2009, fig. 1.

4.2.3 Loss of information and contamination

Loss of residues is in many cases related to the history and life of the single vessel or sherd. Washing and cleaning treatments of potsherds, both in antiquity and during and after the archaeological excavation, can lead to the physical removal of superficial residues and degradation processes of less stable lipids. It has been shown, however, that most of the impact comes from washing with soaps, unusual in archaeological excavations (Oudemans and Erhardt 1996: 141).

Various sources produce contamination of vessels. Deposition in soil for centuries or millennia has been demonstrated to constitute an insignificant contribution to lipid assemblage in the vessel (Heron et al. 1991). Sampling the soil close to the vessel during the excavation can help identify any possible contribution from the burial environment; however, this was not available in the case of the stored material analysed here. Post-excavation treatments can be more invasive. Since light exposure and environmental conditions impact on lipid preservation, storage of sherds after the excavation can produce contamination or lipid degradation, e.g. in the case of sherds stored in wooden boxes or plastic bags in rooms exposed to sun or humidity. Other post-excavation treatments, as prolonged handling, or restoring, can also lead to the absorption of modern lipids in the vessels. In the case of the sherds considered in this project, the post-excavation treatment applied to the sherds (washing only with brush and water, labelling, storing in plastic bags) was known: the introduction of contamination from other products (e.g. soaps or glues) during the post-excavation stage was avoided, and sources of possible contamination from storage (plastic bags) were known and recognisable.

The current project, and as standard procedure in ORA, has focused on absorbed residues since it would be challenging or impossible to remove extraneous contamination from external carbonized deposits. The problem of possible contamination is addressed through the removal of 2 mm of each sherd before sampling, as discussed further in section 5.2. The use of analytical blanks during laboratory procedures also helps to identify any introduction of lipids during extraction and analysis (see 5.2.1). Through the analysis of a large number of vessels originating from the same excavation and the same storage rooms, as in the case of this project, it is often possible to recognise trends suggesting post-depositional or post-excavation contaminations, such as compounds that appear in all lipid extracts. As is demonstrated in Chapter 6, environmental information about the site and information about depositional conditions of the sherds can also be used to recognise contamination.

4.3 Identification of resources

Various classes of products can be identified through organic residue analysis to varying degrees of specificity (Roffet-Salque et al. 2016). At present, these include dietary resources, but also commodities which are of particular interest to archaeologists due to their potential role in manufacturing, improving and repairing vessels used for storage, preparation of cosmetics or perfumes.

Animal fats (4.3.1) are widely recovered in ORA, due in part to the relatively high lipid content of animal products. Animal fats can also be distinguished between aquatic and terrestrial fats, ruminant and non-ruminant fats, ruminant carcass and dairy fats (Evershed et al. 2002; see 4.3.1). Other potential resources that may be detected include plant oils (4.3.2.1), plant leaf waxes (4.3.2.2) and vegetal resins, pitches and tars (4.3.2.3), beeswax (4.3.3.1) and bitumen (4.3.4). Fermented beverages, although not unambiguously detectable through ORA, are briefly mentioned here (4.3.5) due to the degree of research interest they attract in the Mediterranean area, leading to several putative identifications.

4.3.1 Animal fats

Animal fats are the most widely detected commodity in absorbed residues extracted from archaeological pottery (Evershed 2008b). This situation is likely due to the fact that fats are present in meat with a much higher concentration than in plants; it has been experimentally proven that boiling meat five times deposits the same amount of lipid as boiling of vegetable leaves approximately 150 times (Evershed et al. 2008b).

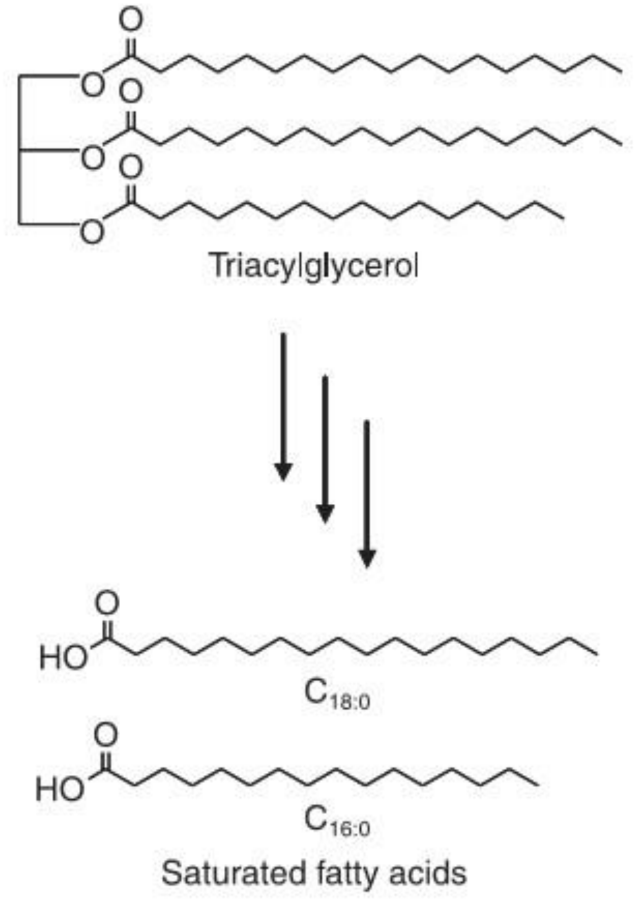


Figure 31. Chemical structure of triacylglycerols, stearic and palmitic acids. From Evershed 2008a, figure 2.

Across the classes of lipids, triacylglycerols (TAGs), as mentioned, constitute 95% of the dietary lipids, so that they are highly abundant in commodities processed in pots. TAGs are comprised of three fatty acids (composed of a hydrocarbon chain and a carboxylic group) esterified to a glycerol backbone (fig. 31). These TAGs readily degrade to release their free fatty acid components, constituting the most common compound to be recovered from archaeological residues (Gregg and Slater 2010; Pollard et al. 2007: 151). Saturated fatty acids (fig. 31), including palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$), together with monounsaturated $C_{18:1}$ fatty acid are major acyl components of TAGs from meat, dairy products, and some oils (see section 4.3.2.1 below; Roffet-Salque et al. 2016). However, some differences exist in the composition of fresh animal fats. In ruminant adipose, for example, odd-chain and branched chain fatty acids from bacterial populations in the rumen are in higher concentration than in non-ruminant fats (Christie 1978). Isomers of octadecenoic ($C_{18:1}$) acid are also multiple and mixed (Evershed et al. 2002; Dudd 1999). Bovine adipose fat has a higher proportion of $C_{16:0}$ than $C_{18:0}$ fatty acids, and a higher relative abundance of C_{50} TAG compare to ovine adipose fat (Dudd 1999). In fresh milk fats short chain $C_{4\text{-}14}$ saturated fatty acids are attested more frequently and in higher abundance (Dudd and Evershed 1998) since they are present in the milk of sheep, goats and cows (Christie 1981). Porcine fats, in contrast, are characterised by an absence or low abundance of branched and odd-number-chain fatty acids (Dudd 1999) and contain only one isomer of octadecenoic acid (Evershed et al. 1997a). They have a higher abundance of $C_{16:0}$ than $C_{18:0}$ fatty acids and a clear dominance of C_{50} and C_{52} over all over saturated components in the TAGs distribution (Dudd 1999). Also, unsaturated fatty acids, with one or more double bonds, are major components of fresh fats, especially aquatic oils (Cramp and Evershed 2014).

However, all these compounds and existing differences in fresh fats are rarely diagnostic in archaeological research (e.g. Evershed et al. 1997a) since the instability of unsaturated fatty acids, TAGs or short chain saturated fatty acid means that these will degrade over time (Dudd and Evershed 1998; Evershed et al. 2002). In the case of TAGs, hydrolysis appears to proceed rapidly once one fatty acid has been removed from the TAG. Diacylglycerols (DAGs) and monoacylglycerols (MAGs) are attested in archaeological pottery in low concentrations (Dudd et al. 1998). At present, these often cannot reliably be regarded as being diagnostic of fat type, apart from rare cases of exceptional TAGs preservation (Mirabaud et al. 2007). Residue degradation has been proved to alter drastically also the ratio between C_{16} and $C_{18:0}$ fatty acids (Dudd and Evershed 1998), which therefore cannot be used as a reliable indicator of lipid origin.

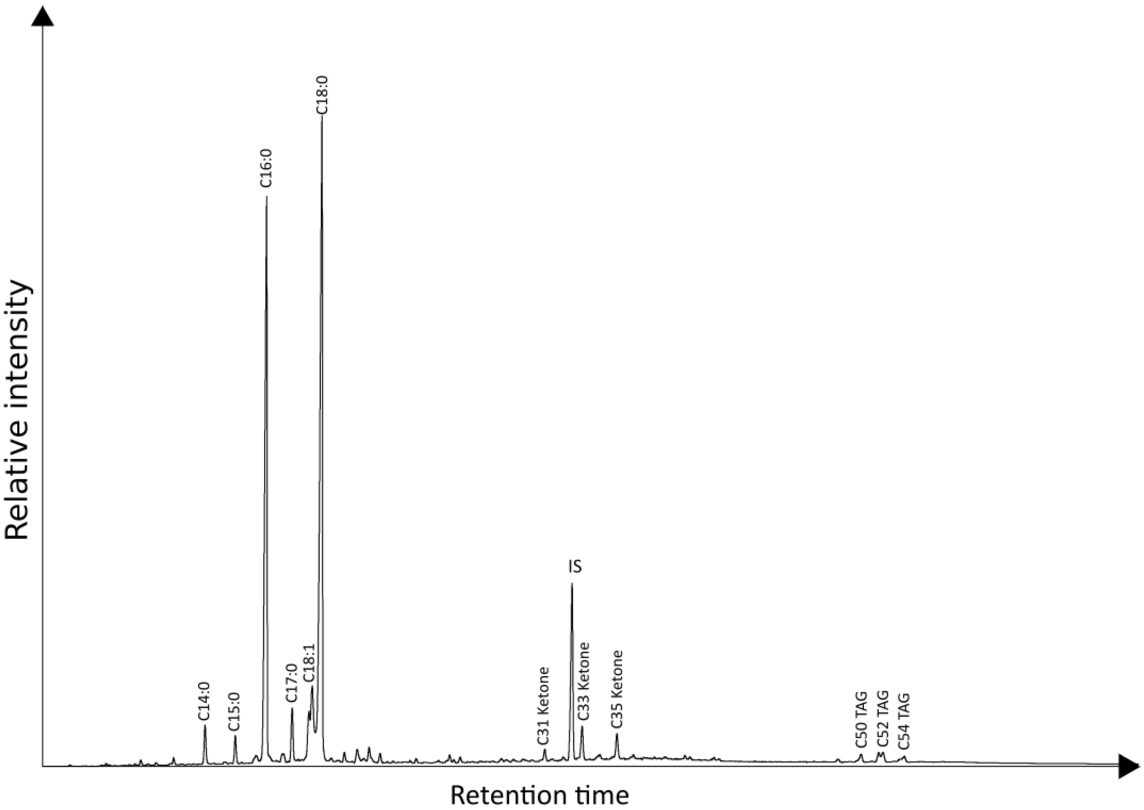


Figure 32. High temperature gas chromatogram of one of the extracts analysed for this project, SUB24 (wheelmade cooking pot), showing a typical distribution of a degraded animal fat including the presence of mid-chain (C_{31}-C_{35}) ketones. IS: internal standard; TAG: triacylglycerol; Cx:y= Fatty acids with x-number of carbons and y-number of double bonds.

In sum, the principal fatty acid in animal fat, palmitic ($C_{16:0}$), stearic ($C_{18:0}$) and oleic ($C_{18:1}$) acids are among the most widely recovered compounds in organic residue analyses, but they are relatively non-specific alone. The presence of $C_{16:0}$ and $C_{18:0}$ fatty acids (fig. 32) can arise from a range of animal fats (terrestrial, aquatic, carcass, dairy) and plant oils. Therefore, a range of chemical criteria, including saturated fatty acid and triacylglycerol distributions and compositions (Mirabaud et al. 2007) or double bond positions in isomers of monounsaturated fatty acid (Evershed et al. 1997a), have been used to assign the origin of ancient animal fats to tissues from animals such as domesticated cattle, pigs, sheep and goats. However, these criteria are appliable only in exceptional conditions. On the other hand, the use of stable carbon isotope ratios from individual fatty acids ($\delta^{13}C$ values of the major saturated fatty acids (palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) has been established as a reliable technique to distinguish animal fat origin. This criterion, based on metabolism, and able to distinguish between ruminant and nonruminant fat, carcass and dairy fat, terrestrial and aquatic fat, is used in the present project and described in detail below (4.3.1.1).

Other compounds detected in ORA may arise from the presence of animal fats. Namely, long chain ketones can be produced by the condensation of $C_{16:0}$ and $C_{18:0}$ fatty acids (fig. 32, 33), due to the exposure to high temperatures (Raven et al. 1997; Evershed et al. 1995). Even though such compounds are known to be common constituents of plant leaf waxes, Raven et al. (1997) established that the ca. 1:2:1 ratio of C_{31}, C_{33} and C_{35} ketones, and the apparent absence of alcohols and alkanes with the same carbon number as ketones is not seen in natural plants. This pattern has been proven to be formed by ketonic decarboxylation of FFAs and TAGs, produced by high temperature cooking processes (or other high temperature heating events (Evershed 2008b: 41)). These compounds are, therefore, likely to offer information about cooking practices and the use of the analysed vessel (Evershed et al. 1995; Raven et al. 1997).

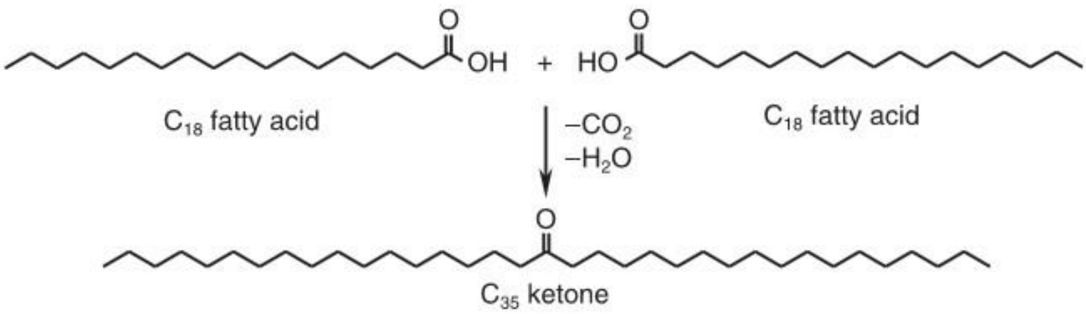


Figure 33. Chemical structure of a long-chain ketone originating from two fatty acids, from Evershed 2008, figure 4.

4.3.1.1 Principles of compound-specific stable carbon isotope ratios

The determination of stable carbon isotope ratios from individual fatty acids has been established as a reliable technique to distinguish ruminant and non-ruminant fats, carcass and dairy fats (Dudd and Evershed 1998; Copley et al. 2003), and marine and freshwater aquatic fats (Cramp and Evershed 2014). This signature has been proven to persist over archaeological timescales (Mottram et al. 1999), offering robust interpretation of the source of fats and, by extension, animal products contained in the vessels. This approach is known as the stable carbon isotope proxy ($\delta^{13}C$ proxy), and it can be applied to address questions on multiple scales, from the identification of the use of specific vessels (Mottram et al. 1999), through to large-scale studies focusing on the use of dairy products in the past (Evershed et al. 2008a; Craig et al. 2011; Dunne et al. 2012; Copley et al. 2005) and diachronic analyses relating to animal resources consumption in European prehistory (Copley et al. 2003; Cramp et al. 2014).

The distinction of animal fats rests on differences in the $\delta^{13}C$ values of the principal fatty acids ($C_{16:0}$ and $C_{18:0}$) that are present in all animal fats. In milk fats, $C_{18:0}$ primarily originates from unsaturated fatty acids present in dietary plants ($C_{18:1}$, $C_{18:2}$, $C_{18:3}$) and is biohydrogenated in the rumen; the remainder is from animal adipose fats. In adipose ruminant fats, $C_{18:0}$ includes carbon predominantly from the carbohydrate component of the animal's diet, having a significantly higher $\delta^{13}C$ value than the fatty acids from the same plants: adipose $C_{18:0}$ fatty acids in ruminant adipose have a seven times more enriched $\delta^{13}C$ value than those in the milk fat (Copley et al. 2003, Dudd and Evershed 1998; fig. 34). In non-ruminant omnivorous and monogastric animals, carbon in fatty acids can be derived from a wider range of sources, including lipids, carbohydrates and proteins from both animals and plants (Scott et al. 1997; Howland et al. 2003). As a result, $\delta^{13}C$ values are significantly different in ruminant dairy, ruminant adipose and non-ruminant adipose animal fats. In brief, fatty acids identifiable as having a predominantly ruminant dairy origin display a $\Delta^{13}C$ value of -3.1‰ or less, whilst fatty acids identifiable as having a predominantly non-ruminant adipose origin display a $\Delta^{13}C$ value of -0.3‰ or higher (Evershed et al. 2008b). Experimental analyses of reference materials confirmed the global applicability of the $\Delta^{13}C$ proxy (Evershed et al. 2008b; Dunne et al. 2012).

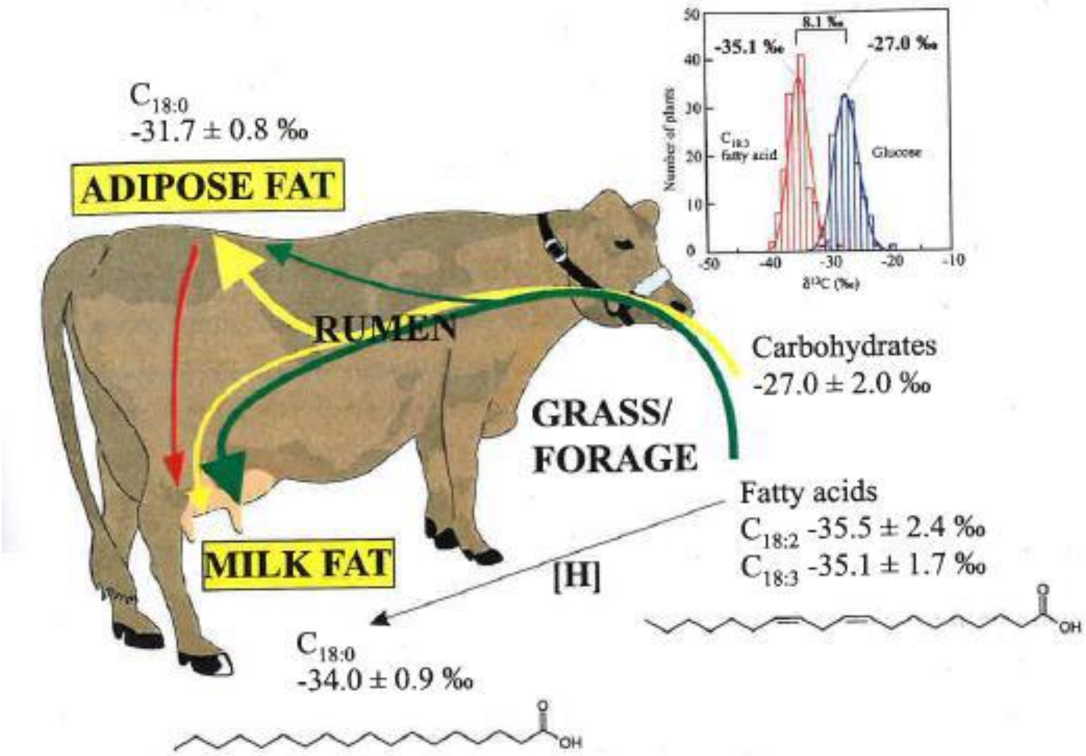


Figure 34. Diagram showing the routing of dietary fatty acids and carbohydrates in the rumen, mammary gland and adipose tissue. The histogram shows the $\delta^{13}C$ values of $C_{18:3}$ fatty acid and glucose extracted from plants demonstrating the 8.1‰ mean difference between them (Mukherjee 2005, fig. 3).

At present, it is not possible to distinguish between the different species of ruminant and non-ruminant animals using this approach, since it is based on metabolism of the animals. Therefore, the distinction between domestic and wild species is hindered, although dairy fats are strong evidence for domestication. For this reason, the archaeological context, and the zooarchaeological and environmental data, are fundamental to understand and interpret the outcomes of organic residue analysis (Barnard et al. 2007). Faunal and environmental knowledge is required to enable further interpretation of the isotope results, e.g. knowing whether C_3 and C_4 plants were available and consumed in the area, or what species of ruminant or non-ruminant animal were reared and hunted around the site, enabling identification of possible origins (Evershed 2008a; Colonese et al. 2017). This information was available and analysed for the project (see Chapter 2 and 6).

In the recent past, identification of animal species has been occasionally proposed when comparing $\delta^{13}C$ values of lipids extracted from pottery with $\delta^{13}C$ isotope values of fatty acids from animal tissues form the same site. This approach led to the association of animal fats recovered in pottery with horse fats in Bronze Age Kazakhstan (Outram et a. 2009) and chicken fats in Anglo-Saxon Flixborough (Colonese et al. 2017). However, since stable carbon isotope approach is not species-specific and it is based on metabolic differences, identification of species proposed needs to be corroborated by further evidence, as in the case of Outram et colleagues (2009).

4.3.1.2 Aquatic fats

Attesting aquatic products through ORA is particularly relevant to archaeology, since identifying the presence of these commodities in the archaeological record is often otherwise hindered by lack of archaeozoological remains (Crabtree 1990). Over the years, the identification of such products in pottery through presence of surviving lipid biomarkers has enabled the detection of relatively rapid changes in subsistence economies in northeastern Atlantic island in the Neolithic period (Cramp et al. 2014) or the identification of the use of the earliest pots introduced in Japan (Craig et al. 2013).

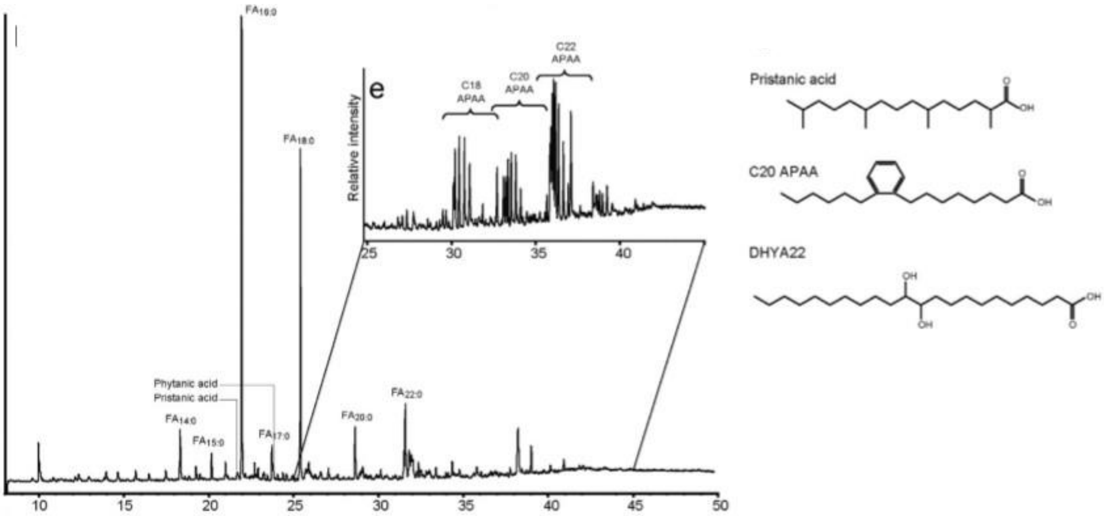


Figure 35. Gas chromatogram showing the characteristic distribution of APAAs and presence of IFAs, and the chemical structure of some of the main biomarkers for archaeological aquatic product processing: 2,6,10,14-tetramethylpentadecanoic acid (pristanic acid, IFA); C_{20} ω-(o-alkylphenyl) alkanoic acid (APAA); 11, 12-dihydroxydocosanoic acid (DHYA). From Roffet-Salque et al. 2016 (figure 3).

Both freshwater and marine lipids are characterised by a high abundance of long-chain polyunsaturated fatty acids, such as eicosapentaenoic acid (EPA; $C_{20:5}$) and docosahexaenoic acid (DHA; $C_{20:6}$) (Cramp and Evershed 2014: 127). However, these compounds will not be recovered in archaeological materials or pottery because they are extremely labile and susceptible to rapid degradation and loss (Cramp and Evershed 2015: 127). Instead, other biomarkers are used to identify marine fats (fig. 34). These biomarkers are specifically long-chain (C_{20} and C_{22}) ω-(o-alkylphenyl) alkanoic acids (APAAs, Hansel et al. 2004), deriving from the heating of polyunsaturated fatty acids in a clay matrix (Hansel et al. 2004; Evershed et al. 2008b; fig. 35); dihydroxy acids arising from the oxidation of monounsaturated fatty acids and preserving the position of the original double bond (Hansel and Evershed 2009; Evershed et al. 2008b), such as 11,12-dihydroxydocosanoic acid originating from the degradation of cetoleic acid ($C_{22}\Delta_{11}$)(Cramp and Evershed 2014); and isoprenoid fatty acids (IFAs, Hansel et al. 2004; Copley et al. 2004), namely 4,8,12-trimethyltridecanoic acid (4,8,12-TMTD), 2,6,10,14-tetramethylpentadecanoic acid (pristanic acid), and 3,7,11,15-tetramethylhexadecanoic acid (phytanic acid), which are synthesised by marine algae. Isoprenoid acids, however, also occur in terrestrial animals, despite in low concentrations, because they accumulate up the food chain: phytanic acid is also present in low quantities in milk, tissues and butterfat of ruminant animals (Ackman and Hooper 1968). TMTD, on the contrary, is only present in marine organisms, so that when TMTD is attested isoprenoid acids are diagnostic of marine fats and oils (Ackman and Hooper 1968).

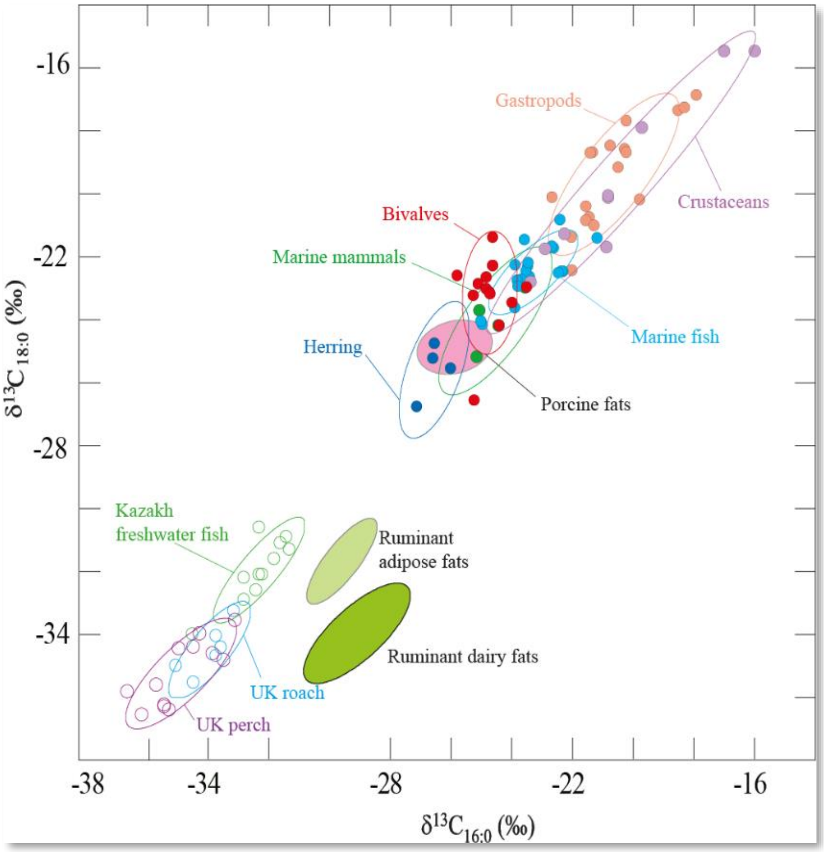


Figure 36. Example of plot of $\delta^{13}C_{16:0}$ against $\delta^{13}C_{18:0}$ values of individual fatty acids *from various terrestrial and aquatic fauna, from Cramp and Evershed 2014 (fig.5).*

In addition to the presence of biomolecular signatures, determining the stable carbon isotope ratio of individual fatty acids can also allow the differentiation of terrestrial and aquatic fats, and marine and freshwater lipids (Cramp and Evershed 2015: 127; fig. 36). This is possible because the isotopic composition of the $C_{16:0}$ and $C_{18:0}$ fatty acids in marine lipids is relatively enriched (Cobabe and Pratt 1995; Evershed et al. 2002; Copley et al. 2004; Cramp and Evershed 2014), while they are relatively depleted in freshwater fats (Outram et al. 2009; Craig et al. 2011; Cramp and Evershed 2014) compared with values derived from a terrestrial origin (fig. 35, Cramp and Evershed 2015: 127). However, if mixed aquatic and ruminant products were both processed in the pots, then distinguishing the sources in the resulting integrated signature is challenging (Cramp and Evershed 2015: 127). This is due to the low content of $C_{18:0}$ in aquatic fats compared to terrestrial fats, leading to measured stable isotope signature of aquatic fats isotopically masked when mixing with terrestrial animal fats: a relatively small amount of ruminant fat can significantly shift the $\delta^{13}C_{18:0}$ values to more terrestrial ones. Therefore, aquatic resources can be isotopically detected only when they have been the predominant commodity contained or processed in the pots (Cramp et al. 2019).

4.3.2 Plants

4.3.2.1 Plant oils

As mentioned above, $C_{16:0}$ and $C_{18:0}$ fatty acids are also components of vegetal oils, but this is not diagnostic in itself as these are also major components of other fats. Most plant oils are characterised by a high abundances of mono-, di- and triunsaturated fatty acids (Rossell 1991), with palmitic ($C_{16:0}$) acid a significant component of these oils; the concentration of stearic ($C_{18:0}$) acid is lower. Monounsaturated $C_{18:1}$ acid, on the other hand, is often found in high concentrations, especially in olive oil (Cramp and Evershed 2015; fig. 37). However, these unsaturated fatty acids easily degrade, and most of them will not be detectable in archaeological remains (Aillaud 2001). In the case of plant oils, the stable carbon isotope ratio does not help in distinguishing them from animal fats because their $\delta^{13}C_{18:0}$ are proven to overlap with non-ruminant animal fats (Steele et al. 2010; Spangenberg et al. 2006). For this reason, identification of plant oils must be based on additional biomarkers, as the ones exposed below, and take the archaeological context into account. If the presence of oil is determined, fats from C_3 and C_4 species can be separated due to the significant carbon isotope difference arising from fractionation during the different photosynthetic pathways (Dungait et al. 2008; 2010; Woodbury et al. 1998; Cramp and Evershed 2015: 129).

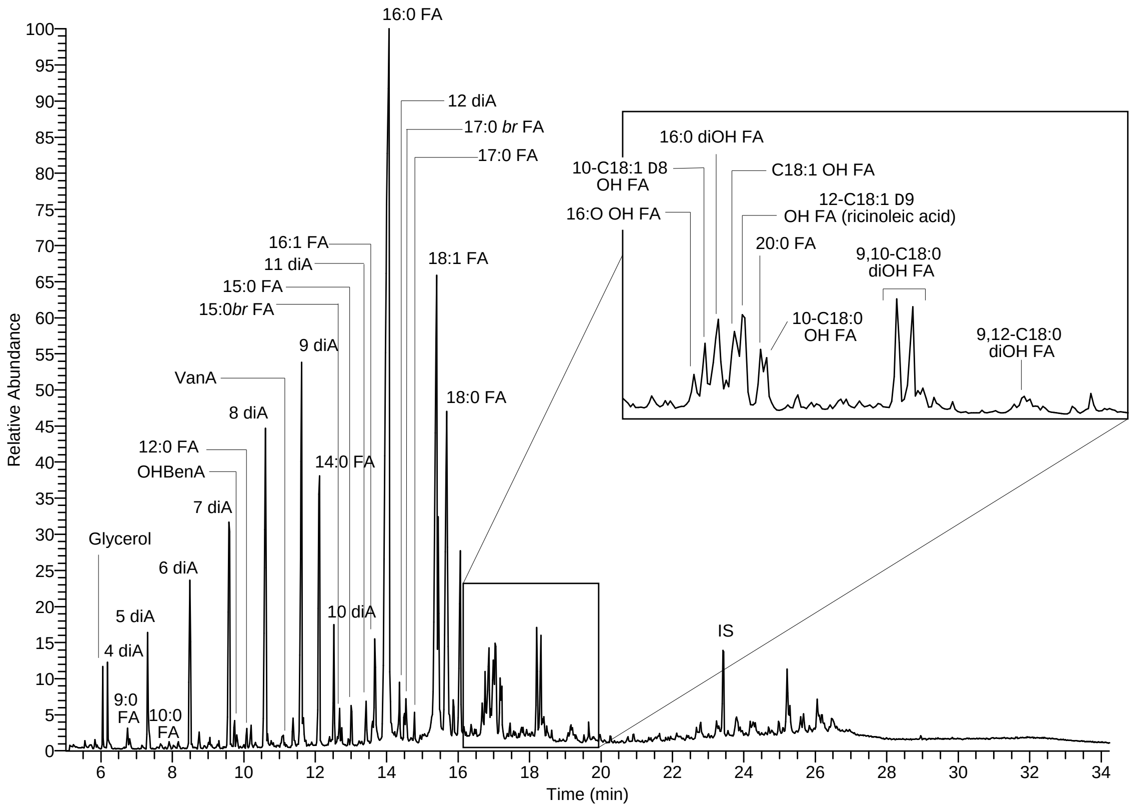


Figure 37. Gas chromatogram from a trimethylsilylated Romano-Egyptian mummy balm. The high relative concentrations of $C_{16:0}$, $C_{18:0}$ and $C_{18:1}$ fatty acids, along with a series of dicarboxylic acids and dihydroxy acids, indicate this balm contains plant-derived oil. Ricinoleic acid (inset) is a biomarker for castor oil. Key: CX diA – dicarboxylic acid with X number of carbon atoms; CX:Y FA – free fatty acid with X carbon atoms and Y degree of unsaturation. CX:Y OH FA – monohydroxy fatty acid with X carbon atoms and Y degree of unsaturation; CX:Y diOH FA – dihydroxy fatty acid with X carbon atoms and Y degree of unsaturation. From Cramp-Evershed 2015 (figure 11.3).

Important biomarkers of plant oils are monounsaturated fatty acids presenting the double bond in a diagnostic position (Regert el al. 1998; Copley et al. 2005). Whilst unsaturated fatty acids are often not preserved, their existence can be inferred from the presence of α,ω-dicarboxylic acids produced from the oxidative cleavage of a double bond and dihydroxycarboxylic acids where hydroxylation occurs at the position of the double bond (Cramp and Evershed 2015: 130). In some cases, these acids are diagnostic of very limited origins. Examples of such biomarkers include ricinoleic acid (12-hydroxy $C_{18:1}$ Δ_9), diagnostic of castor oil (Copley et al. 2005; fig. 37), and $C_{20:1}$ Δ_{11}, $C_{22:1}$ Δ_{13} and $C_{24:1}$ Δ_{15} dicarboxylic acids and the products of the hydroxylation of these compounds (e.g. 11,12-dihydroxyeicosanoic acid, Cramp and Evershed 2015: 130), diagnostic of *Brassica* oils (Copley et al. 2005; Colombini et al. 2005).

Other oils can be recognised by characteristic fatty acid compositions. For example, palm fruit oil is characterised by a high abundance of $C_{12:0}$ and $C_{14:0}$ fatty acids, as observed in post-Meroitic pottery sherds from Egyptian Nubia (Copley et al. 2001; Cramp and Evershed 2015: 130). However, not all species present diagnostic biomarkers. Olive oil, one of the most important commodities in the ancient and modern Mediterranean, cannot be distinguished from other plant oils at present due to the lack of unambiguous biomarkers (Condamin et al. 1976; Cramp and Evershed 2015: 129).

4.3.2.2 Plant leaf waxes

Epicuticular waxes (fig. 38), which form the waterproof outer coating on leafy plants, are comprised of odd carbon alkanes and wax esters, often dominated by C_{29} and C_{31}, even numbered long chain alcohols in the range between C_{22} and C_{34} , odd carbon number mid-chain ketones C_{29-31} (Tulloch 1976; Heron et al. 1994). These biomarkers cannot be attributed to a specific species, and they can only be related to the processing of unspecified leafy plants in the vessel (Cramp et al. 2011; Baeten et al. 2013; Giorgi et al. 2010).

In one specific case biomarkers of leafy plants can be attributed to a genus. This is the case of plant leaf waxes from the *Brassica* genus, based on the presence of *n*-nonacosane, nonacosan-15-ol and nonacosan-15-one (Evershed et al. 1991).

4.3.2.3 Resins, tars and pitches

Other, non-dietary commodities can be identified through organic residue analysis. Terpenoids, the secondary products of plants, can be used to identify amber, pine resins and pitches (diterpenoids, C_{20}) or birch bark tar and *Pinaceae* resins (triterpenoids, C_{30}; Pollard et al. 2007: 154; Dudd and Evershed 1999 (fig. 38)). Due to their defined origin, the detection of these commodities can be useful to highlight trade routes (Regert et al. 2008). Resins can often be provenanced to the botanical family of origin (Pecci 2008), and sometimes even to the genus, allowing their geographic origin to be pinpointed (Roffet-Salque et al. 2016: 10). The detection of resins has also been used to determine information about the vessel use and ceramic technology (Pecci 2008). It has likewise been applied in other archaeological fields, such as the study of sailing technologies, identifying the origin of pitches used in ship manufactures, as pine wood for the 16th century *Mary Rose* (Evershed et al. 1985).

4.3.3 Insect waxes

4.3.3.1 Beeswax

Beeswax can be readily identified through the detection of odd-numbered carbon *n*-alkanes (C_{21}–C_{33}, with C_{27} dominant), even-numbered free fatty acids (C_{22}–C_{30}, with $C_{24:0}$ dominant), long-chain palmitate wax esters (C_{40}–C_{52}, with C_{46} dominant) and hydroxy wax esters (Tulloch 1970; Heron et al. 1994; Regert et al. 2001; fig.38)). These traces of beeswax arise from both the use of wax, or as a by-product of honey processing. Beeswax has been identified as a component of candles (Frith et al. 2004) and other illuminants (Evershed et al. 1997b), as waterproofing for vessels (Salque et al. 2013) and as an ingredient of medicine (Stacey 2011). On a larger scale, organic residue analysis enabled the tracing of the exploitation of honeybees in the Neolithic world, as well as the identification of the geographical borders of this exploitation (Roffet-Salque et al. 2015).

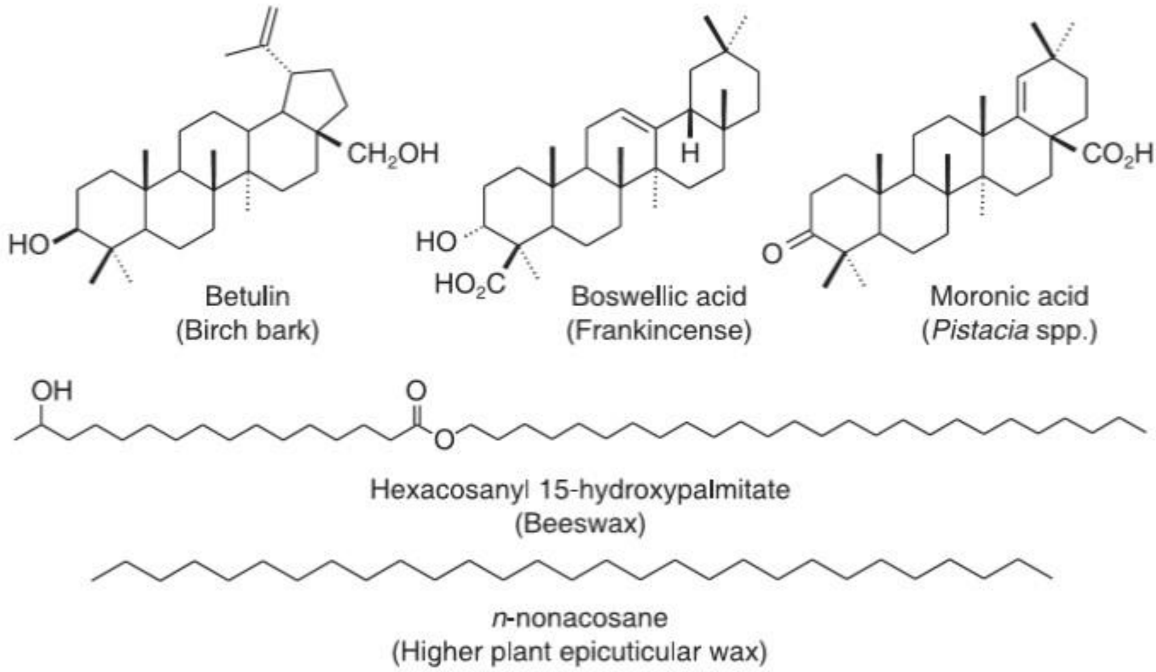


Figure 38. The chemical structure of other biomarkers for resources commonly used in the past that may be identified during organic residue analysis, from Evershed 2008a, figs. 3 and 4.

4.3.4 Bitumen

Petroleum bitumen, a viscous mixture of hydrocarbons widely used by societies in the past and present, can be identified by biomarkers including hydrocarbons, steranes and terpanes (Connan 1999; Roffet-Salque et al. 2016: 10). Used for purposes such as waterproofing, hafting, adhesives and even in embalming, it has been identified through case studies to answer questions related to ceramic technology, art (Stern et al. 2008; Connan et al. 2004) and even the process of mummification (Clark et al. 2016). Being available only in some limited geographic areas (e.g. the Dead Sea) its identification at archaeological sites can also reveal trade routes and movements (Stern et al. 2008).

4.3.5 Controversial identifications: fermented beverages

Alcoholic drinks in Mediterranean archaeology have been a desirable class of commodity to detect through ORA (e.g. Pecci et al. 2013; Garnier and Valamoti 2016). Challenges with the identification of these beverage lies in the fact that the biomarkers commonly adopted (tartaric acid, syringic acids, calcium oxalate, ergosterol) are ubiquitous compounds that are highly labile or soluble in water (Roffet-Salque et al. 2016). Tartaric acid, the most solid biomarker, is highly attested in grapes but it is also present in other fruits, and it can easily migrate from the depositional soil (Drieu et al. 2020). These compounds are not related to fermented beverages, but to fruit juices in general: no unambiguous biomarkers of wine or other fermented drinks exist at this stage of research (Drieu et al. 2020).

For these reasons, the identification of organic residues as biomarkers of alcoholic drinks is possible only if corroborated by strong archaeological evidence and if samples allowing negative control are analysed (as in Pecci et al. 2013; Garnier and Valamoti 2016).

4.4 Research application of organic residue analysis for the study of past foodways

4.4.1 Organic residue analysis, food processing and vessel use

Organic residue analyses have been used to investigate a number of different research questions related to culinary practices, as stated in the introduction of this chapter. These can be grouped into questions regarding food processing and cooking, consumed commodities and diet, vessel use: questions often interrelated among them.

As mentioned (4.1), organic residue analysis can provide information about how commodities were processed in the vessel. For example, mid-chain ketones can be indicative of heating to high temperatures of over 300°C (Evershed et al. 1995; Raven et al. 1997), while a high lipid concentration implies heating for a long time so that cooking or boiling is suggested (Charters et al. 1993). Moreover, the concentration of lipids in different parts of the vessel implies different ways of processing them: if concentrated by the rim, they likely migrated during the boiling or processing of liquids, while if concentrated in the bottom of the vessel, cooking without liquids (or a limited amount of liquids) can be inferred (Charters et al. 1993).

Organic residue analysis on pottery has also been applied to answer questions about consumed commodities and local foodways. For example, ORA has been used to investigate foodways in Neolithic south-eastern Europe (Cramp et al. 2019), revealing that in the Balkans vessels were used mainly to process aquatic products, differently from other regions of the continent where ruminant carcass and dairy products were predominant in Neolithic vessels. Or, as a second example, ORA has been applied to identify the relevance of dairy products in the diet and foodways in the Alps from the Bronze Age (Carrer et al. 2016). Information about food consumed by past communities is often obtained through ORA. However, it has to be considered that organic residue analyses are usually applied to lipids extracted from pots and hence, help to understand vessel contents in the past. As confirmed by some case studies (e.g. Dunne et al. 2019a), the lipids contained in vessels do not necessarily reflect diet, since many of the consumed food could have been consumed and processed without the use of pottery.

Research questions targeted through ORA more often focus specifically on vessel use, aiming to understand how some ceramic shapes were utilised. This approach was undertaken on Roman *mortaria* in Britain (Cramp et al. 2011), which revealed they were used to process multiple products beyond cereals. Sieve forms from the central European Neolithic (Roffet-Salque et al. 2013) were confirmed to be involved in cheese-making, and baby bottle jugs in Bronze and Iron Age Europe were demonstrated as being used as milk containers (Dunne et al. 2019b). Pottery of the Jomon culture in Neolithic Japan was proved to be used predominantly to process fish (Craig et al. 2013). These are only some successful examples of how ORA have led to significant advancements on comprehension of the use of archaeological vessels and, indirectly, food practices.

All the examples exposed above refer to food-related vessels. Still, a similar approach has been applied to other vessel categories, such as lamps (Mottram et al. 1999) or candleholders (Firth et al. 2004), to obtain information about vessel use. Moreover, through ORA other information about vessel technology can be obtained: organic residue analysis detects lipids used as sealing agents (e.g. Salque et al. 2013; Stern et al. 2008), adhesive and repairing elements (Connan et al. 2008) or as a means of decoration (Connan et al. 2004) and waterproofing (Regert et al. 2003).

4.4.2 Organic residue analysis, migrations and cultural changes

Organic residue analysis of pottery has also been used to detect cultural changes and movements of people and goods. The application of organic residue analysis can identify changes or continuity in culinary practices. These changes in culinary practices and consumed foods can, in turn, extrapolate information about changes in the local communities, in population and culture.

For example, in northwestern European islands, lipids detected in vessels revealed a relatively rapid change in diet from fishing to dairy farming after the introduction of farming (Cramp et al. 2014). Meanwhile, in late Neolithic Syria, ORA were used to trace the emergence of secondary product exploitation and social changes (Nieuwenhuyse et al. 2015). Continuity in culinary practices despite the introduction of new pottery was also documented, e.g. in northern Europe after the appearance of ceramics (Craig et al. 2011) and in Japan between the late Pleistocene and the mid-Holocene (Lucquin et al. 2016). All this different information has a relationship with the study of social and cultural changes: it made clear when and how some products were introduced or, on the contrary, kept being consumed despite the introduction of new ceramic assemblages. Organic residue analyses also help understand the impact and use of new ceramics on the local culture. The previously mentioned study of Roman *mortaria* (Cramp et al. 2011), for example, revealed that in Britain, this ceramic shape was used for products and in ways that differed from the Mediterranean area. This evidence suggested that the introduction of *mortaria* did not bring a change in diet but only in the way some food was processed. This approach helped in highlighting archaeological biases connecting too often changes in ceramic assemblages with changes in diet, showing that it is not always the case.

The movements of products can also be detected through organic residue analysis, revealing the distant origin of some resources processed in vessels (e.g. frankincense, Baeten et al. 2014; resins, Regert et al. 2008; bitumen, Stern et al. 2008). This evidence make clear the existence of trade routes and economic or cultural networks, indirectly connected with movements of people and ideas, so with cultural interactions.

4.4.3 Previous applications of organic residue analysis in Sardinia and in the Phoenician and Punic world

The results from existing investigations into organic residue analysis from pottery in the Phoenician and Punic world and the first millennium BCE Sardinia are summarised in this section. This summary will constitute a benchmark for comparisons and a brief contextual background for this research.

The application of organic residue analysis in these focal contexts has been very limited until recently. In Sardinia, published papers that include organic residue analysis do not assess more than 12 samples each (Oggiano and Botto 2012; Pecci 2008; Bordignon et al. 2005; Frère et al. 2012; Gradoli and Garnier 2018). A similar trend is also observed in surrounding areas, both geographically (e.g. Corsica (Rageot et al. 2016); Carthage (Garnier and Dodinet 2013)) and archaeologically (e.g. Iron Age in Jordan (Mayyas and Douglas 2015)). These numbers do not reach the minimum standards recommended in the UK to obtain statistically reliable data, i.e. 40-60 potsherds (Historic England 2017: 16).

To the best of my knowledge, only three partial exceptions exist. These analyse cookware in the ancient Mediterranean and present larger sample sets of up to 70 sherds (Molina 2015; Oltra 2010; Notarstefano 2012). Two of them are unpublished PhD theses, and they focus on the Iberian Bronze Age, which is far removed in time and place from Phoenician and Punic Sardinia (Molina 2015; Oltra 2010). The third is a volume by Florinda Notarstefano, where results of the PhD project by the author are presented. Pottery from three different sites was analysed: a medieval castle in Italy, a Hellenistic and Roman sanctuary in Turkey and a Punic sanctuary in Malta. The latter (Tas-Silġ) is directly related with the present dissertation, being close in time and material culture with the contexts involved in the project. Unfortunately only small numbers of sherds per site were analysed, from 12 to 33, involving amphoras, cooking ware and dining ware, making every comparison or general interpretation very weak. Moreover, the chemical interpretation of results is often not well-based: for example, presence of cholesterol is considered as an evidence for animal product processing, while it can be often connected with contamination since it rapidly degrades (Roffet-Salque et al. 2016; Hamman et al. 2018). For the sanctuary of Tas-Silġ in Malta sherds of 15 vessels connected with food cooking and consumption were analysed: six cooking pots, five casseroles, one baking tray, two dishes and one cup. Concentration in the extracts is very low. Animal fats are identified in seven of the extracts, while identification of fish fats and beeswax proposed does not appear well established: only a very low concentration of $C_{20:1}$ and $C_{22:1}$ fatty acids was detected in the two extracts were fish was said to be identified, while only wax esters (carbon number not known) and alkanes were used as biomarkers of beeswax, being not sufficient (Roffet-Salque et al. 2015). As a result, the full study does not provide reliable interpretations or solid evidence for comparisons, despite offering new lipid evidence for contexts where it was absent. Being the number of sherds very small, and being Punic sherds from a sanctuary, lipid results provided by this study are of limited use for comparisons and discussions (chapter 7).

In pre-Roman Sardinia, until a decade ago published works or conference posters (e.g. Nervi et al. 2015) including organic residue analysis results mainly focused on amphoras, aiming to detect contents and identify trade (Bordignon et a. 2005; Oggiano and Botto 2012). In these analysed amphoras beeswax, resins, vegetal fats and animal fats have been identified, but the biomarkers used to determine them are not often explicitly described in the text of these papers. Palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) free fatty acids were used as biomarkers of animal fats. Diterpenes, such as dehydroabietic and abietic acid, were used as biomarkers of resins. Whilst sitosterol and dicarboxylic acids were used as biomarkers for oils and vegetal fats and *n*-alcohols and *n*-alkanes for beeswax (Oggiano and Botto 2012; Bordignon et al. 2005). In one case (Oggiano and Botto 2012: 164) the tentative identification of carcass fats mixed with dairy fats led the scholars to hypothesise the presence of *puls punica,* a typical Punic recipe made with cereals, honey and cheese, in the amphora. However, compound-specific stable carbon isotope analysis was not undertaken, so the presence of dairy fats cannot be confirmed (4.3.1.1).

More recently, more ceramic shapes have been investigated by ORA. Frére et al. (2012) published results of analyses on 7 glass wares from Punic Sardinia (6th-4th centuries BCE), which were used to store unguents, as *aryballoi* or miniaturistic amphoras. *n*-Alkanols and alkanes have been found in the extracts, together with diterpenes, as dehydroabietic acid, biomarkers of resins, and monoterpenes (camphor). This lipid composition of the analysed vessel does not support the use of animal fats in perfume manufacture, but all the seven extracts appear largely contaminated, making the whole interpretation of results particularly complex. A similar contamination seems probable for the two extracts of perfume-burners described in Oggiano and Botto. The lack of aromatic spices and herbs lead the authors to suggest a secondary use of burners as oil lamps, but biomarkers used to identify oil are not clear (probably $C_{16:0}$ FFA) and the presence of squalene, cholesterol and abundant $C_{16:1}$ monounsaturated fatty acid (Oggiano and Botto 2012: 165) makes contamination very likely and the whole interpretation only tentative. Four lamps have been analysed in work by Lucejko et al. (2012). Animal fats have been detected ($C_{16:0}$ and $C_{18:0}$ FFAs as biomarkers), leading to the hypothesis that animal products were used in lighting. In the same work, vessels used for consumption, such as dishes and cups, have been analysed (Oggiano and Botto 2012; Lucejko et al. 2012). Analyses revealed the presence of animal fats in some extracts and vegetal fats in others, but the small number of analysed vessels (four) hinders any substantial interpretation.

These studies provide a basis for the present study, due to geographical and chronological proximity (indeed, some include sherds of amphoras and perfume burners from my target sites, e.g. Frére et al. 2012; Bordignon et al. 2005). However, vessels analysed in these papers did not include forms used in food preparation and cooking. For this reason, whilst complementary, the data obtained cannot be directly compared with the cookware-derived data coming of the present study.

Previous lipid residue analysis of cooking ware has, however, been carried out from two of the sites selected for this project, Pani Loriga (3.2.3) and Sant'Antioco (3.2.5). From Pani Loriga a total of 3 cooking pots and one basin has been analysed (Botto and Garnier 2018; Botto et al. *in press*). Published results, however, do not appear particularly reliable in their interpretation. The identification of white wine was proposed for each pot, together with animal fats, but tartaric, malic and syringic acids cannot be considered solid biomarkers for wine as established by more recent papers (Drieu et al. 2020; see 4.3.5). From Sant'Antioco, a total of 3 cooking pots, 3 casseroles, and one baking tray were analysed (Pecci 2008). They all derive from the same dump (US 500), and they were analysed as part of Campanella's work (2008) mentioned in section 2.1.1. Results, identifying animal fats, beeswax and resins in the targeted vessels, seem in this case more reliable, as biomarkers used are in line with the current state of the research described in this chapter. The number of sherds, however, is still extremely limited to obtain a broad interpretation. In both cases, results of these analyses are described more in detail in Chapter 6 (section 6.2 and 6.5) because they constitute a direct comparison for data deriving from the current project.

Recently, organic residue analyses have also been applied on cookware (four sherds) from a Bronze Age Sardinian context, Nuraghe Arrubiu in Orroli (Lo Schiavo and Perra 2017). Unfortunately, interpretation of results has been once more not particularly reliable, making the whole study of limited use. The researchers hypothesised the processing of wine and insect-based soups in one of the bowls (Gradoli and Garnier 2018: 143). These products, however, are said to be identified based on lipids as tartaric, malic and syringic acids for wine and C_{28}, C_{30}, C_{32} methyl alkanes for insects. These lipids are not widely accepted as biomarkers of wine and insects in current biochemical research (Drieu et al. 2020; Roffet-Salque et al. 2016).

Table 3 Results of organic residue analysis on cookware undertaken in Phoenician and Punic Sardinia before the current research. White section: Sulky/Sant'Antioco, SU 500 (urban dump) reworked from Pecci 2008 (table 1 and table 2); yellow section: Pani Loriga, multiple contexts (from Botto and Garnier 2018: fig. 8).

Site and paper	Sample number or context	Shape and chronology	Identified commodities
Sant'Antioco (Pecci 2008)	732 A	Cooking pot, second/third quarter 4th century BC	Animal fats (non ruminant?) *Pinaceae* (tar?) Mineral wax Beeswax/honey
Sant'Antioco (Pecci 2008)	286	Cooking pot, half 3rd century BC	Animal fats (ruminant?) *Pinaceae* resin
Sant'Antioco (Pecci 2008)	313B	Cooking pot, end 4th – beginning 3rd century BC	Animal fats (fish?) Vegetal fats? *Pinaceae* resin
Sant'Antioco (Pecci 2008)	212	Casserole, end 5th – 4th century BC	Vegetal fats (Oils?) *Pinaceae* resin
Sant'Antioco (Pecci 2008)	214	Casserole, end 5th – 4th century BC	Animal fats (non ruminant?) *Pinaceae* resin
Sant'Antioco (Pecci 2008)	215	Casserole, end 5th – 4th century BC	Animal fats (non ruminant + dairy fats? Fish?) Vegetal fats (Oils?) *Pinaceae* resin
Sant'Antioco (Pecci 2008)	477A/477B	Baking tray, half 8th – half 7th century BC	Animal fats (mixed) *Pinaceae* resin
Pani Loriga (Botto and Garnier 2018)	Necropolis, 2006	Handmade pot with handle	Animal fats (non ruminant?); contaminants; triterpenes; white wine (?)
Pani Loriga (Botto and Garnier 2018)	PLB 12.S7.1147.6 settlement	Wheelmade pot	Animal fats (non ruminant?); plasticisers; white wine (?)
Pani Loriga (Botto and Garnier 2018)	PLB 12.S3.1215.11 settlement	Basin (bottom)	Animal fat (non ruminant?); white wine (?)

Thus, whilst the availability of direct comparisons for this study is limited, some previous work has indicated that there does exist the potential and suitability for the application of organic residue analyses to pottery from the island. Several small-scale studies have proven ORA as a suitable tool for the investigation of Sardinian past, from different points of views. Before the present research, ORA in Sardinia, analysing small numbers of vessels, were focused on detecting what was contained in each vessel, addressing research questions of limited scope. However, much wider research questions can be addressed through ORA, as illustrated in this chapter. In particular, there exists the absence of large-scale studies, which creates the opportunity to undertake a large-scale comparative analysis of vessels, like the one presented in this dissertation. This project, analysing 368 from six different sites and five different vessel categories (see Chapter 5), aims in fact to answer questions regarding vessel use, differences between sites, and changes in time and space. It will, more broadly, tackle questions on cultural implications of the results obtained. It is something new on the island, despite a growing scholarly interest (see Chapter 2, section 2.1.1), and it is likely to work as a significant stimulus for the application of organic residue analyses on the island and the surrounding regions in the near future.

Chapter 5
Sample selection and analytical methods

5.1 Selection of sherds

Sherds from 368 vessels were analysed in this study. These sherds were selected and sampled during four trips to Sardinia (May 2017; July 2017; January-February 2018; June 2018). Selection and permission to analyse the sherds has been allowed by the *Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Cagliari e le province di Oristano e Sud Sardegna,* a partner institution in this project. The main ceramic categories believed to be involved in food preparation and cooking have been included in the analysis, based on current archaeological literature (see section 5.1.2). The focus period is the 8th century (the foundation of Phoenician settlements in Sardinia) to the 3rd century BCE (Roman occupation). The list of sherds and the analyses carried out on them is shown in the Appendix.

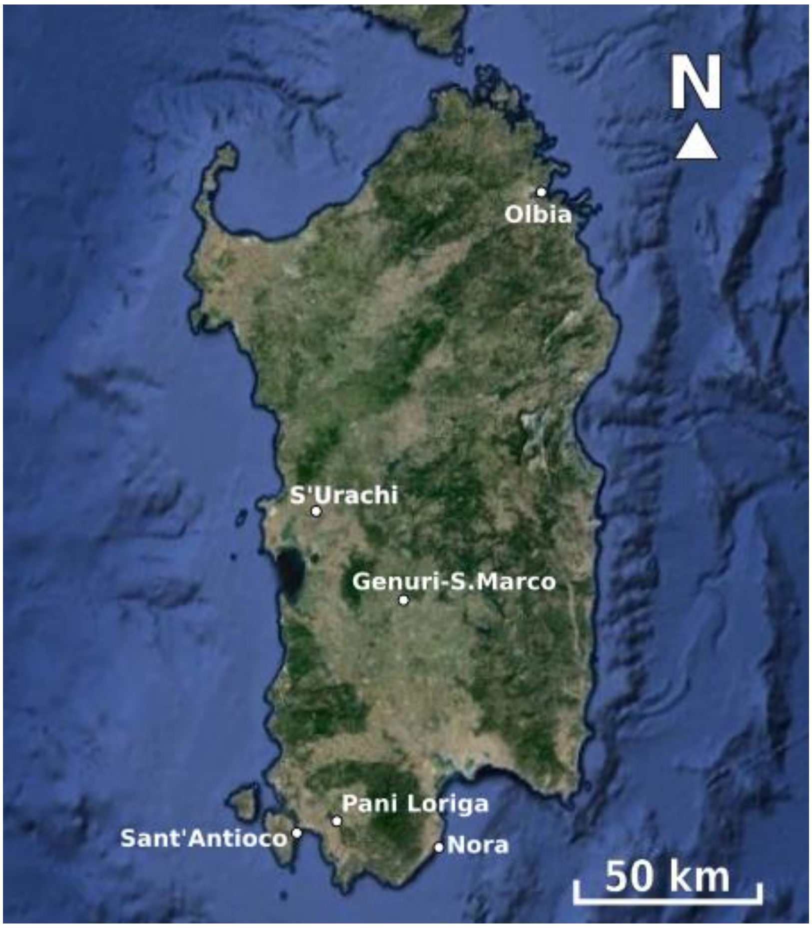


Figure 39. Map of Sardinia indicating the sites included in the project.

The overall assemblage of analysed sherds is the result of selection based on the following premises:

1) *Representativity in space.* Sherds come from sites located in different areas of the island (fig. 39): Sulcis (southwest), Campidano (south), Oristanese (west) and Gallura (northeast). Each of these areas was affected by Phoenician and Punic migration, with Levantine people settling in these regions and founding new settlements. Both inland and coastal sites are included.

The northwestern area was not involved in the foundation of Phoenician or Punic settlements (Moscati et al. 1997). Since historical and archaeological developments are substantially different in this region compared to the other targeted areas, it was not included in the project to avoid the creation of an inconsistent database (see points 4 and 8). Some Phoenician settlement areas (southeast and part of the

Oristano Gulf) were excluded due to the lack of known suitable material, or due to its unavailability during the sample collection trips, as in the case of Tharros (Manca di Mores 1991; Campisi 2000).

2) *Representativity in time.* Sites were selected to cover the entire Phoenician and Punic period in Sardinia, from the 8th to the 3rd centuries BCE. Some of the sites were occupied for the entire period, some for just a few centuries (see 3.2). The original intention was to analyse a similar number of sherds per century (see point 6). This strategy, however, was unproductive because of the abundant discrepancies of available material over time. The availability of settlement layers dated to the Punic period (5th to 2nd centuries BCE) are abundant compared to the first centuries of Phoenician presence (see Chapter 3; 3.1 and 3.2). In agreement with public officials and excavation directors, a selection that was more representative of the archaeological record appeared to be the best choice, as this would avoid overrepresentation of small Phoenician contexts. Later centuries will have greater representation than earlier ones, following the greater availability of contexts and sherds (see Appendix). This choice also avoided damaging (during the sampling process, see 5.2.1) sherds from contexts where materials are limited in numbers.

   Finally, some of the selected sherds are dated to the 3rd–2nd centuries BCE. The inclusion of these sherds is due to continuity in production after the Roman occupation of the island, leading to unchanging manufacturing processes and shapes that cannot be more precisely dated (see 3.3 for more detail). With the agreement of scholars cooperating in the selection, the inclusion of these vessels was necessary to avoid the exclusion of several ceramic categories in use during the last part of the Punic era.

3) *Representativity of ceramic categories.* The selected assemblage of sherds includes the main ceramic categories thought to be involved in cooking food and baking (cooking pots, casseroles, ovens and baking trays; see 3.3) and food processing and preparation (basins and tripod bowls) with the exception of mortars (see point 7). Wheelmade and handmade vessels used in the settlements were selected, regardless of their hypothetical cultural affiliation (Phoenician-Punic, indigenous). When vessel categories include subtypes (e.g. there are more than 15 subtypes of cooking pots and basins; see 3.3), several samples for each subtype have been selected.

   Subtypes and vessels presumed unlikely to yield a high lipid recovery have also been analysed, including some vessels interpreted as possibly used in food preparation, food serving, or bread baking (see 3.3). Subtypes of basins and tripod bowls that were possibly but not certainly involved in food processing (3.3.2) have also been included. Quantifying and characterising lipids absorbed into these vessels (or not) has the potential to clarify their use further.

4) *Site character.* The six sites involved in the project (fig. 38) are varied in character: Sant'Antioco was the only Phoenician city in Sardinia; Nora and Olbia are Phoenician foundations (8th-7th centuries BCE) with very different developments; S'Urachi and San Marco are indigenous settlements each built around an earlier *nuraghe*. Each site is further described in section 3.2. At all these sites, during the Phoenician and

especially the Punic period, the same vessel shapes were adopted by their inhabitants. For this reason, the same categories were sampled in each site. But it is well known that similar vessels can have different uses and meanings when adopted by different communities (Cramp et al. 2011; Curé et al. 2015). On the one hand, this variety of sites enables comparisons within the same ceramic category and between sites. On the other hand, there is a recognised risk that the relatively limited number of sherds per site and the spread across different vessel types could prevent the development of more generalised interpretations. This aspect will be considered when discussing the results (Chapter 7). However, the nature and aims of the project and the very limited existing database available for organic residue analysis in Sardinia to date (see Chapter 4, section 4.4) encouraged the inclusion of different sites. This site selection strategy seemed the best way to obtain a diachronic and synchronic study between Phoenician, Punic and indigenous sites and to provide insights and a solid foundation for further questions.

5) *Available data for each site.* When carrying out organic residue analysis on archaeological pottery, existing contextual data are extremely relevant for both refining research questions and interpreting findings. Archaeological stratigraphy and the typological study of pottery, detailed faunal and palaeonvironmental data, and information about the site, in general, allow more effective contamination detection, the connection of chemical compounds to past commodities consumed on the site and a better interpretation about the implications from the chemical results (Dunne et al. 2019a). In this project, sites with most of these features have been selected. Stratigraphy has always been considered: in four cases, I spoke with and selected the pottery with the excavator, and in two cases, the site stratigraphy was fully published (see 6.1). Archaeofaunal data have been collected and published from five of the sites, representing some of the best data for the period (see 6.1). Extensive environmental data are available only for two of the selected sites (Nora and S'Urachi), but other studies on palaeoenvironment are considered to contextualise results in the past environment better (see also Chapter 2, 2.2).

6) *Available data for each sherd.* Contextual archaeological data (layer, place, year of excavation, name of the excavators) are available for each sherd involved in the analysis. Most of the sherds are dated based on context as well as of typology (see Appendix). For some sites (Nora, Sant'Antioco), sherds have been selected using detailed and comprehensive catalogues (Campanella 2008; 2009 a, b, c; Botto 2009); for other sites, excavators and pottery experts responsible for the study of materials have been actively involved in sherd selection. As a result, a specific and precise archaeological context is available for each sherd. In addition, information regarding potential contamination has been recorded, as well as properties about soil, post-excavation treatments, and storage containers. These data provide a robust foundation for my chemical analysis.

7) *Feasibility and practical issues.* In some cases, the choice of sherds was constrained by practical issues. One obvious constraint is the availability of material. Some sites, centuries, or ceramic categories have not been sampled due to the lack of available material in the archaeological record (point 1 and 2), or the inaccessibility of material during my short trips to Sardinia. A second issue involves the sampling process, which requires removing 2 grams of ceramic for each sherd sampled (see 5.2.1). This method is inherently destructive,

particularly for small, thick sherds, which are prone to break apart when a small piece is removed. As a result, the Soprintendenza would not grant permission to take samples from mortars, and from some thicker-walled baking trays (see point 8).

8) *Balance of numbers and consistency.* Finally, the decision to include different sites (point 4) and ceramic categories derives from the need to obtain comparable representation for each site and each ceramic category, thus enabling a better understanding and interpretation of the results. Considering the points and limitations outlined above, I tried to obtain a balanced and consistent selection of sherds, following two principles: 1) When 25 or fewer sherds were available, the site was not included; 2) When large quantities of suitable sherds were available (e.g. more than 200), a limited number of sherds was included per archaeological layer and site (see Appendix, tables I-VI).

As a result, the minimum number of sherds per site is 27, and the maximum is 105 (table 4). The maximum number of sherds per archaeological layer at a given site is 27, while the maximum number of sherds per subcategory, in the overall selection, is less than 50. This choice leads to the underrepresentation of major subtypes in the analysed assemblage compared to the archaeological record. P2 pots, for example, likely constitute more than the 50% of cooking pots in Phoenician and Punic settlements in Sardinia (see 3.2.1), but only 20% of the targeted assemblage. This selection enables a similar quantity and quality of data for different contexts and periods to be obtained (see Chapter 6), allowing comparisons between sites and vessel categories. In this way, excessive focus on a particular century, vessel category or site was avoided, such a focus being inconsistent with the aims and research questions outlined in Chapter 1.

Table 4 Number of sherds analysed per site and per vessel category, with general chronology.

Site/ceramic category chronology	Wheelmade pots 8th-2nd centuries BCE	Handmade pots 8th-3rd centuries BCE?	Basins and tripod bowls 8th-2nd centuries BCE	Casseroles 5th-2nd centuries BCE	Baking trays 8th-3rd centuries BCE?	Ovens 5th-2nd centuries BCE?	TOTAL
S'Urachi 6th-2nd centuries BCE	63	5	18	8	2	5	**101**
Pani Loriga 6th-5th centuries BCE	10	19	17	0	4	2	**52**
Nora 8th-2nd centuries BCE (type)	25	8	30	6	3	6	**78**
Olbia 4th-2nd centuries BCE	52	9	12	9	1	0	**83**
Genuri S.M. 4th-3rd centuries BCE	5	13	8	1	0	0	**27**
S. Antioco 5th-4th centuries BCE	13	1	6	6	1	0	**27**
TOTAL	**168**	**55**	**91**	**30**	**11**	**13**	**368**

It must be noted that the small number of baking trays and ovens analysed may seem inconsistent (see table 4). In the case of ovens, the lack of preserved lipids (see Chapter 6) has discouraged further analysis. Baking trays, on the other hand, are not common in Phoenician and Punic Sardinia, and some of the originally selected sherds were too small to be cut. During my trips to Sardinia, I sampled the largest possible number, but unfortunately, it is still quite limited compared to my original plans. The relevance of the results, however, warrant inclusion of this category in the dissertation despite the limited number of samples.

5.2 Analytical protocol

5.2.1 Sampling pottery and analytical precautions

According to the Italian regulations, sherds found on archaeological excavations are not allowed to leave the excavation area. Therefore, in agreement with the Sardinian *Soprintendenza* which granted permission for the analyses, the first phase of the sampling process had to take place in Sardinia. Approximately 3-4 g of pottery was removed from each ceramic sherd using a hammer and a chisel. When the sherd was too fragile or too archaeologically meaningful (e.g. rare vessel types) to be clipped using hammer and chisel, it was cut using a diamond cutting disc (22 mm, washed with acetone before each use) inserted in a 135w multi-tool (Wilko). These 3-4 g subsamples were individually wrapped in aluminium foil, labelled and sent to the Archaeological Chemistry Laboratory in the Archaeology and Anthropology Department at the University of Bristol.

Once in Bristol, every 3-4 g sherd was treated using the following procedure. The surface of every sherd was cleaned using a modelling drill fitted with an abrasive drill bit, removing approximately 1 mm of superficial ceramic to remove any surface contamination from the soil or post-excavation handling. Approximately 2 g of pottery was removed from the cleaned area using a hammer and a chisel. The remaining part of the sherd was wrapped in aluminium foil and conserved for future analyses.

All solvents used were HPLC grade (Rathburn) and the reagents were analytical grade (typically >98% of purity). Reusable glassware was washed with Decon 90 (Decon laboratories), rinsed with acetone and a mixture of chloroform and methanol (2:1 v/v, Rathburn) and oven dried, or they were furnaced at 450ºC for a minimum of 4 hours. All batches of samples were accompanied by an analytical blank in order to monitor any contamination introduced during the extraction or analytical procedures.

5.2.2 Lipid extraction and derivatisation

Total lipid extracts were obtained by applying the solvent extraction method following the protocol described in past literature (e.g. Evershed et al. 1990; Charters et al. 1993). The solvent extraction method was preferred to the recently widespread acidified methanol method (Correa Ascencio and Evershed 2014), which can lead to higher recovery of lipids but also to loss of compounds as wax esters, which were targeted in this research.

The sampled sherd was crushed to a fine powder using a washed glass mortar and pestle, and then weighed accurately. An internal standard (20 µl of a solution of C_{34} *n*-alkane at 1 mg/ml) was added to each sample to allow quantification. The lipids were then extracted with a mixture of chloroform and methanol (2 × 10 ml, 2:1 *v/v*) by sonication (2 × 20 minutes). After each extraction, the solvent extract was transferred into a clean test tube and then centrifuged to remove any suspended particulates (2500 rpm, 10 minutes). The supernatant solution was finally transferred to vials and the solvent removed gently under a N_2 flow at 40 °C to obtain the total lipid extract (TLE). Approximately one quarter of each total lipid extract was filtered through a silica column and then blown down under N_2. Each filtered sample was derivatised using *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) with 1% trimethylsilyl chloride (40 µl, 70°C, 1 h). Excess BSTFA was blown down gently under N_2. The sample was dissolved in 100 µl hexane before analysis.

5.2.3 High Temperature Gas Chromatography (HTGC)

All total lipid extracts, as their TMS derivatives, were screened and quantified using an Agilent 7890 fitted with a high temperature non-polar column with a 100% dimethyl polysiloxane stationary phase (15 m × 0.32 mm internal diameter, 0.1 µm film thickness). Helium was used as a carrier gas. The temperature programme comprised of a 2 min isothermal at 50°C, increasing at 10°C min^{-1} to 350°C, ending with a 10 min isothermal.

5.2.4 Hydrolysis and methylation of lipid extracts

To allow GC-MS and GC-C-IRMS analysis, hydrolysis and methylation of TLEs was carried out. A methanolic sodium hydroxide solution (0.5 M, 2 mL) was added to an aliquot of each selected TLE, then heated for 1 hour at 70°C. After cooling to room temperature, the neutral fraction was extracted using 3 x 3 mL hexane. The methanol phase was acidified to pH 3 with 1M HCl. Consequently, the free fatty acids were extracted (3 x 3 mL $CHCl_3$) and methylated using 100 µL isotopically-measured BF_3/MeOH (70°C, 1 h). Dichloromethane-extracted double distilled water (1 mL) was then added and the methyl ester derivatives were extracted with chloroform (3 x 2 mL). The solvent was evaporated to dryness under N_2. The fatty acid methyl esters (FAMEs) were stored in a freezer until required for analysis. Finally, the FAMEs were dissolved into an appropriate concentration of hexane (typically 50 to 500 µL) for analysis by GC-MS and GC-combustion-isotope ratio MS (GC-C-IRMS).

5.2.5 Gas Chromatography-Mass spectrometry (GC-MS) operated in Full Scan (FS) and Selected Ion Monitoring (SIM) modes

Gas chromatography-mass spectrometry (GC-MS) analyses of trimethylsilylated TLE aliquots and FAMEs was carried out to allow compound identification, using methods described in earlier papers (e.g. Evershed et al. 1990; Charters et al. 1993). TMS derivatives were injected onto a ThermoFinnigan single quadrupole TraceMS run in EI mode (electron energy 70 eV, scan time of 0·6 s) fitted with a non-polar column (100% dimethyl polysiloxane stationary phase; 60 m × 0.25 mm i.d., 0.1µm film thickness). The temperature programme comprised an isothermal hold at 50 °C for 2 min, increasing to 300 °C at 10° min^{-1}, followed by an isothermal hold at 300 °C (15 min). Scan was set to full scan mode (*m/z* 50–650). Data acquisition and processing were carried out using the HP Chemstation software (Rev. B.03.02 (341), Agilent Technologies). Peaks were identified based on their mass spectra and gas chromatography (GC) retention times, and by comparison with the NIST mass spectral library (version 2.0).

For the detection of *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs) and isoprenoid fatty acids (IFAs), following earlier papers (e.g. Evershed et al. 2008b), FAME derivatives were injected onto a 60 m × 0.32 mm fused silica capillary column coated with a VF-23ms stationary phase (50% cyanopropyl-methylpolysiloxane, Varian, Factor Four, 0.15 µm). The GC temperature programme comprised of a 50 °C isothermal for 2 min, followed by a gradient to 100 °C at 10 °C min^{-1} and then to 240 °C at 4 °C min^{-1} before a final isothermal at 240 °C for 15 min. Helium was used as the carrier gas and maintained at a constant flow of 2 mL min^{-1}. The MS was operated in electron ionisation (EI) mode, 70 eV, GC transfer line temperature 250 °C and source temperature 200 °C; the emission current was set to 150 µA. The MS was set to operate in selected ion monitoring (SIM) mode, acquiring at *m/z* 105, 262, 290, 312 and 346 at 1.2 scans s$^{-1,}$ for the detection of APAAs and in full scan for the detection of isoprenoids fatty acids (IFAs, *m/z* 50-650).

5.2.6. High Temperature–Gas Chromatography–Mass Spectrometry (HT-GC-MS)

HTGC/MS analyses of trimethylsilylated TLE aliquots were performed using a Thermo Scientific Trace 1300 gas chromatograph coupled with an ISQ single quadrupole mass spectrometer, following the programme exposed in earlier papers (e.g. Roffet-Salque et al. 2015). Diluted samples were introduced using a PTV injector in split mode (split flow of 30 ml min^{-1}, split ratio of 6.0) onto a 0.53 mm fused silica pre-column connected to a 15 m × 0.32 mm i.d. fused-silica capillary column coated with dimethyl polysiloxane stationary phase (Rxi-1HT; film thickness, 0.1 µm; Restek). The initial injection port temperature was 50 °C with an evaporation phase of 0.05 min, followed by a transfer phase from 50 °C to 380 °C at 0.2 °C min^{-1}. The oven temperature was held isothermally for 2 min at 50 °C, increased at a rate of 10 °C min^{-1} to 280 °C, then at a rate of 25 °C min^{-1} to 380 °C and finally held at 380 °C for 5 min. Helium was used as a carrier gas and maintained at a constant flow 5 ml min^{-1}. The mass spectrometer was operated in the electron ionization (EI) mode (70 eV) with a GC interface temperature of 380 °C and a source temperature of 340 °C. The emission current was 50 µA and the mass spectrometry set to acquire in the range of *m/z* 50–950 Daltons at two scans per second. Data acquisition and processing were carried out using the Thermo XCalibur software (version 3.0.63). Peaks were identified based on their mass spectra, gas chromatography (GC) retention times and by comparison with the NIST mass spectral library (version 2.0).

5.2.7 Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS)

The protocol for Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS) described in previous papers (e.g. Evershed et al. 1994; Mottram et al. 1999) was used. GC-C-IRMS analyses of selected FAMEs were performed with an Agilent 6890 GC coupled to an IsoPrime 100 mass spectrometer. Samples were introduced via a split/splitless injector in splitless mode onto a 50 m × 0.32 mm fused silica capillary column coated with a HP-1 stationary phase (100 % dimethylpolysiloxane, Agilent, 0.17 µm). The GC oven temperature programme comprised a 2 min isothermal at 40°C, then increasing of 10 °C min $^{-1}$ to 300 °C, followed by a 10 min isothermal. Helium was used as a carrier gas and maintained at a constant flow of 2 mL min^{-1}. A quartz tube filled with copper oxide pellets constituted the combustion reactor: it was maintained at a temperature of 850 °C. Instrument accuracy was determined using an external FAME standard mixture (C_{11}, C_{13}, C_{16}, C_{21} and C_{23}) of known isotopic composition. All samples were run twice, and the average was then taken. External standards were run every 4 runs. Instrument error was ±0.3‰. Data processing was carried out using Ion Vantage software (version 1.5.6.0, IsoPrime).

5.3 Data processing

5.3.1 Lipid quantification and contamination

Lipid concentrations in each crushed and extracted sherd have been quantified as follows:

$$\text{Lipid concentration } (\mu g/g) = M\,\frac{(100-IS)/IS}{m}$$

Where *M* is the mass of internal standard (µg), *IS* is the internal standard percentage area and *m* is the mass (in grams) of the crushed potsherd (see 5.2.1). Lipid concentration per single sherd can be found in the Appendix (tables I-VI).

When the total lipid extract (TLE) was revealed to contain contaminants, such as common plasticisers from storage bags, the following approaches have been applied:

1) In some contaminated extracts (e.g. in fig. 40, SUB94), the number and distribution of compounds identified as contaminants made it difficult to distinguish archaeological from modern contamination lipids. In these cases, the sample was excluded from the evaluations and interpretations. These samples are highlighted in red in the Appendix and will not be discussed or considered in Chapter 6.
2) When contamination contributed to more than 10% of the overall lipid concentration of the sample, but it was possible to distinguish and isolate contaminants, the concentration of the contaminants is not included in the lipid concentration of the sherd. The following formula was applied, where *C* is the percentage area of the contaminants:

$$\text{Lipid concentration } (\mu g/g) = M\,\frac{100-(IS+C)/IS}{m}$$

3) When the sample was potentially contaminated (e.g. containing unidentified or compounds; e.g. unsaturated fatty acids), but it was not possible to establish it with certainty, the concentration of all lipids has been included in the "quantitative results" paragraphs (see Chapter 6), but they will be considered as possibly contaminated in "qualitative analysis" and "discussion" paragraphs included in Chapters 6 and 7, and in further interpretation.

These choices allow for reliable average lipid concentrations and recovery rates to be obtained while isolating and removing significant contaminations and avoiding possible over-interpretations. Lipid concentrations for each extract and the average lipid concentration has been rounded up to the whole number, without a decimal place, since the error embedded in the methodology does not allow higher precision.

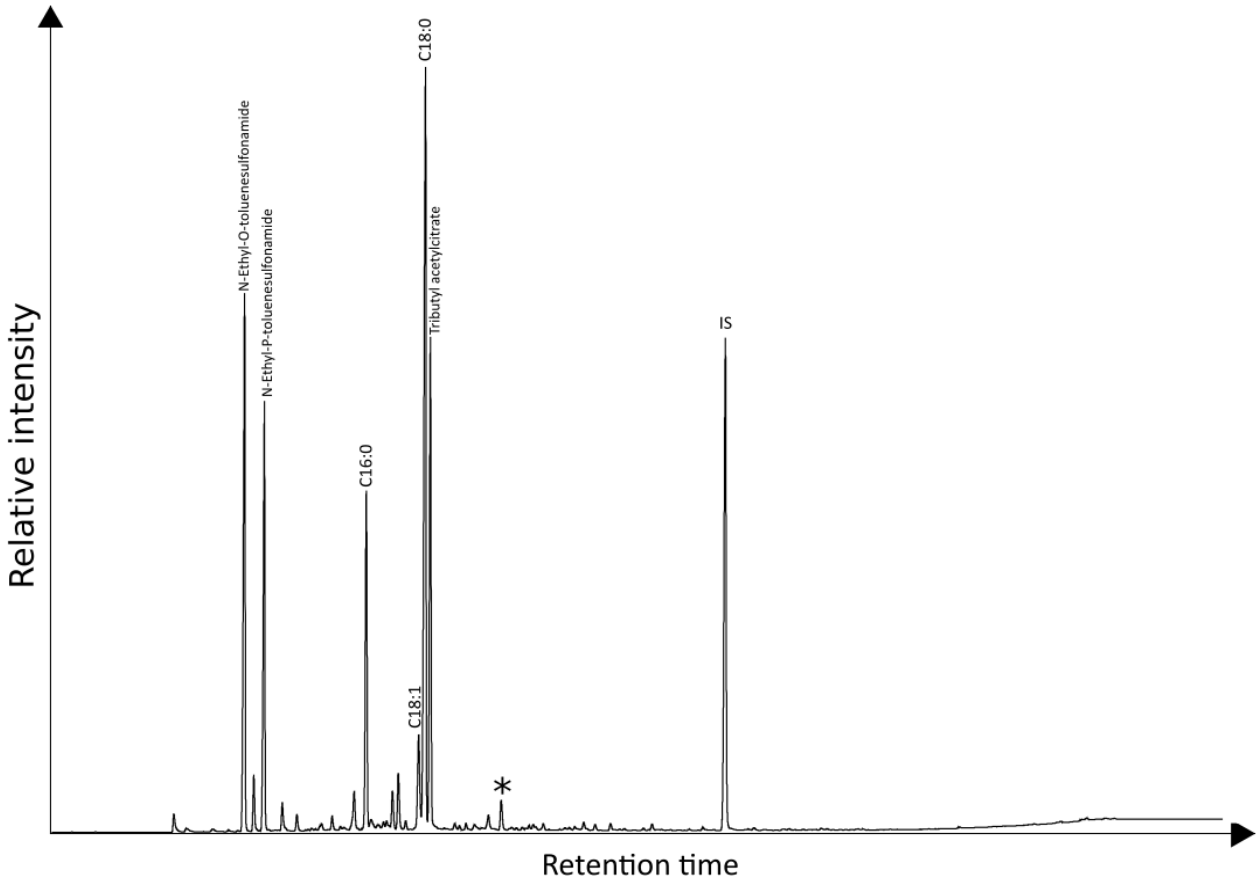


*Figure 40. High temperature gas chromatogram of a typical highly contaminated extract, SUB94 (wheelmade pot). IS: internal standard; *: phthalate; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

5.3.2 Isotope ratio mass spectrometry: values, definitions and comparisons

As mentioned above (4.3.1), isotope ratio mass spectrometry enables the origin of animal fats to be distinguished based on metabolic differences between the different animals and carbon sources utilised in the biosynthesis of different fat types (Evershed 2008a: 899; Evershed et al. 2002). The isotope ratios are quantified through $\delta^{13}C$ (‰) values relative to a standard, obtained as follows (Ambrose 1993: 65):

$$\delta^{13}\mathrm{C}(‰) = [(R\mathrm{sample}\text{-}R\mathrm{standard})\text{-}1]\mathrm{x}1000$$

where *R* is the ratio of the heavier to the lighter isotope of stable carbon. Standards for carbonates refer to the Vienna Pee Dee Belemnite *Bellemnitella Americana* Pe (vPDB), which is assigned a $\delta_{13}C$ value of 0‰ (Hut 1987: 2). The results were calibrated against reference CO_2, injected directly into the ion source three times at the beginning and end of the run.

The $\delta^{13}C$ values for the individual fatty acids were then corrected for the carbon atoms added during methylation with BF_3/CH_3OH, using the following mass balance equation (Rieley 1994):

$$\delta^{13}\mathrm{C}FA = \frac{(nC\mathrm{FAME} \times \delta^{13}C\mathrm{FAME}) - \delta^{13}C\mathrm{CH_3OH}}{nC\mathrm{FA}}$$

Where *δ^{13}C*FA is the $\delta^{13}C$ value of the original fatty acid, *δ^{13}C*FAME the same value of the FAME; *nC*FAME is the total number of carbon atoms in the FAME and *nC*FA the total number of carbon atoms in the initial fatty acid. *δ^{13}C*CH_3OH stands for the $\delta^{13}C$ value of the CH_3OH used for the methylation of the fatty acid.

5.3.3 Statistical treatment of the data

Statistical analysis of the data was carried out using Systat 12 (version 12.02.00), revealing normal distribution in the dataset of lipid concentrations obtained using the internal standard method ($\alpha = 0.05$). A two-tailed *t*-test (dissimilar variance) was applied to test the hypothesis that two sets of data are significantly different from one another. The comparison has been considered significant when $p < 0.05$.

Box and whisker plots, scattered graphs and all other graphs included in Chapters 6 and 7 were created using Microsoft Excel 365 (version 16.0.13231.20110, 32 bits).

Chapter 6
Results of the analysis

As discussed in Chapter 5, a total of 368 ceramic vessels was analysed during this research: 223 cooking pots, 30 casseroles, 85 basins and 6 tripod bowls, 13 ovens, and 11 baking trays from six different sites. The types of vessels sampled and analysed are summarised in Chapter 5, table 4.

HTGC analysis was carried out on every lipid extract obtained from each sherd, GC-MS analysis on 68 extracts, and GC-C-IRMS analysis on 66 extracts identified as animal fat based on the molecular composition. GC-MS-SIM analysis to detect aquatic biomarkers has been performed on 72 extracts identified as containing animal fat. HTGC-MS analysis was carried out on 20 extracts whose chromatographic profile was characterised high molecular weight lipids. In the Appendix (tables I-VI), six tables organised per site compile the main information for each analysed extract: vessel category and type, analyses undertaken, typological chronology, chronological context, identified compounds, identified commodities and $\delta^{13}C$ values. Over 50% of the analysed sherds contained more than 5 µg of lipids per gram of sherd, a percentage defined as the recovery rate. However, within this overall average is considerable variability, which correlates in particular with the vessel category and site (see Chapter 7).

In this chapter results of the analysis are outlined. Description and enumeration of results is structured per site, in six sections, as follows. For each site, useful background information to aid interpretation of results is illustrated. This includes faunal, palaeobotanical and, when available, lipid data for each site. Information about ceramic assemblage and archaeological context is also described. Overall lipid preservation and quantitative results are illustrated before qualitative results are described in detail, summarising the lipids detected, the biomarkers present, the stable isotope signatures of fatty acids, and consequently the commodities identified at the site. The findings are then presented according to vessel category, showing examples of chromatograms and outlining biomolecular composition and $\delta^{13}C$ values. When present, other site-specific patterns will be highlighted. Any chronological patterns in each site, when identified, are briefly outlined at the end of each section.

The tables in each section summarise information about analysed sherds: archaeological context, vessel type, chronology. All results described in this chapter are discussed further in Chapter 7, with particular focus to the research questions.

6.1 S'Urachi

The Phoenician and Punic age settlement of S'Urachi is a 7^{th}-2^{nd} centuries BCE indigenous settlement built around a Bronze Age Nuraghe, in the hinterland of Oristano gulf, west of the island (see 3.2.1). The site code for extracts from S'Urachi is "SUB".

6.1.1 Faunal and palaeoenvironmental evidence

The published palaeobotanical and faunal results from S'Urachi constitute the most comprehensive faunal and palaeobotanical assemblage analysed to date for Phoenician, Punic and Iron Age Sardinia. Published data are just preliminary (Van Dommelen et al. 2018; Pérez-Jordà et al. 2020), but they are sufficient for comparative needs. The currently available faunal data is summarised in table 5 (Ramìs et al. *in press*). The percentages here are calculated based on the number of fragments (NISP), and not on the minimum number of individuals (MNI).

Within the zooarchaeological remains, ovicaprines are the most frequently represented animals at the site, followed by cattle, red deer and pigs. The proportions of wild (18%) and domestic animals (82%) is consistent across the two excavation areas under investigation, E (6th-4th centuries BCE) and D (5th-2nd centuries BCE). Some interesting differences between the two areas, however, do exist. In earlier layers (Area E), cattle and deer are far more common than in later ones (Area D). In Area D, wild birds are more prevalent (42% of wild animals) and sheep/goat become more dominant (63% of domestic animals) than before (50%); chicken is more common in later layers, as is established for the island (see Chapter 2, 2.2.2.4). Pigs represent around the 15-16% of domestic animals in both areas, while horse and dog are always marginal. With regards to the results obtained (6.1.3), it is worth noting that red deer are more commonly found than pig in Area E.

Table 5 Number of fragments of animal bones (NISP) and percentage of fragments in the assemblage of the two excavation areas at the site of S'Urachi (reworked from Ramìs et al. in press).

	Area D (NISP)	%	Area E (NISP)	%
Domestic ovicaprid Sheep (*Ovis aries*) Goat (*Capra hircus*)	1135 (107) (10)	63.5	2144 (251) (9)	50.4
Bovine (*Bos taurus*)	286	16.0	1420	33.4
Pig (*Sus scrofa domestica*)	301	16.8	648	15.2
Dog (*Canis familiaris*)	12	0.7	15	0.4
Equine Horse (*Equus caballus*) Donkey (*Equus asinus*)	12 (2)	0.7	22 (1) (2)	0.5
Chicken (*Gallus gallus*)	41	2.3	4	0,1
Domestic fauna, total	1787	82.3	4253	82.3
Red deer (*Cervus elaphus*)	167	43.4	882	96.6
European pond turtle (*Emys orbicularis*)	15	3.9		
Fox (*Vulpes vulpes*)	1	0.3	2	0.2
Hedgehog (*Erinaceus europaeus*)	1	0.3		
Wild birds (total)	161	41.8	18	2.0
Fish (Osteichtyes)	26	6.8	1	0.1
Hare (*Lepus* sp.)	8	2.1		
Rabbit (*O. cuniculus*) [Intrusive]			[4]	
Prolagus sardus	1	0.3	3	0.3
Mouflon (*Ovis musimon*)	2	0.5	4	0.4
Boar (*Sus scrofa*)	3	0.8	3	0.3
Wild fauna, total	385	17.7	913	17.7

Some palaeoenvironmental and palaeobotanical information is also available, revealing that S'Urachi was located in a favourable and fertile area (Van Dommelen et al. 2018: 205). Some preliminary results from palaeobotanical studies have been recently published (Pérez Jordà et al. 2020). The analyses were focused on the ditch in Area E (7th-4th centuries BCE). They attest that "particularly abundant are the caryopsis of naked wheat (*Triticum aestivum-durum*), broad beans (*Vicia faba*), flax *(Linum usitatissimum*) and melon (*Cucumis melo*). Also plentiful are fruits such as grapes (*Vitis vinifera*), figs (*Ficus carica*), pomegranate (*Punica granatum*) and olive (*Olea europea*). The remains of wild plants include mastic (*Pistacia lentiscus*) and sloe (*Prunus spinosa*)" (Pérez Jordà et al. 2020: 6).

The analysis and study of the findings are ongoing, but the researchers have already stated that due to waterlogged conditions "the botanical remains at S'Urachi not only make it possible to investigate agricultural production and consumption within this Iron Age community, but they also open up a new window on the early stages of economic and cultural interactions between the local Sardinian communities of west-central Sardinia and the wider Phoenician and Mediterranean world" (Peréz Jordà et al. 2020: 7).

6.1.2 Pottery assemblage and general information about lipid results

The 101 sherds analysed from S'Urachi derive from two different excavation areas around the *nuraghe* (fig. 41). They have been selected through consultation with the researchers studying pottery at the site, in particular Andrea Roppa, Jeremy Hayne and Emanuele Madrigali.

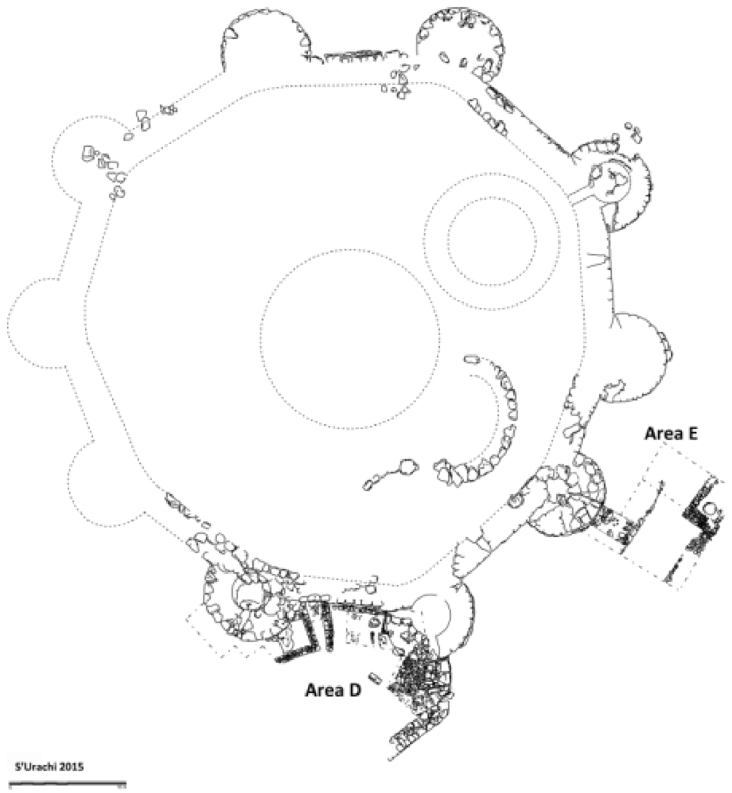


Figure 41. Structure of nuraghe S'Urachi with an indication of the two archaeological areas involved in my project (from Stiglitz et al. 2015).

Twenty-five sherds come from Area D (table 6), which is located between tower 1 and 7. It is characterised by the construction of a wall and a cobbled space around the late 7th century BCE. Later, the wall was demolished and the area was converted to housing and domestic spaces around the beginning of the 5th century BCE (Van Dommelen et al. 2018: 144). All selected sherds come from this later phase and are dated from the 5th to the 2nd centuries BCE. A total of 14 wheelmade cooking pots, 4 casseroles, 5 basins, 1 baking tray and 1 *tannur* from the area has been analysed.

Seventy-six sherds come from Area E (table 6), which is located by tower 2 on the east of the *nuraghe*. It is characterised by the presence of a large ditch filled with domestic waste dated from the 7th century BCE to the 4th century BCE. Around it, the floor plane was set up during the 5th century BCE. There is no evidence of buildings or any post-4th century material (probably due to past excavations; Van Dommelen et al. 2018: 145-146); the sherds involved in the analysis from this context come from layers dated between the 6th and the 4th centuries BCE. A total of 49 wheelmade cooking pots, 5 handmade cooking pots, 4 casseroles, 13 basins, 4 *tannurs* and one baking tray from the area has been analysed.

Table 6 Number of sherds per excavation area and vessel category, from the site of S'Urachi.

	Wheelmade pots	Handmade pots	Casseroles	Basins	Baking trays	Ovens	Total
Area E (6th-4th centuries BCE)	49	5	4	13	1	4	76
Area D (5th-2nd centuries BCE)	14	0	4	5	1	1	25

In table 7, the available information and for each sherd from S'Urachi is summarised. This includes sample name, excavation area, vessel type/subtype and chronology. In the appendix (table I) analyses undertaken on the extract, lipid concentration, identified compounds, $\delta^{13}C$ values and identified commodities are listed per each sherd.

6.1.2.1 Quantitative results and introductory information

The quantitative results are shown in figure 42, divided between the two excavation and sampling areas (see 6.1.1). The results from three extracts (two in Area E, one in Area D) were discarded due to contamination and not considered for comparisons (highlighted in red in table I, Appendix).

Mean lipid concentrations per vessel category in S'Urachi are in general higher than the means for the entire assemblage on an island level (*island mean*). The mean lipid concentration for extracts of wheelmade cooking pots from S'Urachi is 165 µg/g (standard deviation 241 µg/g, maximum value 1066 µg/g), with 85% recovery rate. For extracts of handmade cooking pots, the mean lipid concentration is 62 µg/g (standard deviation 54 µg/g, maximum value 121 µg/g), with 80% recovery rate. Mean lipid concentration obtained from all 6 sites sampled (*island mean*) is 73 µg/g for wheelmade cooking pots and 96 µg/g for handmade cooking pots.

The mean lipid concentration for casseroles is 65 µg/g, higher than the mean obtained from casseroles across all 6 sites sampled for the island (27 µg/g; $p = 0.16$). The standard deviation is 67 µg/g, with a maximum value of 205 µg/g, and recovery rate 100%. The mean lipid concentration for basins is 8 µg/g, with a maximum value of 29 µg/g and a standard deviation of 9 µg/g, (recovery rate 44%), in line with the island mean (6 µg/g). Two sherds of baking trays were also analysed, with one of the two containing lipids but probably contaminated and discarded. None of the five oven sherds contained significant concentrations of lipid (mean lipid concentration 1 µg/g, maximum value 4 µg/g).

Comparison of the mean lipid concentrations between the two areas per vessel category is not statistically significant. The only clear difference in lipid concentration between areas is found in casseroles (fig. 42), with a lipid concentration five times higher in casseroles from area D (n= 4, mean lipid concentration = 111 µg/g) compared to the casseroles from area E (n = 4, mean lipid concentration = 20 µg/g), but this comparison is also not statistically significant ($p = 0.08$).

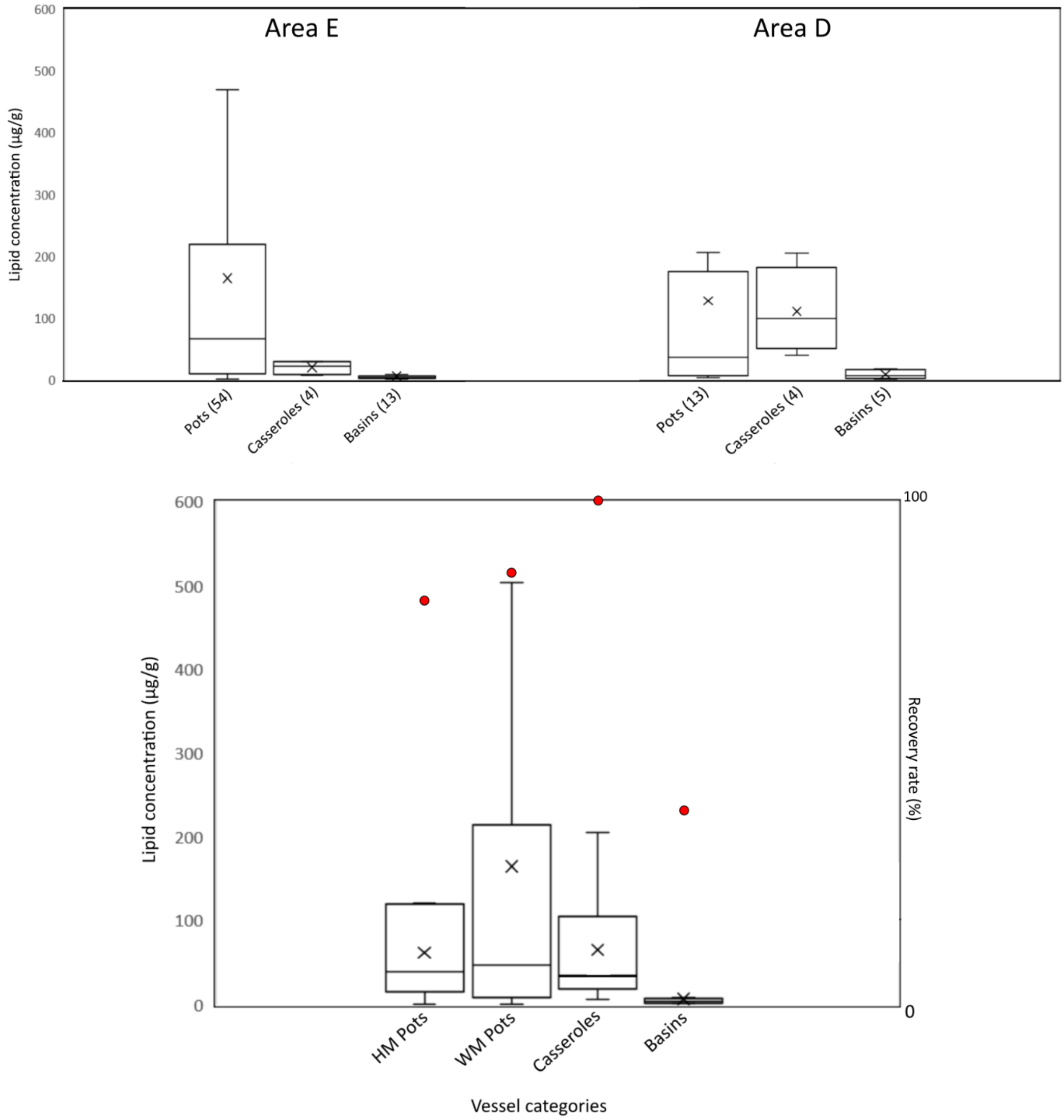


Figure 42. Below: Box plots showing lipid concentration (X = mean) and recovery rate (red dot) of the extracts coming from the site of S'Urachi, per vessel category. WM pots: 63; HM pots: 5; casseroles: 8; basins: 18. Top: Box plot showing mean lipid concentrations of these same extracts grouped by excavation area, with number of sherds in brackets (X = mean).

The higher rate of lipid recovery and overall lipid concentrations compared to other sites is likely the result of the water table in the area of the nuraghe being only one meter below ground level. This specific geomorphological feature produced humid and, at deeper levels, waterlogged archaeological layers, allowing exceptional preservation conditions (Van Dommelen et al. 2018: 146). These peculiar lipid preservation conditions, with anoxic archaeological contexts, allowed the detection of higher lipid concentrations (fig. 43) and greater biomolecular varieties than usual, with lipids as TAGs and monounsaturated fatty acids, usually rapidly degrading, more often preserved as it is illustrated by chromatograms in section 6.1.3. This is typical for such contexts since anoxic conditions favour the preservation of organic materials and residues (Evershed 2008a: 911).

Table 7 List of analysed sherds from S'Urachi, with context, type and chronology. When not specified, more detailed context was not available at the time of writing.

Sample name	Sherd code-details	Context	Chronology (context)	Vessel category-type	Chronology (type)
SUB1	SU2013-E012-012	Area E, fill	4^{th} century BCE	Casserole	4th century BCE
SUB2	SU2013-E012-040	Area E, fill	4^{th} century BCE	P2 pot	5^{th} century BCE
SUB3-4	SU2013-E012-042	Area E, fill	4^{th} century BCE	P3 pot	5^{th}-4^{th} centuries BCE
SUB5	SU2013-E012-044	Area E, fill	4^{th} century BCE	P2 pot	6th century BCE
SUB6	SU2013-E012-037	Area E, fill	4^{th} century BCE	P3 pot	5th-4th centuries BCE
SUB7	SU2013-E012-060	Area E, fill	4^{th} century BCE	Baking tray	8^{th}-5^{th} centuries BCE?
SUB8	SU2013-E012-052	Area E, fill	4^{th} century BCE	Wheelmade pot	5^{th}-4^{th} centuries BCE
SUB9	SU2013-E012-041	Area E, fill	4^{th} century BCE	P2 pot	6^{th}-5^{th} centuries BCE
SUB10-15	SU2013-E012-039	Area E, fill	4^{th} century BCE	P2 pot	6^{th} century BCE
SUB16	SU2014-E012-099	Area E, fill	4^{th} century BCE	P2 pot	End 6th-5th centuries BCE
SUB17	SU2014-E012-089	Area E, fill	4^{th} century BCE	Casserole	First half 5th century BCE
SUB18	SU2014-E012-116	Area E, fill	4^{th} century BCE	P1 pot	7^{th}-half 6^{th} centuries BCE
SUB19	SU2014-E012-114	Area E, fill	4^{th} century BCE	P2 pot	6^{th}-5^{th} centuries BCE
SUB20	SU2014-E018-028	Area E, fill	3^{rd} century BCE?	Tannur	5th century BCE?
SUB21	SU2014-E027-335	Area E, fill	4^{th} century BCE	P2 pot	End 6th-5th centuries BCE
SUB22	SU2014-027-383	Area E, fill	4^{th} century BCE	P2 pot	Second half 6th century BCE
SUB23	SU2014-E027-407	Area E, fill	4^{th} century BCE	P2 pot	End 6th-5th century BCE
SUB24	SU2014-E027-398	Area E, fill	4^{th} century BCE	P3 pot	5^{th}-4^{th} centuries BCE
SUB25	SU2014-E027-350	Area E, fill	4^{th} century BCE	P2 pot	Second half 6^{th} century BCE
SUB26	SU2014-E027-334	Area E, fill	4^{th} century BCE	Handmade pot	7th-5th centuries BCE?
SUB27	SU2014-027-337	Area E, fill	4^{th} century BCE	P3 pot	5^{th}-4^{th} centuries BCE
SUB28	SU2014-E024-009	Area E, modern ditch	20^{th} century excavation (Lilliu)	P6 pot	4th-2nd centuries BCE
SUB29	SU2014-E024-010	Area E. modern ditch	20^{th} century excavation (Lilliu)	P2 pot	End 6th-5th centuries BCE
SUB30	SU2014-E021-126	Area E, fill	4^{th} century BCE	P2 pot	Second half 7th-6th centuries BCE
SUB31	SU2014-E021-135	Area E, fill	4^{th} century BCE	P3 pot	5^{th}-4^{th} centuries BCE
SUB32	SU2014-E021-136	Area E, fill	4^{th} century BCE	Tannur	5th-4th centuries BCE?
SUB33-34	SU2014-E021-148	Area E, fill	4^{th} century BCE	Casseroles	First half 5^{th} century BCE
SUB35	SU2014-E021-166	Area E, fill	4^{th} century BCE	P2 pot	End 7th-first half 6th centuries BCE
SUB36	SU2014-E021-140	Area E, fill	4^{th} century BCE	P2 pot	Second half 7th century BCE
SUB37	SU2014-E021-137	Area E, fill	4^{th} century BCE	P3 pot	5^{th}-4^{th} centuries BCE

SUB38	SU2014-E021-145	Area E, fill	4th century BCE	P2 pot	Second half 6th century BCE
SUB39	SU2014-E021-160	Area E, fill	4th century BCE	P10 pot	4th century BCE
SUB40	SU2014-E030-044	Area E, fill	4th century BCE	P3 pot	5th-4th centuries BCE
SUB41	SU2015-E055-007	Area E, levee	First half 5th century BCE	P2 pot	Half 7th-first 6th centuries BCE
SUB43	SU2015-E058-049	Area E, levee	First half 5th century BCE	Tannur	5th-4th centuries BCE?
SUB44	SU2015-E056-038	Area E, floor foundation	5th century BCE	P2 pot	Second half 7th centuries BCE
SUB45	SU2015-E056-089	Area E, floor foundation	5th century BCE	P2 pot	End 7th century BCE
SUB46	SU2015-E056-091	Area E, floor foundation	5th century BCE	P2 pot	Second half 7th century BCE
SUB47	SU2015-E056-090	Area E, floor foundation	5th century BCE	P2 pot (Miniaturistic)	6th-5th centuries BCE
SUB48	SU2015-E056-108	Area E, floor foundation	5th century BCE	P3 pot	5th-4th centuries BCE
SUB49	SU2015-E056-213	Area E, floor foundation	5th century BCE	P2 pot	Second half 6th century BCE
SUB50	SU2015-E059-102	Area E, floor foundation	5th century BCE	P2 pot	Second half 7th-first 6th centuries BCE
SUB51	SU2015-E059-117	Area E, floor foundation	5th century BCE	P2 pot	6th century BCE
SUB52	SU2015-E059-147	Area E, floor foundation	5th century BCE	P3 pot	5th-4th centuries BCE
SUB55	SU2015-E059-101	Area E, floor foundation	5th century BCE	P2 pot	Second half 7th-first 6th centuries BCE
SUB56, 57, 59	SU2015-E060-071	Area E, filled ditch	Second half 6th century BCE	P2 pot	Second half 6th centuries BCE
SUB58	SU2015-E060-087	Area E, filled ditch	Second half 6th century BCE	P2 pot	End 7th-first 6th centuries BCE
SUB60	SU2015-E060-777	Area E, filled ditch	Second half 6th century BCE	"S profile" pot	7th-5th centuries BCE?
SUB61	SU2015-E072-006	Area E, external wall	First half 7th century BCE	Handmade pot	7th-5th centuries BCE?
SUB63	SU2015-E063-111	Area E, filled ditch	Second half 6th century BCE	P2 pot	Second half 6th centuries BCE
SUB64	SU2015-E063-120	Area E, filled ditch	Second half 6th century BCE	Miniaturistic pot	6th-5th centuries BCE
SUB65	SU2015-E063-119	Area E, filled ditch	Second half 6th century BCE	P3 pot	5th-4th centuries BCE
SUB66	SU2015-E069-103	Area E, filled ditch	Second half 6th century BCE	Tannur	5th-4th centuries BCE?
SUB67	SU2015-E072-018	Area E, external wall	First half 7th century BCE	Handmade pot	8th century BCE?
SUB68	SU2013-E012-010	Area E, fill	4th century BCE	BA7 basin	4th century BCE
SUB69	SU2014-E012-112	Area E, fill	4th century BCE	BA3 basin	7th-6th centuries BCE
SUB70	SU2014-E027-381	Area E, fill	4th century BCE	Basin	4th century BCE
SUB71	SU2014-E016-012	Area E, fill	3rd century BCE?	BA5 basin	7th-6th centuries BCE
SUB72	SU2014-E021-130	Area E, fill	4th century BCE	BA9 basin	4th-3rd centuries BCE
SUB73	SU2014-E030-033	Area E, fill	4th century BCE	BA5 basin	5th-4th centuries BCE
SUB74	SU2015-E055-008	Area E, floor foundation	First half 5th century BCE	BA2 basin	7th-6th centuries BCE
SUB75	SU2015-E056-050	Area E, floor foundation	5th century BCE	BA3 basin	7th-6th centuries BCE
SUB76	SU2015-E059-130	Area E, levee	First half 5th century BCE	BA1 basin	7th-half 6th centuries BCE

SUB77	SU2015-E059-154	Area E, levee	First half 5th century BCE	Handmade pot	7th-5th centuries BCE?
SUB78	SU2015-E059-159	Area E, levee	First half 5th century BCE	Basin	Half 6th century BCE
SUB79	SU2015-E059-163	Area E, levee	First half 5th century BCE	BA2 basin	7th-6th centuries BCE
SUB80	SU2015-E059-165	Area E, levee	First half 5th century BCE	BA1 basin	7th-6th centuries BCE
SUB81	SU2015-E060-075	Area E, levee	First half 5th century BCE	BA2 basin	7th century BCE
SUB83	SU2013-D024-393	Area E, external wall	Second half 6th century BCE	P6	3rd-2nd centuries BCE
SUB84	SU2013-D024-409	Area D (More detailed context not available at the time of writing - MDCNA)	2nd century BCE?	Casserole	3rd-2nd centuries BCE
SUB85	SU2013-D024-410	Area D - MDCNA	2nd century BCE?	Pot	3rd-2nd centuries BCE
SUB86	SU2013-D024-398	Area D - MDCNA	2nd century BCE?	Casserole	3rd-2nd centuries BCE
SUB87	SU2013-D024-400	Area D - MDCNA	2nd century BCE?	Casserole	4th century BCE
SUB88	SU2013-D024-454	Area D - MDCNA	2nd century BCE?	P10 pot	3rd-2nd centuries BCE
SUB89	SU2013-D024-462	Area D - MDCNA	2nd century BCE?	P8 pot	4th century BCE
SUB90	SU2014-D024-038	Area D - MDCNA	2nd century BCE?	Tannur	5th-2nd centuries BCE?
SUB91	SU2014-D024-051	Area D - MDCNA	2nd century BCE?	P10 pot	3rd-2nd centuries BCE
SUB92	SU2014-D024-052	Area D - MDCNA	2nd century BCE?	Pot	3rd-2nd centuries BCE
SUB93	SU2014-D024-056	Area D - MDCNA	2nd century BCE?	P3 pot	5th-4th centuries BCE
SUB94	SU2014-D024-066	Area D - MDCNA	2nd century BCE?	P10 pot	3rd-2nd centuries BCE
SUB95	SU2014-D034-004	Area D - MDCNA	4th century BCE	P2 pot	End 7th-first 6th centuries BCE
SUB96	SU2014-D037-021	Area D - MDCNA	3rd century BCE	Baking tray	5th-2nd centuries BCE?
SUB97-101, 108	SU2014-D060-015	Area D - MDCNA	3rd-2nd centuries BCE	P6 pot	3rd-2nd centuries BCE
SUB102	SU2014-D074-041	Area D - MDCNA	3rd century BCE	Casserole	3rd-2nd centuries BCE
SUB103	SU2013-D024-448	Area D - MDCNA	2nd century BCE?	Basin	4th century BCE
SUB104	SU2014-D024-071	Area D - MDCNA	2nd century BCE?	BA1 basin	7th-6th centuries BCE
SUB105	SU2014-D024-572	Area D - MDCNA	2nd century BCE?	BA11 basin	4th-3rd centuries BCE
SUB106	SU2013-D024-582	Area D - MDCNA	2nd century BCE?	BA9 basin	3rd-2nd centuries BCE
SUB107	SU2014-D037-020	Area D - MDCNA	3rd-2nd centuries BCE	BA16 basin	3rd-2nd centuries BCE

These environmental conditions also require caution with the interpretation of results. On the one hand, the exceptional lipid preservation allows for more detailed and in-depth site-based interpretations, due to the higher amount of information and lipids available, on average, per extract. Since this is occurring at a site where faunal and palaeobotanical data are also available, it suggests more organic residue analysis to be carried out at the site (see 8.3). On the other hand, since this lipid preservation is unique among the sites involved in this research, inter-site comparisons and interpretations are not straightforward, requiring careful consideration as to whether the peculiarity of data from S'Urachi is due to these environmental reasons or is a result of cultural and functional differences. This peculiarity needs to be taken into account in the discussion and interpretation of results. In such a good environment for lipid preservation, compounds usually interpreted as contaminants (e.g. $C_{16:1}$ monounsaturated fatty acid or short chain fatty acids) could also be interpreted as well-preserved ancient lipids. In S'Urachi, only clearly contaminated TLEs (containing phthalates and other compounds, such as bis(2-ethylhexyl) cyclohexane-1,2-dicarboxylate or N-Ethyl-O-toluenesulfonamide, components of food packaging, probably coming from post-excavation contamination) have been discarded from further analysis (Chapter 5, fig. 40). Caution is used in interpreting other potentially contaminated vessels, since in this context preservation of ancient lipids which degrade more readily elsewhere is possible (see 6.1.3).

6.1.3 Qualitative results by vessel type

6.1.3.1 Cooking pots

The distribution of detected compounds in the extracts of cooking pots from S'Urachi is in most of the cases (*n* = 49) characteristic of degraded animal fat (Evershed et al. 2002): palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) free fatty acids, usually $C_{18:1}$ monounsaturated fatty acids, diacylglycerols (C_{32-36}) and triacylglycerols (C_{48-54}) dominate the chromatographic profile (fig. 43). Cooking pot extracts containing well-preserved triacylgycerols (C_{48-54}) from animal fat (see fig. 43), which degrade into free fatty acids (see Chapter 4), are numerous (*n* = 38) due to of the good lipid preservation at the site. The presence of $C_{15:0}$ and $C_{17:0}$ free fatty acids, attested in the majority of the extracts being interpreted as animal fat (*n* = 37), suggests a ruminant origin of the fats (Evershed et al. 2002).

Shorter chain free fatty acids such as $C_{12:0}$ and $C_{14:0}$ have been detected in 3 extracts. These short chain fatty acids are present in low concentrations in modern adipose fats, and they can denote the presence of milk in the extract in small proportions (up to 20% of the total fatty acid content (Christie 1981; Copley et al. 2003), e.g. in fig. 43B). Other components present in cooking pot extracts include a series of long-chain fatty acids (in low abundance), typically containing C_{20} to C_{24} carbon atoms (fig. 43AC). It is thought these LCFAs likely originated directly from animal fats, incorporated via routing from the ruminant animal's plant diet (Whelton et al. 2018; Halmemies-Beauchet-Filleau et al. 2013; 2014). Finally, in ten cooking pot extracts, C_{31-35} ketones are found, indicating the heating of fatty acids over 300°C (Evershed et al. 1995; Raven et al. 1997; see SUB12, fig. 46B).

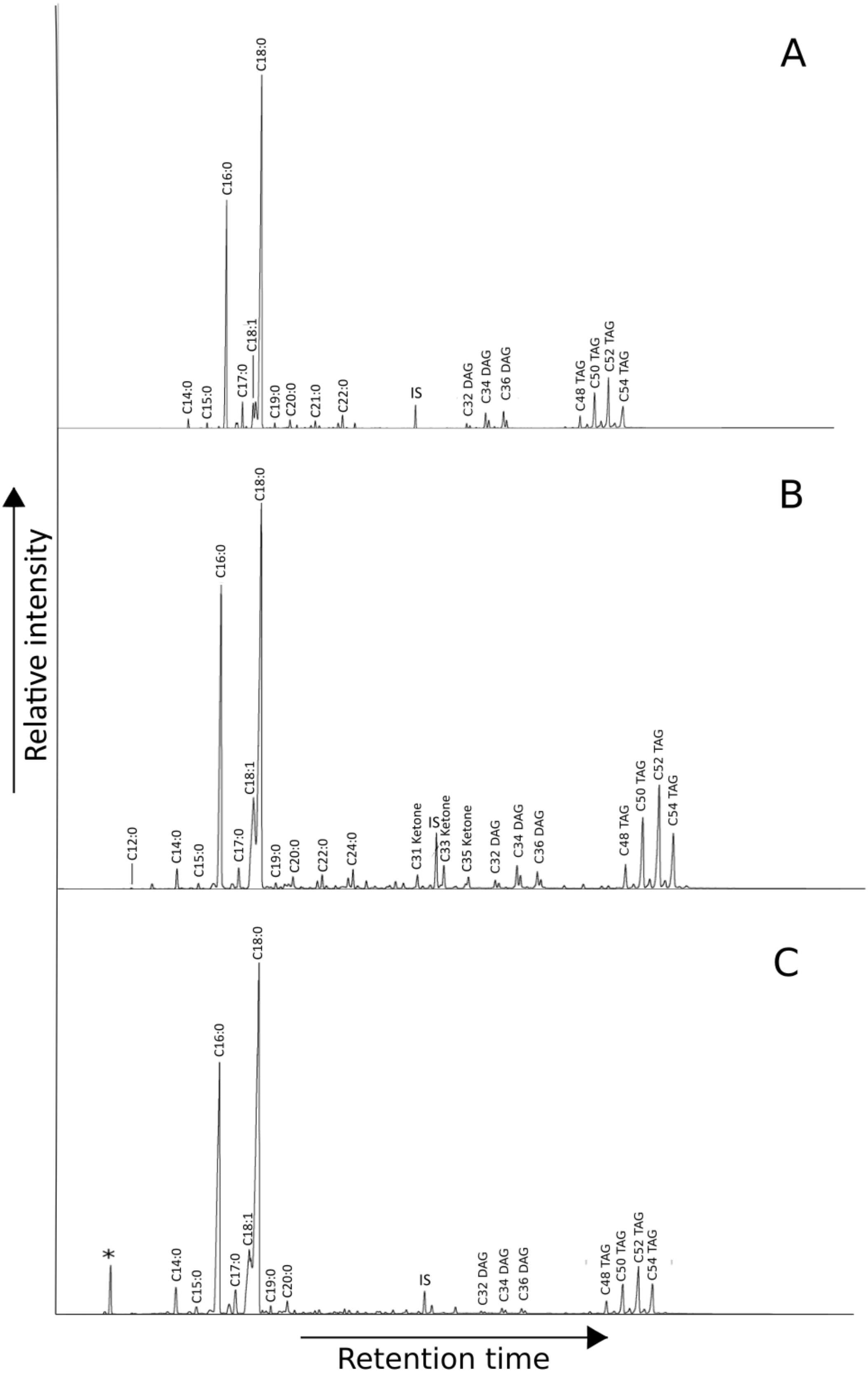


*Figure 43. High temperature gas chromatograms of the extracts SUB88 (A, wheelmade pot); SUB16 (B, wheelmade pot); SUB25 (C, wheelmade pot), indicative of degraded animal fat. IS: internal standard; *: phthalate; DAG: diacylglycerol; TAG: triacylglycerol; with Cn: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

Compound-specific stable carbon isotope analysis was carried out on 34 cooking pot extracts from S'Urachi identified as animal fat (fig. 44). In three of the extracts palmitic ($C_{16:0}$) FFA was more concentrated than stearic ($C_{18:0}$) FFA, not excluding the presence of oil or aquatic fat in the extract: these extracts are highlighted with a square in figure 44.

A slight difference in the range of stable carbon isotope values between Area D (5th–2nd century BCE) and Area E (6th–4th century BCE) can be identified. $\Delta^{13}C$ values in Area E range between -4.8 and -0.3‰, with 24 of the 25 extracts displaying values characteristic of ruminant adipose fats and ranging between -3.1 and -0.3‰. $\Delta^{13}C$ values in Area D range between -2.2 and 1.9‰, but seven out of the nine extracts display values under -1.1‰, thus consistent with ruminant adipose fat. In total, 32 on 34 extracts contained predominantly ruminant carcass fat. One of the cooking pot extracts from area E contained predominantly dairy fats (SUB15, $\Delta^{13}C$ = -4.8‰). In one of the cooking pot extracts from area D stable carbon isotope values consistent with non-ruminant fats (SUB85, $\Delta^{13}C$ = 1.9‰): in this extract, however, the chromatographic profile suggests possible aquatic or plant origin of the fat (oil), since the $C_{16:0}$ fatty acid is more abundant than $C_{18:0}$ (fig. 45). Contamination cannot be excluded due to the relatively high abundance of C_{48} TAG compared to other TAGs, not typical of degraded animal fats (Evershed et al. 2002). Based on this evidence, caution is needed in interpreting this extract as non-ruminant animal fat.

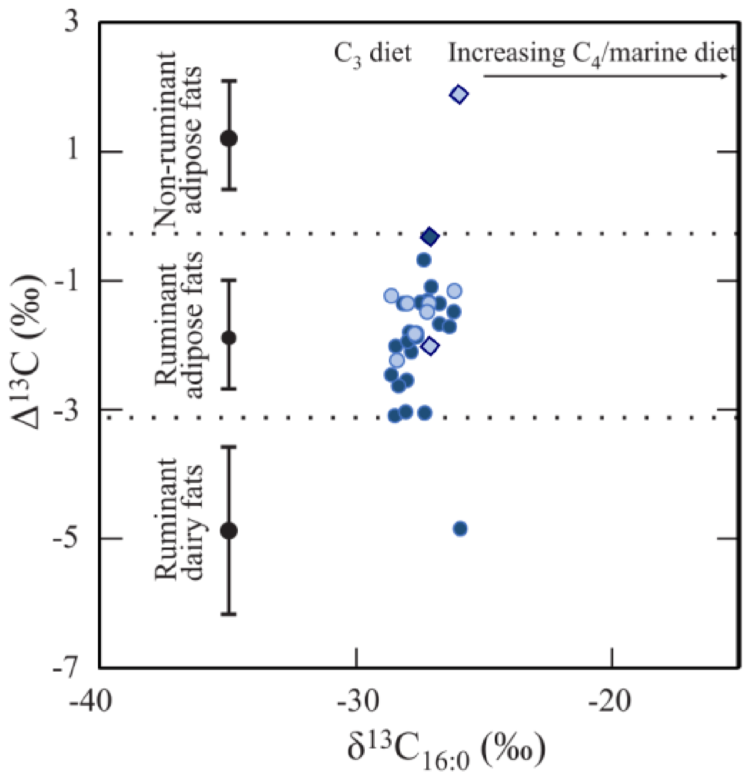


Figure 44. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for pot extracts from S'Urachi. Dark blue dots: area E; light blue dots: area D. Extracts that possibly contain oil together with animal fat are indicated with a square. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in extracts of cooking pots from S'Urachi (*n* = 36) containing degraded animal fats.

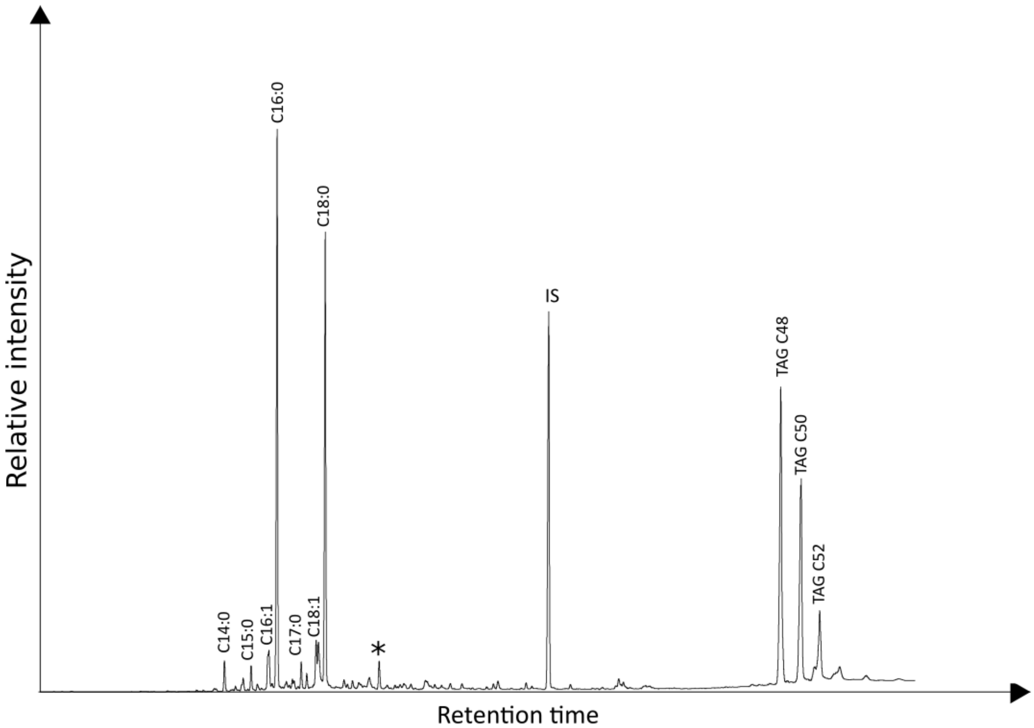


*Figure 45. High temperature gas chromatogram of the extract SUB85 (wheelmade pot), indicating presence of animal fat or oil. Contamination possible. IS: internal standard; *: phthalate; TAG: triacylglycerol; with Cn: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds*

Other commodities

In other cooking pot extracts animal products were possibly mixed with other commodities. In extract SUB60 (fig. 46A) compounds typical of degraded animal fats (C_{14-18} FFAs; C_{32-36} DAGs; C_{48-54} TAGs) are detected together with C_{22-28} even numbered FFAs, $C_{26, 28}$ alcohols and C_{29-33} odd numbered alkanes, suggesting leafy plant processing (Tulloch 1976, Dunne et al. 2016): it has not been possible to further define any additional detail or interpretation (e.g. plant species) for this extract (Evershed et al. 1991) since these distributions are non-specific to any particular origins. In the same extract, dehydroabietic acid and methyl dehydroabietate have been detected. These compounds generally indicate the presence of resins in the vessel, but other biomarkers are needed to exclude contamination and external contribution (Colombini et al. 2005; Rageot et al.2015: 322; see discussion in section 7.1.3).

In two extracts (fig. 47AC), the detection of compounds related to beeswax processing (C_{42-46} palmitate wax esters, C_{26-32} long-chain alcohols, C_{27-31} alkanes) could suggest presence of beeswax in the extracts. However, biomarkers unambiguously indicating beeswax are not detected in either extract. In SUB13 (fig. 47C) only C_{44-50} palmitate wax esters are attested, with C_{46} dominating, but long-chain alcohols and alkanes are absent. The lack of alkanes potentially indicates that beeswax was exposed to heating processes (Regert et al. 2001), but the lack of alcohols make the identification only tentative. In SUB30 (fig. 47A), on the contrary, C_{26-32} alcohols, with C_{30} dominating, and C_{25-31} alkanes with C_{27} dominating are identified, but the presence of wax esters at a very low concentration, makes once more the identification tentative (Heron et al. 1994). In both cases, the presence of plant waxes is a possible but less likely interpretation (Charters et al. 1997). In general, beeswax appears to have been an uncommon commodity at the site, and its presence is more often attested in other sites with poorer lipid preservation. In other extracts (*n* = 25) the presence of alcohols (typically $C_{16\text{-}20}$) and free fatty acids ($C_{14\text{-}24}$, dominated by C_{16} and C_{18}) suggests the possible coexistence of animal fats and plant lipids, as in the case of SUB67 shown in figure 47B. Biomarkers are insufficient to provide a more detailed interpretation.

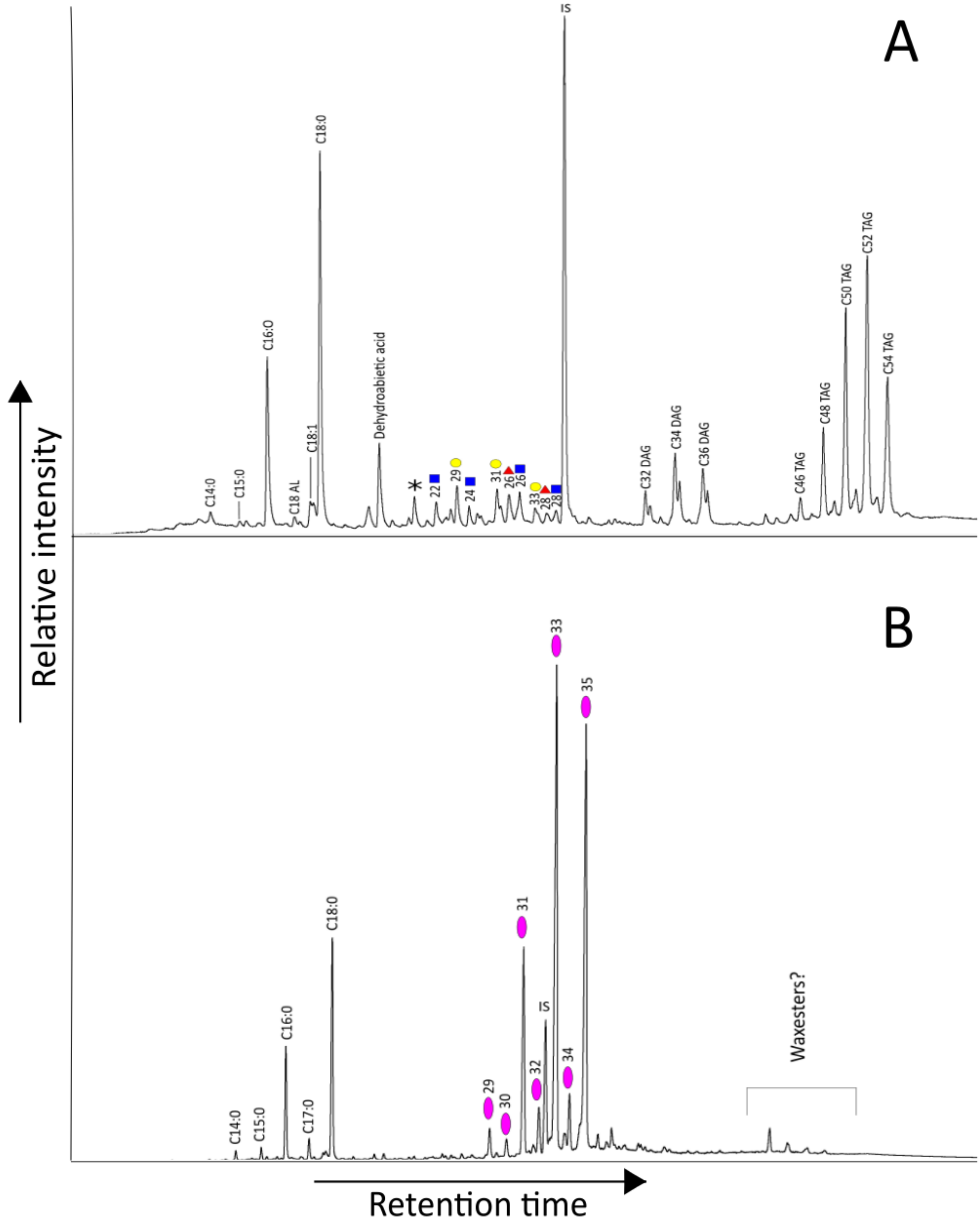


Figure 46. High temperature gas chromatograms of the extract SUB60 (A; wheelmade pot), indicating mixture of animal fat and leafy plants; SUB12 (B; wheelmade pot) indicating the presence of animal fats heated over 300°C. IS: internal standard; pink ellipse: ketone; blue squares: fatty acid; red triangle: alcohol; yellow circle: alkane; with N *carbon atoms number; Cx:y = Fatty acids with X-number of carbons and Y-number of double bonds.*

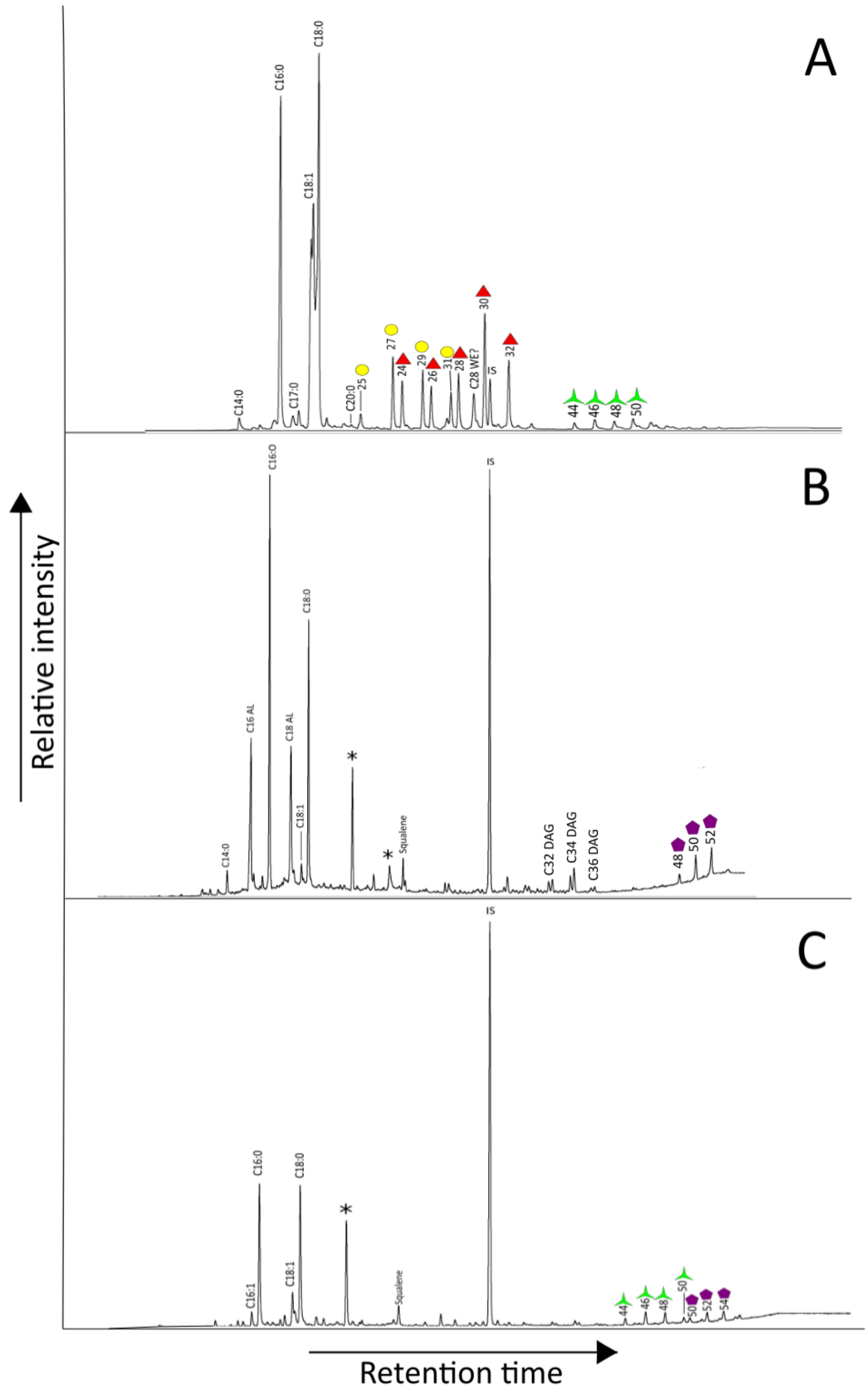


*Figure 47. High temperature gas chromatograms of the extracts SUB30 (A, wheelmade pot); SUB67 (B, handmade pot); SUB13 (C, wheelmade pot), indicative of a possible mixture of animal fats with beeswax (A, C) or plant lipids (B, C). IS: internal standard; AL: alcohol; *: phthalate; red triangle: alcohol; yellow circle: alkane; green star: wax ester; purple pentagon: triacylglycerol; DAG: diacylglycerol; with N: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.1.3.2 Basins

At S'Urachi, 8 extracts of basins contain lipids. Several of the extracts (*n* = 6) contained poorly concentrated FFAs (typically $C_{14\text{-}20}$, $C_{16:0}$ dominating) and alcohols (typically $C_{16\text{-}20}$). For these extracts plant lipid processing or, more likely, contamination is possible. In fact, plant waxes usually contain long chain alcohols in the range of $C_{22\text{-}34}$ (Tulloch 1976), which are absent in these extracts. In the example given in figure 48, $C_{25,\ 27}$ alkanes are also attested, but the presence of squalene, cholesterol and relatively high concentration of the $C_{16:1}$ monounsaturated fatty acid makes modern contamination a likely source also in this case.

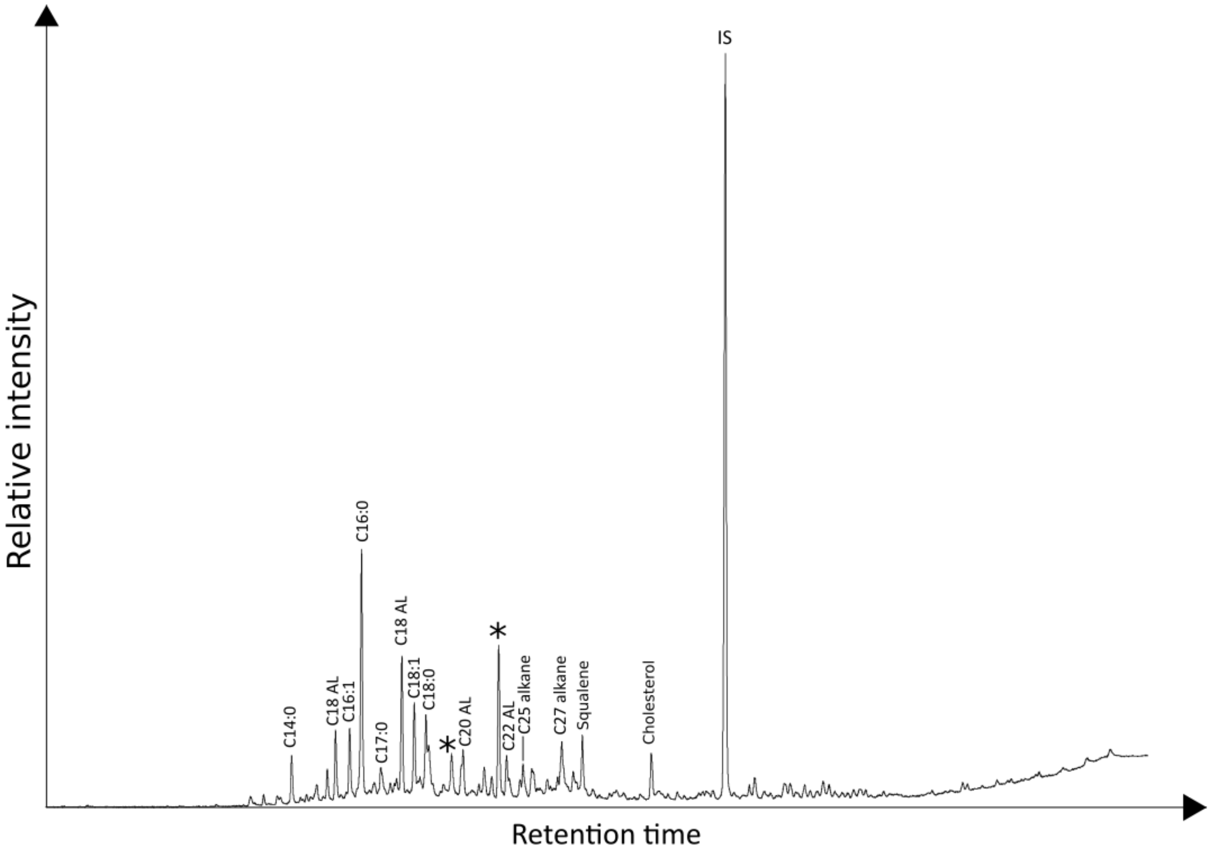


*Figure 48. High temperature gas chromatogram of the extract SUB107 (basin), indicating possible presence of contaminants. IS: internal standard; *: phthalate; AL: alcohol; with* Cn*: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

Other two examples are given in figure 49. In SUB70 (fig. 49A), free fatty acids are coupled with a high abundance of $C_{18:1}$ monounsaturated fatty acids and even-numbered mid-chain alcohols ($C_{16\text{-}20}$). The presence of squalene and $C_{16:1}$ monounsaturated fatty acid again suggests modern contamination. A similar observation is made in SUB105 (fig. 49B), where a sequence of free fatty acids ($C_{14\text{-}20}$) alternates with alcohols ($C_{16,18,20,21,24}$) and highly abundant $C_{16:1}$ and $C_{18:1}$ monounsaturated fatty acids. In these extracts, commodity identification is limited to a broad "mixture of animal fats and plant lipids". The presence of $C_{16:1}$ fatty acid in extracts from S'Urachi is not assumed as contamination due to the outstanding lipid preservation at the site (see 6.1.1).

In none of the basin extracts from S'Urachi biomarkers detected allow to identify one specific commodity, but the chromatographic profiles suggest that these vessels were used to process different commodities, and especially plant products releasing small amounts of lipids: comparison with extracts from other sites in section 7.2.2. Notably, no basin from S'Urachi appears to be predominantly linked to animal products processing. Since animal fats are the most commonly identified lipids in ORA (see 4.3.1), this absence or low concentration indicates basins were not commonly used to process animal products.

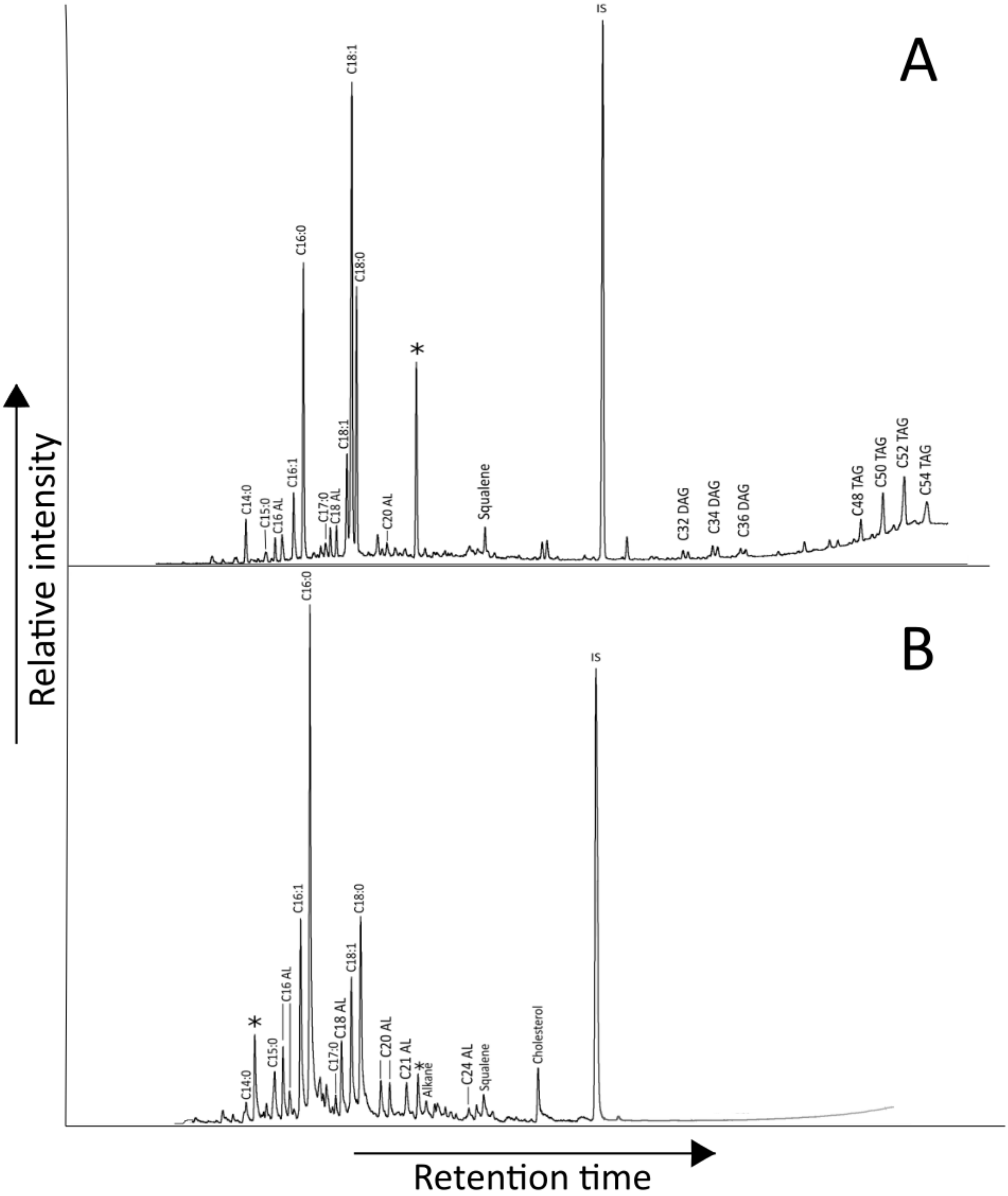


*Figure 49. High temperature gas chromatograms of the extracts SUB70 (A); SUB105 (B), indicative of mixtures of animal and plant products. Contamination possible in SUB105. All extracts come from basins. IS: internal standard; *: phthalate; AL: alcohol; DAG: diacylglycerol; TAG: triacylglycerol; with* Cn*: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.1.3.3 Casseroles

At S'Urachi, all extracts of casseroles analysed contained lipids (*n* = 8). In five of them (4 from area D; 1 from area E) biomarkers of degraded animal fats are attested, with palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) free fatty acids dominating the lipid profiles, together with C_{32-36} diacylglycerols and C_{48-54} triacylglycerols (e.g. fig. 51B), or with long-chain FFAs C_{20-24} (fig. 51A). In one extract biomarkers of animal fats (C_{12} to C_{24} FFAs) are detected together with C_{31-35} ketones. These indicate fatty acid heating over 300°C (Raven et al. 1997), suggesting the casserole was used for cooking.

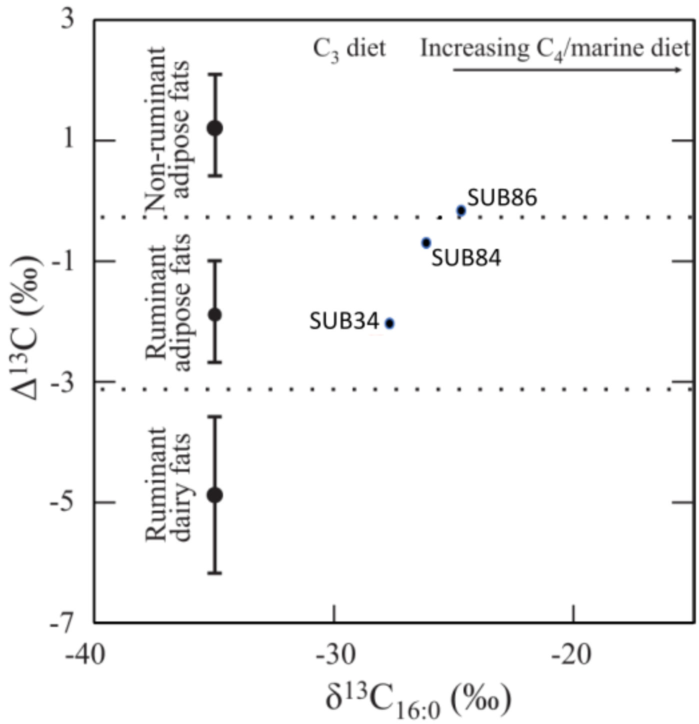


Figure 50. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for casseroles extracts from S'Urachi. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

Short chain fatty acids ($C_{12:0}$ and $C_{14:0}$) are attested in three extracts of casseroles. These fatty acids are attested in low concentrations in adipose fats, while they denote the composition of milk fats, typically suggesting presence of milk in low proportions in the extract (up to 20% of the total fatty acid content (Christie 1981; Copley et al. 2003)). However, this identification remains putative since it is not supported by the stable carbon isotope values of the extracts.

Three extracts where animal fat was dominating have been selected for analysis by GC-C-IRMS, and the results are shown in fig. 50. $\Delta^{13}C$ values range from -2.0 and -0.2‰. In two of the extracts $\Delta^{13}C$ values are consistent with a ruminant adipose origin, while in the last one ($\Delta^{13}C$ = -0.2‰) non-ruminant adipose origin is suggested.

No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in extracts of casseroles from S'Urachi (*n* = 3) containing animal fat.

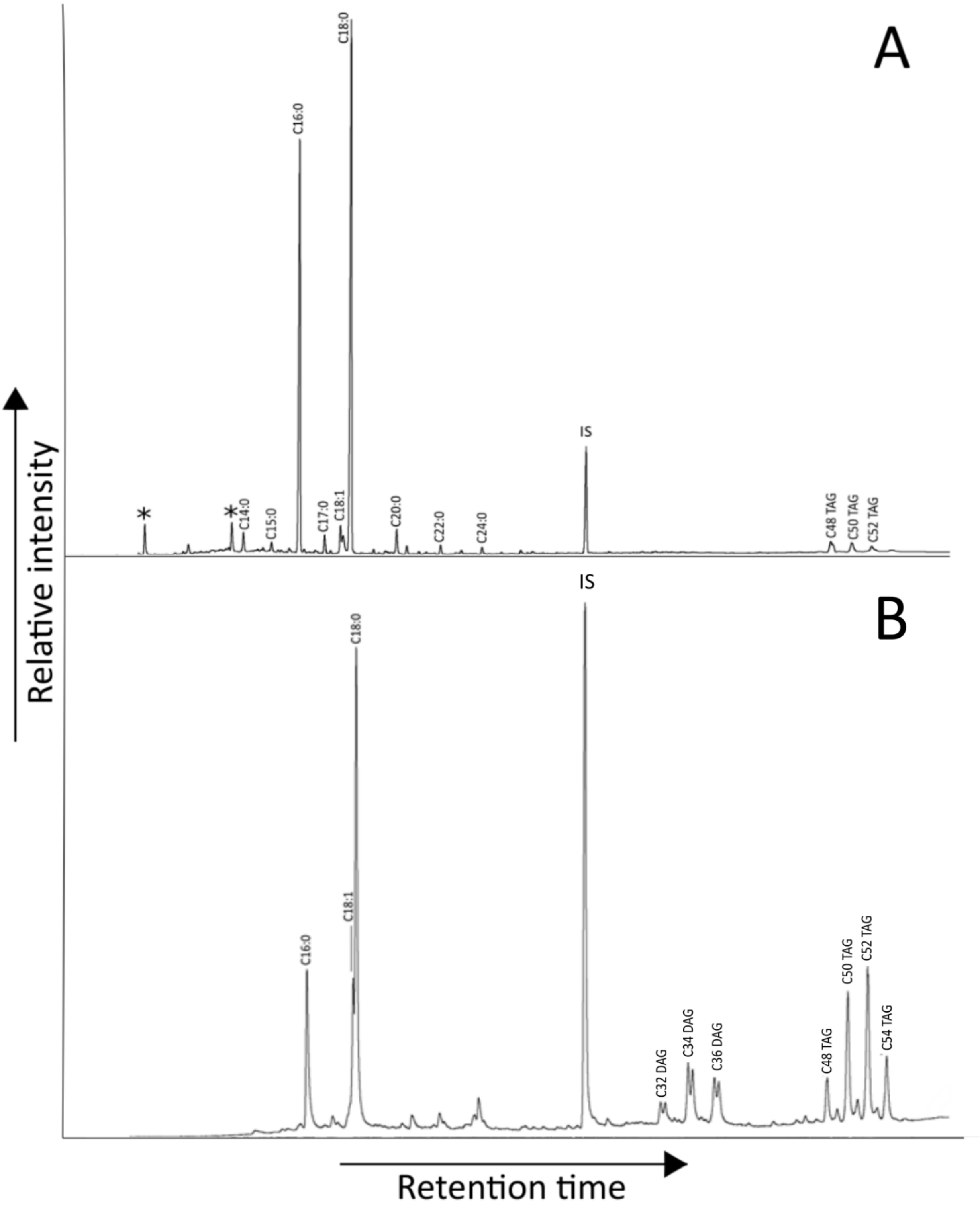


*Figure 51. High temperature gas chromatograms of the extracts SUB84 (A) and SUB34 (B), indicative of the presence of degraded animal fat. Both extracts come from casseroles. IS: internal standard; *: phthalate; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

In three extracts of casseroles, all of them deriving from the excavation area E, the identification of commodities processed in the vessel is less straightforward. In SUB17 (fig. 52), as an example, higher concentration of $C_{16:0}$ compared to $C_{18:0}$ fatty acids and presence of C_{16} and C_{18} alcohols could suggest processing of plant oils. However, the presence of squalene, cholesterol and the TAGs distribution with C_{48} dominating lead to not exclude contamination, since the three compounds could come from human fingers (Hammann et al. 2018).

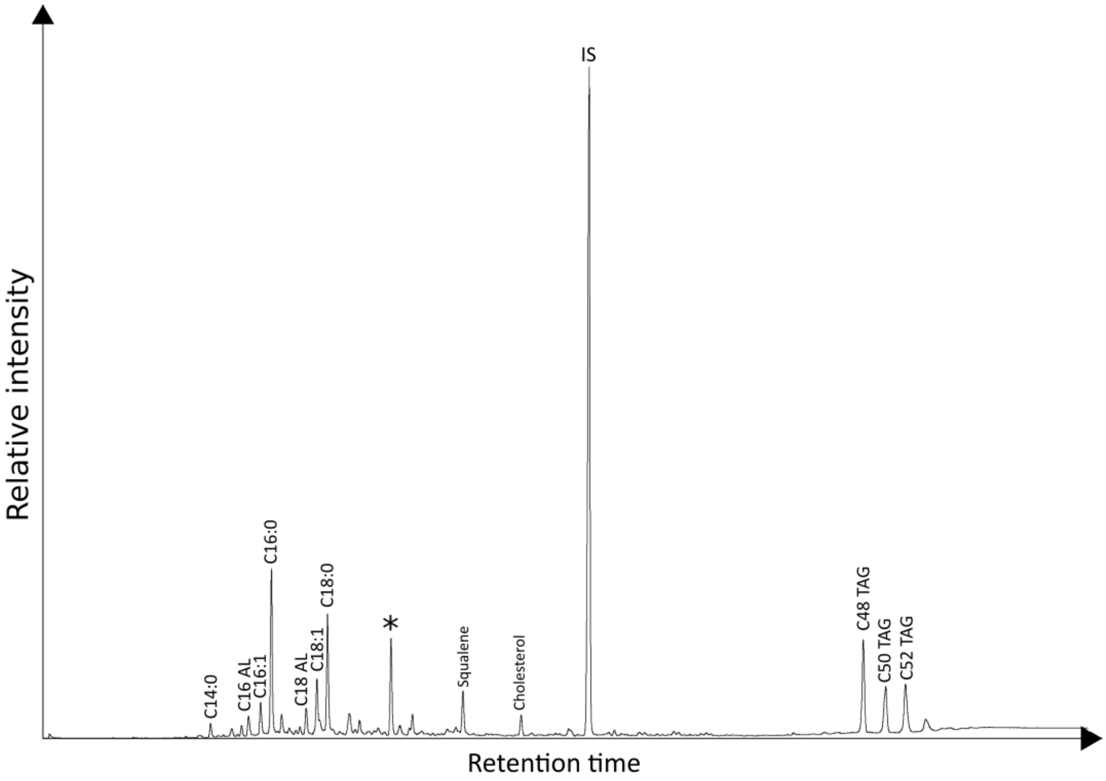


*Figure 52. High temperature gas chromatogram of the extract SUB17 (casserole), indicative of a low concentration of degraded animal fat and contaminants. IS: internal standard; *: phthalate; AL: alcohol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.1.3.4 Baking trays

Two lipid extracts of baking tray have been analysed from S'Urachi. One of them contained no lipids. The second one, shown in figure 53, is clearly contaminated, due to the high concentration of phthalates and the presence of squalene. It has been discarded and not considered for comparisons (see table I, Appendix).

6.1.3.5 Ovens

Extracts of ovens from S'Urachi (n = 5) contained no lipids.

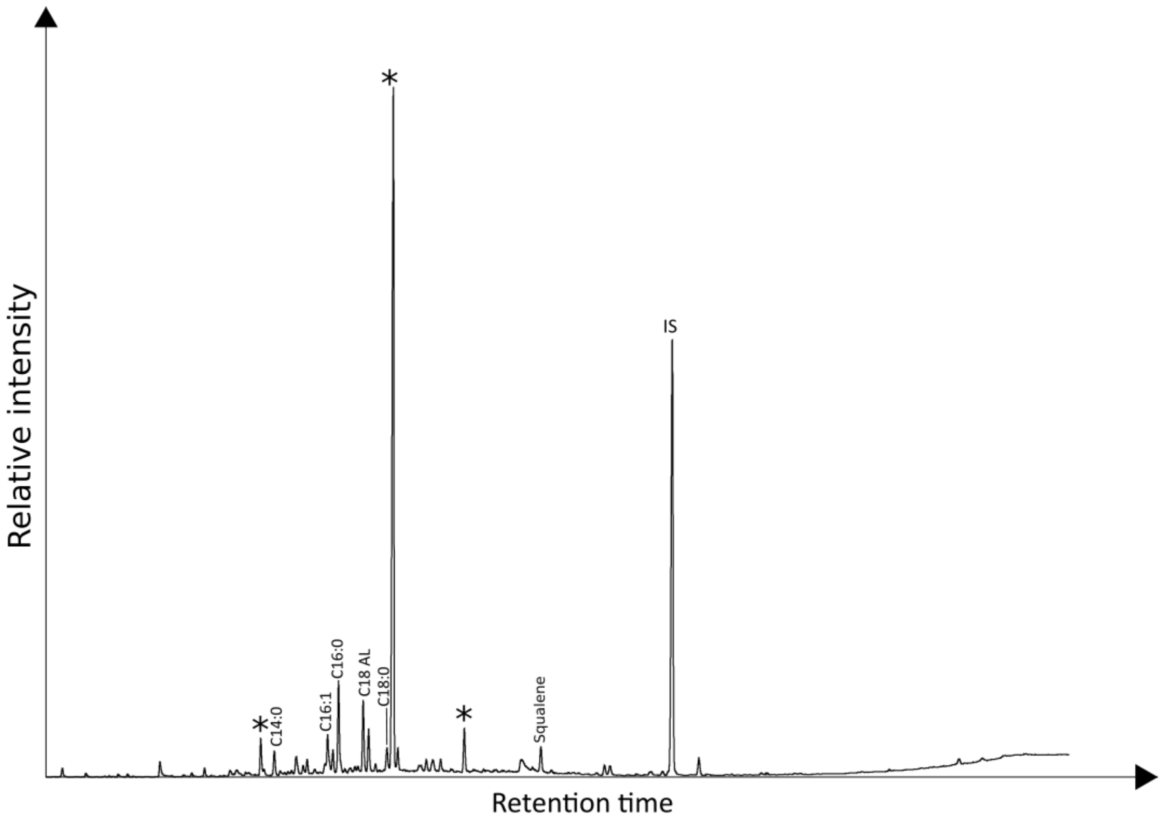


*Figure 53. High temperature gas chromatogram of the extract SUB7 (baking tray), clearly contaminated. IS: internal standard; *: phthalate; AL: alcohol with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.1.3.6 Chronological patterns

Two possible chronological patterns have been identified comparing extracts from S'Urachi. Both patterns are identified comparing results from area E, where sherds are dated between 6^{th} and 4^{th} centuries BCE, with results from area D, where sherds are dated between 5^{th} and 2^{nd} centuries BCE: this means that these are both chronological and spatial trends.

The first pattern relates to stable carbon isotope values of cooking pot extracts, shown in figure 44. The $\Delta^{13}C$ values for extracts from area E range between -4.84 and -0.32‰, while the $\Delta^{13}C$ values for extracts for area D range between 1.89 and -2.23 ‰. This difference in $\Delta^{13}C$ values, being more enriched in area D, suggest that ruminant products, both dairy and adipose, were more often processed in pots from area E, so in the 6^{th}-4^{th} centuries BCE, compared to pots from area D (5^{th}-2^{nd} century BCE). This outcome will be further discussed in Chapter 7 (section 7.1.1, animal fats).

The second pattern relates to animal products processing in casseroles. The lipid concentration in casserole extracts from area D is five times higher compared to lipid concentration in casserole extracts from area E (fig. 42). This difference in lipid concentration strictly relates to the higher animal fat detection in casseroles from area D compared with E. In all casserole extracts from area D (*n* = 4) animal fats are detected and dominate the chromatographic profile, while in only one of the four casserole extracts from area E the chromatographic profile is consistent with a degraded animal fat (fig. 51; 52). This difference, possibly related to a change in casserole use over the centuries, is further discussed in Chapter 7 (section 7.2.3, casseroles).

6.1.4 Summary

The results from the Phoenician and Punic age settlement around the nuraghe S'Urachi revealed to be the most informative in this project, for three different reasons. First, faunal and palaeobotanical material was recovered systematically and faunal and palaeobotanical analyses have been already undertaken. This ensures a comprehensive understanding of the floral and faunal evidence as possible (see Van Dommelen et al. 2018). Second, the chronology of targeted contexts (archaeological layers) spans from the 6th to the 2nd centuries BCE. Third is the surprisingly favourable preservation conditions for organic materials, such as seeds, wood and also organic residues (Van Dommelen et al. 2018). Favourable lipid preservation conditions also allowed detection of more lipids and commodities compared to the average, both in Sardinia and worldwide (Evershed 2008a). These peculiar conditions made S'Urachi a benchmark for comparisons in this research: 101 sherds have been analysed.

The major insights about S'Urachi results can be summarised as follows.
The lipid concentration in cooking pots, casseroles and basins is higher than the island means for the same vessel categories, but this appears to be generally connected to local lipid preservation conditions outlined above (6.1.2). Animal fats are well preserved in a significant number of vessels, particularly in cooking pots (*n* = 49) and some casseroles (*n* = 6). This high animal fat detection, at least compared with other sites involved in the project (see comparison in section 7.4) seems only partially related to peculiar lipid preservation conditions (see 6.1.1). It suggests, on the contrary, animal products as commonly processed and consumed in the site. Animal fats are more commonly detected in casseroles from area D compared to area E, and this suggests a possible change in use (see 7.2.3). It is relevant to underline that this higher animal fats detection in not attested at all in basins: no basin from S'Urachi seems to be connected with animal product processing (comparison with other sites in section 7.2.2).

Animal products processed in vessels from S'Urachi were mainly ruminant adipose, but extracts containing evidence for predominantly ruminant dairy (2,5%) and non-ruminant adipose products (5%) are also attested. The predominance of ruminants is consistent with the faunal evidence summarised in section 6.1.1, with cows, sheep, goats and deer constituting the 80% of the bone fragments (86% in area E and 73% in area D). On the contrary, the low presence of dairy fat is unexpected based on the same faunal evidence, since ovicaprines and bovines constitute more than the 75% of domestic animal remains and more than 60% of the total faunal assemblage in both areas. As it will be discussed below (7.1.1.3) the only dairy fat was identified from area E (6th-4th centuries BCE), with no evidence from later pots from area D (5th-2nd centuries BCE). Other insights into the origin of the animal products identified are discussed collectively with data from other sites (see 7.1.1).

In general, trends observed in S'Urachi show a connection of cooking pots with animal products, of basins with plants and low-lipid commodities and more varied chromatographic profiles in casseroles, with mixed plant and animal fats (comparisons with other sites in 7.2). Among other commodities identified in the extracts, it is worth noting that one cooking pot extract contained biomarkers of leafy plants (SUB60, fig. 46), while the presence of oil and plant lipids are likely in 15 more extracts (4 basins, 2 casseroles, 9 cooking pots). These markers are in most of the cases non-specific: in three cases identification of beeswax instead of plant waxes is possible, and in the other 12 extracts contamination cannot be excluded. In the case of SUB60, presence of leafy plants is unambiguously detected, but biomarkers are not species-specific (see 4.3.2). However, this evidence suggests a widespread processing of plant products in the settlement and in cooking pots. It was suggested by palaeobotanical remains (see 6.1.1), which cannot detect vegetables, and it is confirmed by these residue analyses. On the contrary, none of the extracts unambiguously contained beeswax (see general picture in section 7.1.2). More insights about leafy plants and beeswax will be discussed in Chapter 7, when comparing results from S'Urachi with the whole assemblage of samples.

6.2 Pani Loriga

Pani Loriga is a site located on a hill in the Sulcis region, south-west of the island, founded in the 7th century probably by Phoenician people from Sant'Antioco together with local people (see 3.2.2). The site code for extracts from Pani Loriga is "PLO".

6.2.1 Faunal and palaeoenvironmental evidence, past lipid evidence

Figure 54 Map of the sampling area (Area B) with indication of room names (reworked from Botto 2016: 8).

The palaeobotanical and faunal information for Pani Loriga is limited due to generally poor preservation of organic remains (E. Madrigali, *pers. comm.*). Regarding faunal data, a closed sacred context containing animal bones has been recently analysed (Botto 2016: 40) and found to contain the remains of ovicaprines, cattle, pig and deer. Faunal data from settled areas and from the layers included in the current project are under investigation and unpublished. Thanks to the kind permission of the archaeozoologist Damià Ramìs and the excavation director Massimo Botto, I have been allowed to see this data and discuss them with the researcher. I was not allowed to illustrate data in detail and include tables and numbers, since data are preliminary and unpublished. Briefly summarising, ovicaprines represent the most common group (only sheep have been identified), followed by red deer, cattle and pigs. Notably, red deer constitutes the second most abundant group, despite being a wild animal: this is an exception on an island level (see 2.2.2.4). Faunal data described is based on the number of fragments (NISP), not on the minimum number of individuals (MNI).

No paleobotanical information from Pani Loriga has been published. Regional surveys in its area (Sulcis), however, revealed the existence of small settlements interpreted as potential farms since the Phoenician period. This happens centuries before the beginning of the intensive agricultural exploitation recorded here and in other parts of the island by the 4th century BCE (Finocchi 2009; see also 3.1.3).

Pani Loriga is also one of the few Sardinian sites where organic residue analysis has been more widely performed (Botto-Oggiano 2012; Botto-Garnier 2018; Botto et al. *in press*). As mentioned in Chapter 4 (4.4), these analyses have limited relevance for the current research. Most of the analyses targeted various vessels as dishes, amphoras and only four vessels connected with cooking. Published results, however, do not appear particularly reliable in their interpretation. In a recently published study (Botto and Garnier 2018), organic residue analysis carried out on grave goods including jugs, cups, a miniature pot and a storage amphora has detected animal fat, oil and epicuticular waxes in the vessels. Citrus is said to be identified in one of the jugs, based on the detection of flavanones. Flavanones, however, are not widely accepted as reliable biomarkers in current literature (Roffet-Salque et al. 2016). Results of additional analyses already undertaken will be published in a new paper, not available at the time of writing (Botto et al. *in press*). Results of those analyses are summarised in a table inserted in Botto and Garnier 2018: notably, the biomarkers used for identification of commodities are not known at this stage. Results concerning cooking and preparation vessels (3 cooking pots, 1 basin) are illustrated above in table 8. Animal fat, supposed to be non-ruminant, is said to be identified. The identification of white wine in the vessels, proposed by the scholars, is once more not widely accepted in current literature since biomarkers used are ubiquitous and soluble (Drieu et al. 2020), making the whole interpretation not very reliable.

Table 8 Results of organic residue analysis on cookware undertaken in Pani Loriga before the current research. Reworked from Botto and Garnier 2018, fig.8. Biomarkers used to identify commodities not available.

Site and paper	Sample number or context	Vessel description	Identified commodities and compounds
Pani Loriga (Botto and Garnier 2018)	Necropolis, 2006	Handmade cooking pot with handle	Animal fats (non ruminant?); contaminants; triterpenes; white wine (?)
Pani Loriga (Botto and Garnier 2018)	PLB 12.S7.1147.6 settlement	Wheelmade cooking pot	Animal fats (non ruminant?); plasticisers; white wine (?)
Pani Loriga (Botto and Garnier 2018)	PLB 12.S3.1215.11 settlement	Basin (bottom)	Animal fats (non ruminant?); white wine (?)
Pani Loriga (Botto and Garnier 2018)	PLB 09.S2.1057.2 settlement	Wheelmade cooking pot with two handles	Animal fats (non ruminant?); beeswax ; plasticisers ; white wine (?).

6.2.2 Pottery assemblage and general information about lipid results

A total of 52 extracts from Pani Loriga has been analysed (table 9). The sherds included in the project come from the ongoing excavation in the Punic settlement run by the *Istituto di Studi sul Mediterraneo Antico* – CNR (National Research Council), which started in 2007 and is now directed by Massimo Botto (Botto 2016: 8). These sherds were selected with the excavators (Massimo Botto and Emanuele Madrigali) and they come from Area B (fig. 15), a domestic complex that was divided into rooms with open spaces thought to be courtyards or streets (fig. 54). It is dated between the end of the 6th and the 5th centuries BCE (Botto 2016: 38). The selected assemblages include sherds from 29 cooking pots (10 wheelmade, 19 handmade), 17 basins, 4 baking trays and 2 *tannurs.* No casseroles have been analysed because casseroles were not found in the targeted context (6th–5th centuries BCE).

Table 9 Number of sherds per vessel category, from the site of Pani Loriga

	Wheelmade pots	Handmade pots	Basins	Baking trays	Ovens	Total
Number of sherds	10	19	17	4	2	**52**

Available information for each sherd from Pani Loriga is summarised in table 10. This information includes excavation area and vessel type/subtype with chronology. In the Appendix (table II) analyses undertaken on the sherd, lipid concentration, identified compounds, $\delta^{13}C$ values and identified commodities per each sherd are listed.

6.2.2.1 Quantitative results

The mean lipid concentration and the recovery rate for extracts of sherds from Pani Loriga, per vessel category, is shown in fig. 55. The results from one of the extracts (PLO14) have been discarded due to contamination and not considered (highlighted in red in table II).

The mean lipid concentration for wheelmade cooking pots in Pani Loriga is 13 µg/g (standard deviation 19 µg/g, maximum value 64 µg/g), with 60% recovery rate. The mean lipid concentration for handmade cooking pots is 133 µg/g (standard deviation 254 µg/g, maximum value 1015 µg/g), with 68% recovery rate. The mean lipid concentration from Pani Loriga is lower than the mean obtained from all 6 sites involved in the project (*island mean*) in the case of wheelmade cooking pots (73 µg/g) and higher in the case of handmade cooking pots (96 µg/g).
The mean lipid concentration for extracts from basins is 7 µg/g (standard deviation 17 µg/g, maximum value 69 µg/g), with 19% recovery rate: island mean lipid concentration is 6 µg/g. The mean lipid concentration for baking trays is 3 µg/g (standard deviation 5 µg/g), with 25% recovery rate: island mean lipid concentration is 15 µg/g. Ovens (three sherds) are not shown in the chart (fig. 55) due to a null recovery rate and lipid concentration (island mean is 1.5 µg/g).

The lower recovery rate and lipid concentrations compared to the island means are probably due to less favourable lipid preservation conditions, as also suggested by chromatographic profiles: easily degrading compounds as triacylglycerols or short-chain fatty acids are less frequently detected compared to other sites (see 6.2.3). Archaeologists observed during the excavation that in general organic materials and residues are poorly preserved at the site (M. Botto; E. Madrigali, *pers. comm.*): no precise explanation for this phenomenon has been found up to this point.

Table 10 List of analysed sherds from Pani Loriga, with context, type and chronology.

Sample name	Sherds code-details	Context	Chronology (context)	Vessel category-type	Chronology (type)
PLO1	PLB13.S2.PUL.1	Area B, superficial layer	Late 6th-5th centuries BCE	Baking tray	8th-6th centuries BCE?
PLO2	PLB13.S4 1033.6	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO3	PLB13.S11 1265.3	Area B, open space	Late 6th-5th centuries BCE	P2 pot	7th-6th centuries BCE
PLO4	PLB13.S3 1215.27	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO5	PLB13.S5 1261.13	Area B, storage room	Late 6th-5th centuries BCE	Archaic basin	8th-6th centuries BCE
PLO6	PLB13.S13 1271.1	Area B, open space	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO7	PLB13.S5 1256.11	Area B, storage room	Late 6th-5th centuries BCE	Bottom of a basin	
PLO8	PLB13.S5 1256.1	Area B, storage room	Late 6th-5th centuries BCE	P2 pot	7th-6th centuries BCE
PLO9	PLB13.S7 1320.2	Area B, room	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO10	PLB13.S7 1147.16	Area B, room	Late 6th-5th centuries BCE	P5 pot	5th century
PLO11	PLB13.S11 1273.5	Area B, open space	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO12	PLB14.S2 1057.1	Area B, room	Late 6th-5th centuries BCE	Bottom of a basin	
PLO13	PLB14.S6 1363.2	Area B, room	Late 6th-5th centuries BCE	Baking tray	8th-6th centuries BCE?
PLO14	PLB14.S8 1360.1	Area B, room (kitchen?)	Late 6th-5th centuries BCE	Basin with carinated rim	7th-6th centuries BCE?
PLO15	PLB14.S13 1374.8	Area B, open space	Late 6th-5th centuries BCE	Bottom of a basin	
PLO16	PLB14.S11 1294.29	Area B, open space	Late 6th-5th centuries BCE	Baking tray	8th-6th centuries BCE?
PLO17	PLB13.S7 1262.3	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO18	PLB13.S7 1127.16	Area B, room	Late 6th-5th centuries BCE	P2 pot	7th-6th centuries BCE
PLO19	PLB13.S7 1293.5	Area B, room	Late 6th-5th centuries BCE	Wheelmade pot, bottom	
PLO20-21	PLB14.S7 1242.1	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO22	PLB14.S7 1278.18	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO23	PLB14.S6 1355.1	Area B, room	Late 6th-5th centuries BCE	Tannur	5th century BCE?
PLO24	PLB14.S13 1374.5	Area B, open space	Late 6th-5th centuries BCE	"S profile" pot	8th -6th centuries BCE
PLO25	PLB14.S7 1373.2	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO26	PLB14.S7 1342.1	Area B, room	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO27	PLB14.S11 1302.1	Area B, open space	Late 6th-5th centuries BCE	BA2 basin	7th-6th century BCE
PLO28	PLB15.S11 1329.3	Area B, open space	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO29	PLB15.S8 1405.1	Area B, room (kitchen?)	Late 6th-5th centuries BCE	Basin with carinated rim	7th-6th century BCE?

PLO30	PLB15.S6s 1372.4	Area B, room	Late 6th-5th centuries BCE	"S profile" pot	8th-6th centuries BCE
PLO31	PLB15.S9 1503.2	Area B, room	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO32	PLB15.S6 1375.1	Area B, room	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO33	PLB15.S11/13 1147/1428.1	Area B, open space	Late 6th-5th centuries BCE	BA2 basin	7th-6th centuries BCE
PLO34	PLB15.S8 1474.2	Area B, room (kitchen?)	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO35	PLB15.S8 1397.10	Area B, room (kitchen?)	Late 6th-5th centuries BCE	BA9 basin	6th-5th centuries BCE
PLO36	PLB15.S8 1419.10	Area B, room (kitchen?)	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO37	PLB15.S8 1409.2	Area B, room (kitchen?)	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO38	PLB15.S13 1461.7	Area B, open space	Late 6th-5th centuries BCE	Wheelmade pot, wall	
PLO39	PLB15.S13 1451.1	Area B, open space	Late 6th-5th centuries BCE	P2 pot	7th-6th centuries BCE
PLO40	PLB15.S6n 1492.3	Area B, room	Late 6th-5th centuries BCE	P2 pot	6th century BCE
PLO41	PLB15.S6N 1422.2	Area B, room	Late 6th-5th centuries BCE	BA2 basin	7th-6th centuries BCE
PLO42	PLB15.S6N 1517.1	Area B, room	Late 6th-5th centuries BCE	Baking tray	8th-6th centuries BCE?
PLO43	PLB15.S6s 1420/1430/1483.3	Area B, room	Late 6th-5th centuries BCE	P5 pot	5th century BCE
PLO44	PLB15.S6s 1372.10	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO45	PLB17.S16 1491.6	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO46	PLB17.S6n 1507.1	Area B, room	Late 6th-5th centuries BCE	BA3 basin	7th-6th centuries BCE
PLO47	PLB17.S9 1573.2	Area B, room	Late 6th-5th centuries BCE	P2 pot	7th-6th centuries BCE
PLO48	PLB17.S9 1531.1	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO49	PLB17.S9 1573.22	Area B, room	Late 6th-5th centuries BCE	"S profile" pot	8th-6th centuries BCE
PLO50	PLB17.S6n 1563.28	Area B, room	Late 6th-5th centuries BCE	Handmade pot	8th-5th centuries BCE?
PLO51	PLB17.S6N 1519.10	Area B, room	Late 6th-5th centuries BCE	BA6 basin	8th-7th centuries BCE
PLO52	PLB13.S5 1261.19	Area B, storage room	Late 6th-5th centuries BCE	Tannur	5th century BCE?
PLO53	PLB15.S6s 1420/1430/1483.2	Area B, room	Late 6th-5th centuries BCE	P5 pot	5th century BCE

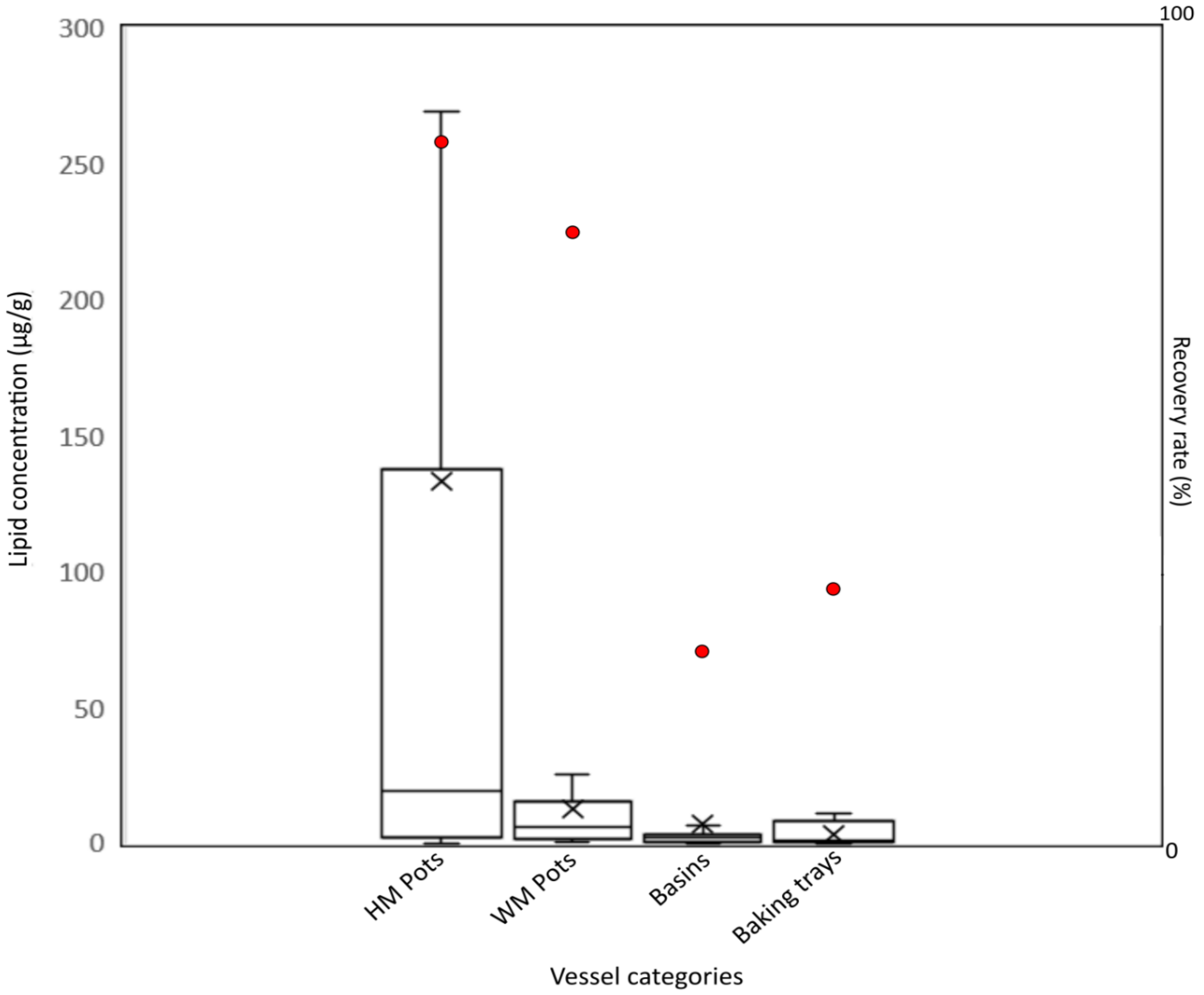


Figure 55. Box plots showing lipid concentration (X = mean) and recovery rate (red dot) of the analysed extracts coming from the site of Pani Loriga, per vessel category. Number of extracts: HM pots: 19; WM pots: 10; basins: 16; baking trays: 4.

6.2.3 Qualitative results per vessel type

6.2.3.1 Cooking pots

In Pani Loriga, palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) free fatty acids are attested in most of the cooking pots (fig. 57), with $C_{18:0}$ fatty acids always more concentrated than $C_{16:0}$, indicating the presence of animal fats. $C_{15:0}$ and $C_{17:0}$ fatty acids are consistently detected (n = 11), suggesting the processing of ruminant fats (Evershed et al. 2002), as confirmed by the δ^{13}C values of the major fatty acids. Notably, animal fats are attested in 63% of the handmade pot extracts analysed (12 of 19), and only in the 30% of wheelmade pots (3 of 10). Short chain fatty acids are rarely found ($C_{14:0}$ was detected in five cooking pots), and triacylglycerols are, in general, absent (fig. 57AC) or present in low abundance (fig. 57B), suggesting less favourable lipid preservation compared to other sites. $C_{31\text{-}35}$ odd numbered ketones, indicating exposure of animal fats to temperatures over 300°C, were detected in one extract (fig. 58A).

At Pani Loriga, compound-specific stable carbon isotope analysis was carried out on extracts from ten cooking pots containing animal fats (fig. 56), 9 of which are handmade pots. $\Delta^{13}C$ values for nine of the extracts are consistent with ruminant adipose fats, ranging between -1.5 and -2.6‰; $\delta^{13}C_{16}$ values for this group of extracts ranges between -28.2 and -26.9‰. Only one extract (PLO4) provides values indicating non-ruminant products processing (handmade pot, $\Delta^{13}C$ 0.2‰, $\delta^{13}C_{16}$ -26.0‰). None of the analysed extracts contained ruminant dairy fats.

No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in cooking pot extracts from Pani Loriga (*n* = 11) containing animal fats.

In three handmade cooking pots (fig. 58; see also 94C), the detection of $C_{42\text{-}50}$ wax esters with C_{46} dominating, $C_{24\text{-}32}$ long-chain alcohols with C_{30} dominating and $C_{20\text{-}26}$ LCFAs, together with $C_{16:0}$ to $C_{18:0}$ free fatty acids, suggests the mixing of beeswax and animal fat (Roffet-Salque et al. 2015). The absence of alkanes suggests that beeswax was exposed to high temperature, probably due to cooking in the case of these pots (Regert et al. 2001). No mixture of animal fat and plant lipids is indicated in cooking pots from Pani Loriga.

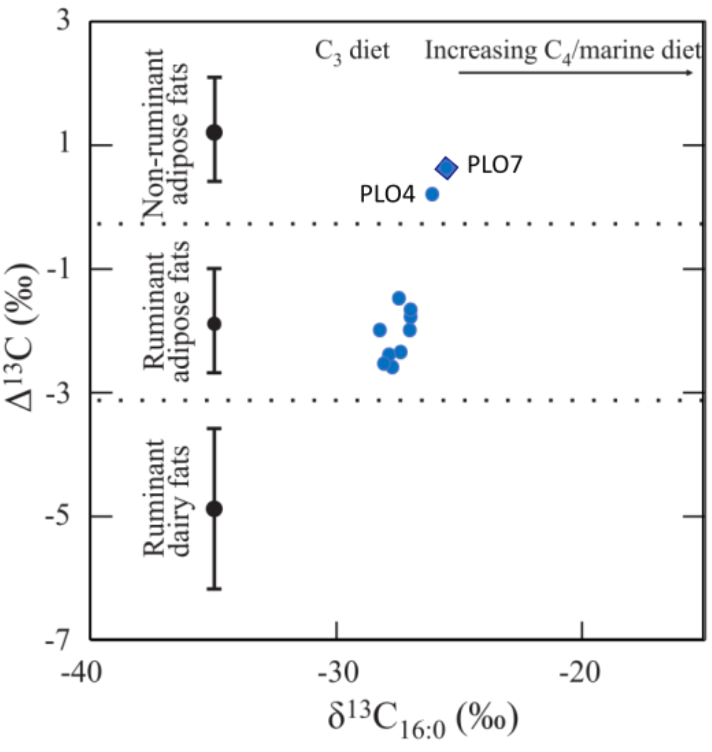


Figure 56. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for extracts from Pani Loriga. PLO7: basin. All other extracts: cooking pots. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

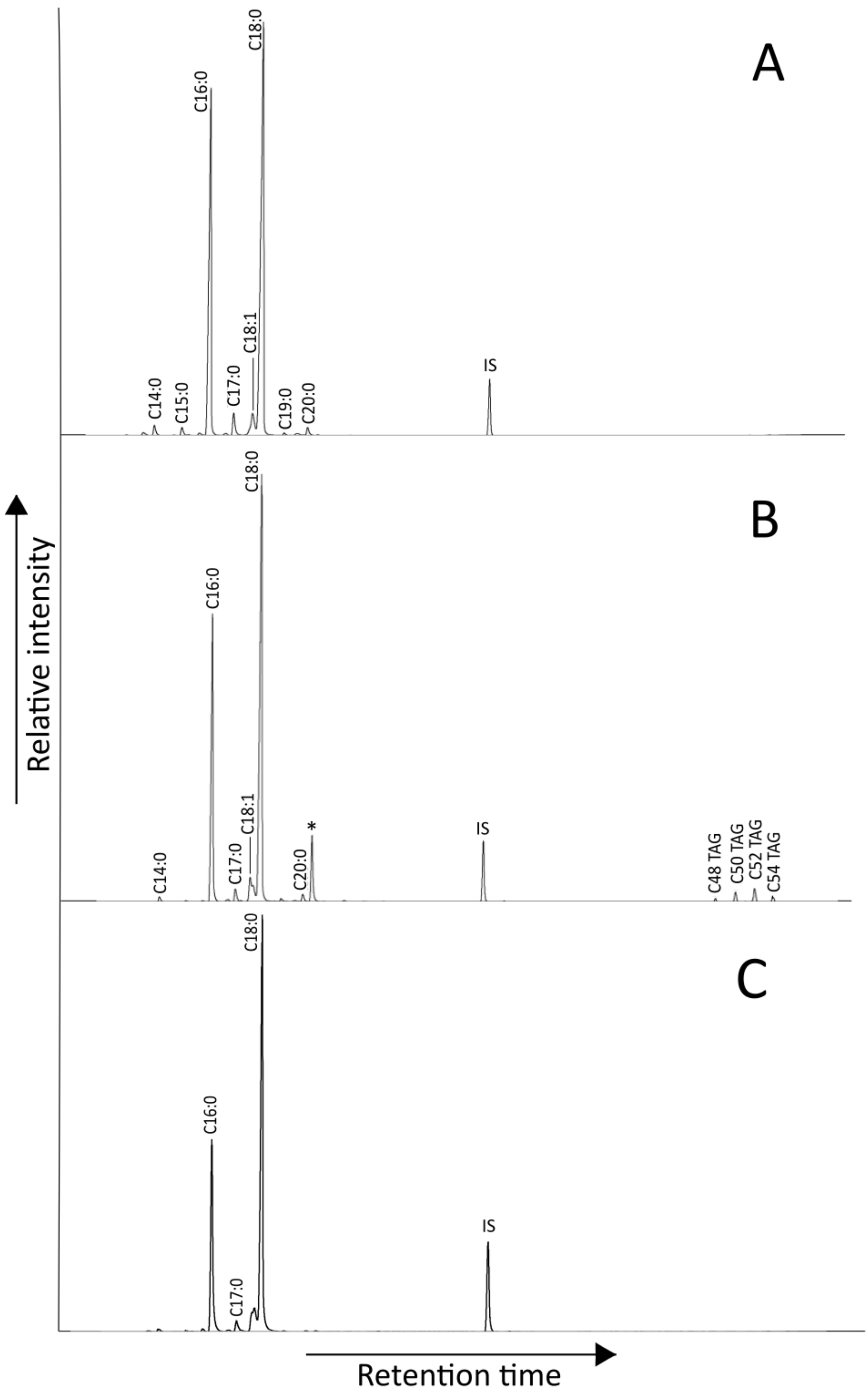


*Figure 57. High temperature gas chromatograms of the extracts PLO4 (A, handmade pot); PLO34 (B, handmade pot); PLO19 (C, wheelmade pot), indicative of presence of degraded animal fat. IS: internal standard; *: phthalate; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

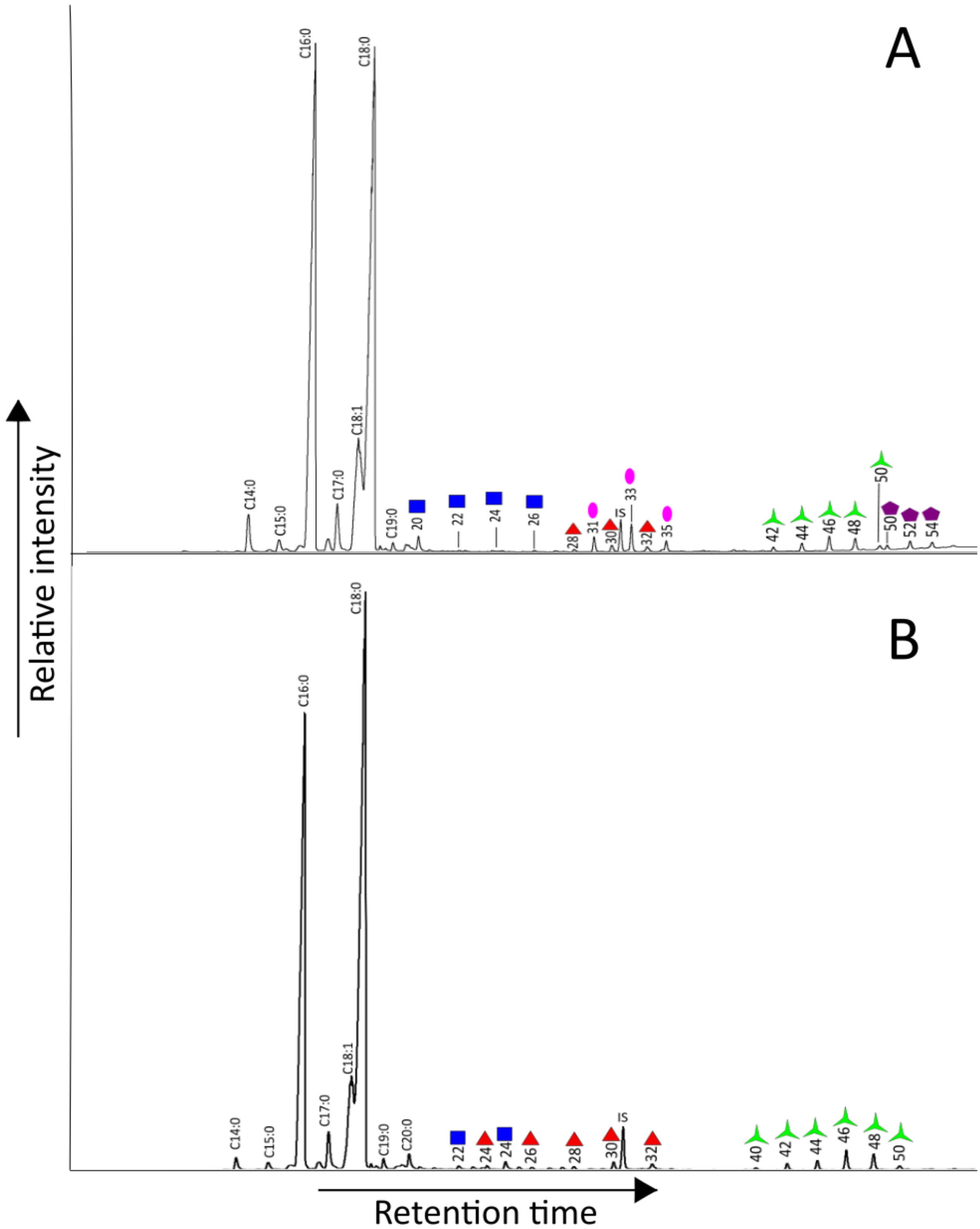


*Figure 58. High temperature gas chromatograms of the extracts PLO2 (A), PLO48 (B), indicating presence of animal fat mixed with beeswax. Both extracts come from handmade pots. IS: internal standard; *: phthalate; red triangle: alcohol; pink ellipse: ketone; green star: wax ester; purple pentagon: triacylglycerol; DAG: diacylglycerol; with* N: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.2.3.2 Basins

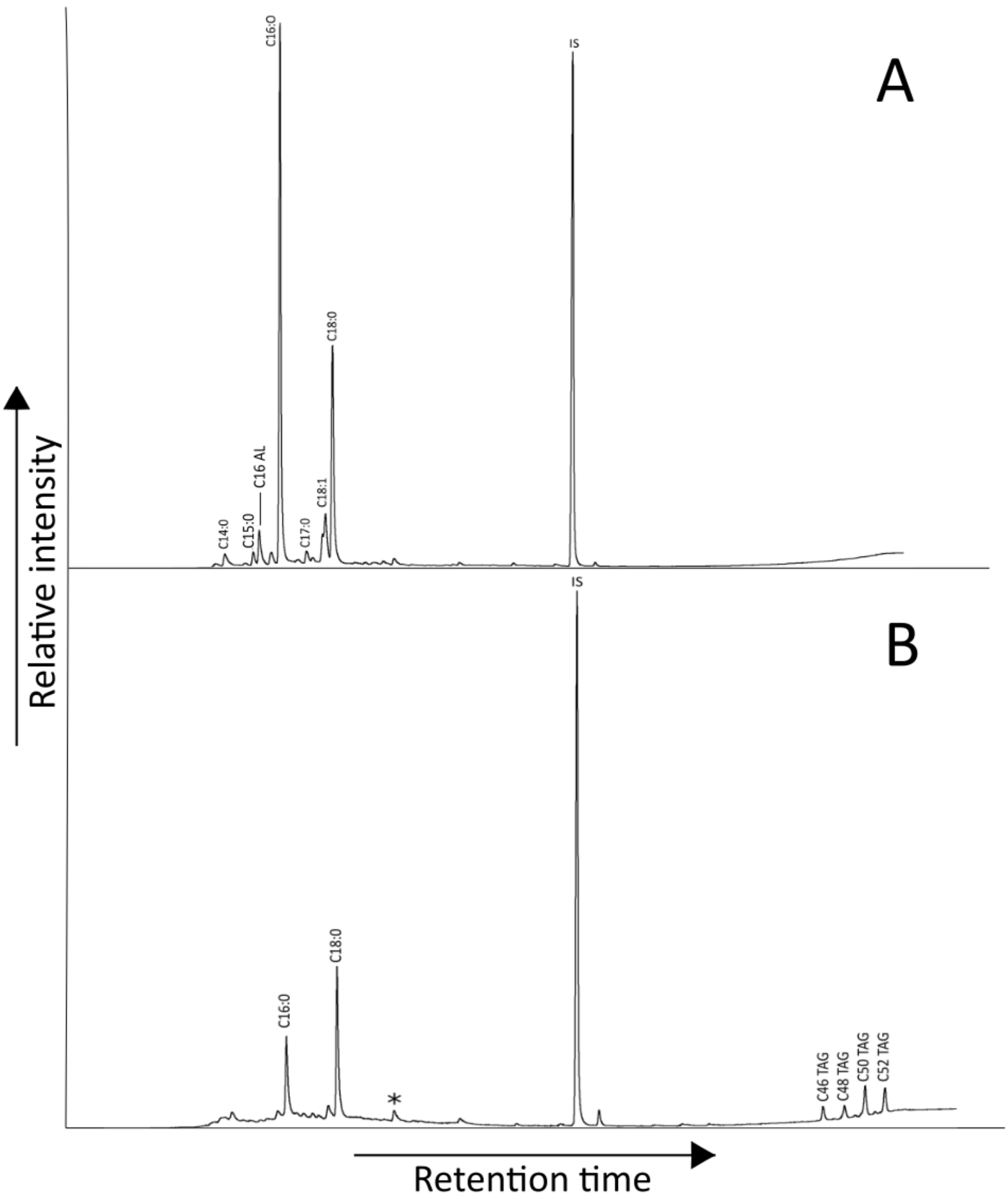


*Figure 59. High temperature gas chromatogram of the extract PLO7 (A); PLO29 (B); indicative of degraded animal fats or oil (A). Both extracts come from basins. IS: internal standard; *: phthalate; AL: alcohol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

At Pani Loriga, only three lipid extracts from basins (out of 16) have lipid concentrations higher than 5 µg/g. In PLO7 (fig. 59A) and PLO29 (fig. 59B), dominant $C_{16:0}$ and $C_{18:0}$ free fatty acids are attested. PLO7 is the only extract coming from a basin selected for stable carbon isotope analysis. Isotope values ($\delta^{13}C_{16:0}$ = -25.5‰; $\delta^{13}C_{18:0}$ = -24.8‰) are consistent with non-ruminant fat (fig. 56), but the higher concentration of $C_{16:0}$ fatty acid compared to $C_{18:0}$ suggests possible presence of plant oil or aquatic fats. However, nor of the necessary biomarkers to identify one of the two commodities was detected. In PLO29 (fig. 59B), the chromatogram can be interpreted as poorly preserved degraded animal fat due to the presence of $C_{48\text{-}54}$ TAGs and $C_{16:0}$ and $C_{18:0}$ FFAs, thus being a unique exception in the basin category.

Extract PLO 51 (fig. 60) shows the distinctive lipid profile of beeswax (Roffet-Salque et al. 2015), with $C_{42\text{-}50}$ odd numbered palmitate wax esters, with C_{46} dominating, even numbered long-chain alcohols $C_{24\text{-}34}$, with C_{30} dominating, and $C_{29,31}$ alkanes. In this extract beeswax was probably mixed with animal fat, as indicated by the presence of $C_{18:0}$ free fatty acid, $C_{32\text{-}36}$ DAGs and $C_{48\text{-}56}$ TAGs.

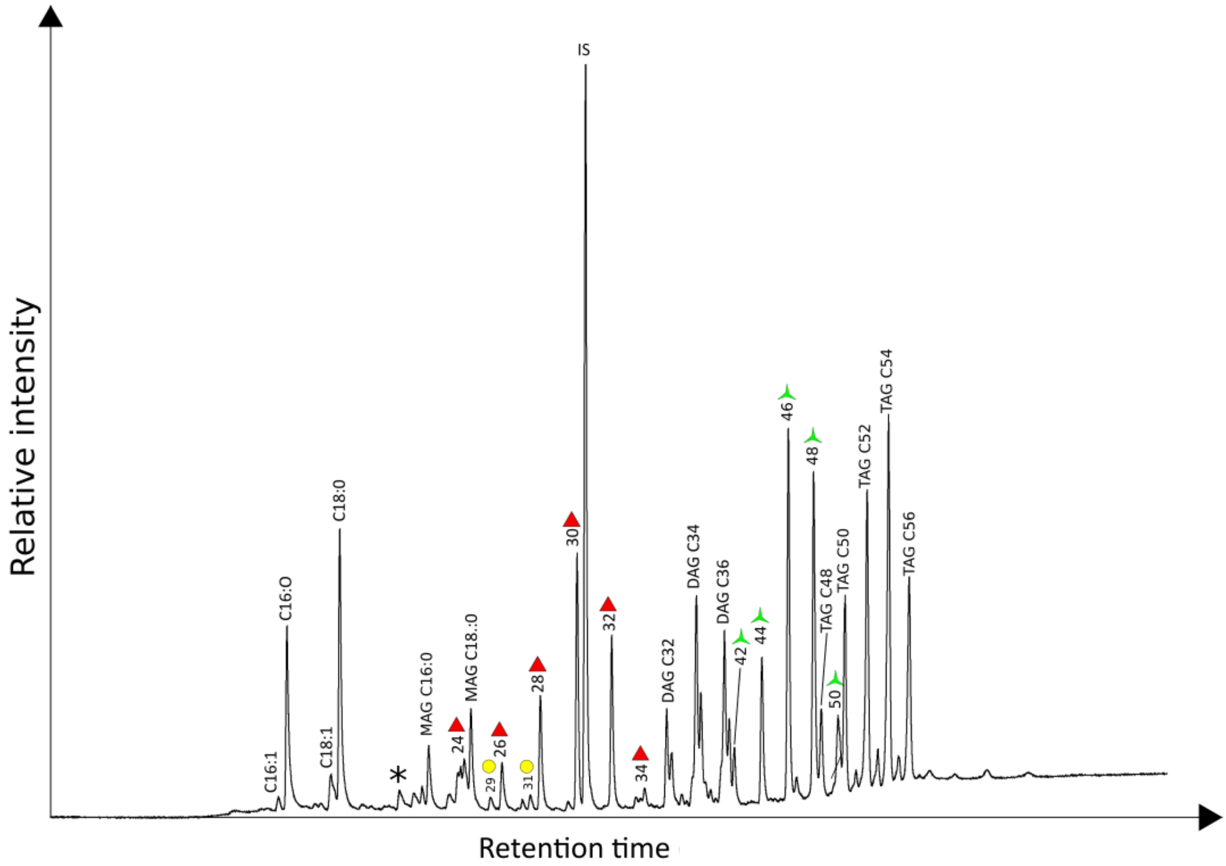


*Figure 60. High temperature gas chromatogram of the extract PLO51 (basin), indicating presence of beeswax mixed with animal fat. IS: internal standard; *: phthalate; red triangle: alcohol; yellow circle: alkane; green star: wax ester; MAG: monoacylglycerol; DAG: diacylglycerol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.2.3.3 Baking trays

The chromatogram of the only baking tray extract from Pani Loriga containing lipids is shown in figure 61. In this extract $C_{16:0}$ and $C_{18:0}$ FFAs, $C_{16:1}$ and $C_{18:1}$ monounsaturated fatty acids, C_{16} and C_{18} alcohols and $C_{48\text{-}54}$ TAGs have been identified. The content of this extract can be characterised broadly as animal fat, but contamination cannot be excluded due to the presence of $C_{16:1}$ and $C_{18:1}$ monounsaturated fatty acids present in relatively high concentrations.

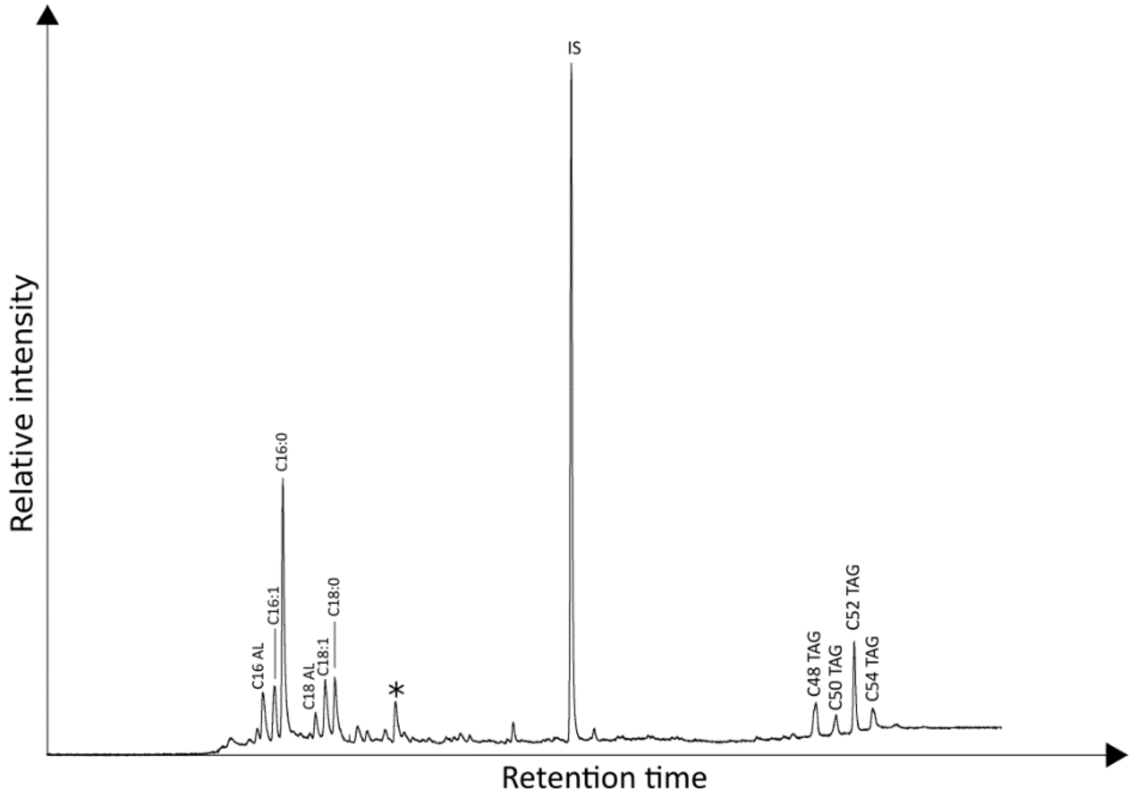


*Figure 61. High temperature gas chromatogram of the extract PLO1 (baking tray), indicative of presence of animal fat possibly mixed wirh oil. IS: internal standard; AL: alcohol; *: phthalate; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.2.3.4 Ovens

No lipid extract of ovens from Pani Loriga (*n* = 2) contained lipids.

6.2.3.5 Chronological patterns

In the case of Pani Loriga only one chronological phase of the settlement was investigated, so that no chronological patterns among the assemblage investigated from Pani Loriga have been identified.

6.2.4 Summary

The results from Pani Loriga provide a good window on vessel use in a precise phase of the settlement (late 6th-5th centuries BCE). Cooking pots were used to process mainly ruminant animal adipose products, consistently with available faunal evidence (6.2.1). Ruminant animals (cows, ovicaprines, deer), constituting 85% of animal remains, were much more numerous than non-ruminants (pig, chicken). The proportions of ruminant vs non-ruminant fats emerging from isotope analyses on lipids (90% ruminant) is similar. The lack of dairy fat on the contrary is unexpected and needs explanation, since milk processing in Pani Loriga was strongly suggested by ovicarprines and bovines presence. This theme is discussed in section 7.1.1.2.

Basins were used to process low lipid commodities and in general non animal commodities, as baking trays. But, notably, in Pani Loriga one basin used to process predominantly animal fat was identified: the low number of samples involved does not allow more broad interpretation of the evidence obtained.

Two main issues specifically connected with the site of Pani Loriga emerged during the analysis.

The first one is the apparent connection of Pani Loriga with beeswax use and processing. Beeswax was detected in five out of 52 samples, with a presence in 21% of all handmade cooking pots. The use of beehive products appears to have been common in Pani Loriga (comparison with other sites in 7.1.2).

The second issue is the strong existing difference in lipid concentration between handmade (133 μg/g) and wheelmade pots (13 μg/g). Despite sample numbers being small, this difference has been proved to be statistically significant ($p = 0.05$). Archaeology provides elements to investigate this difference: the available evidence testifies to the existence of people with different origins in the settlement of Pani Loriga (see 3.2.2), and the two cooking pot categories are connected with different cultural and technological traditions (see 3.3.1). A more detailed exploration of this difference, contextualised in the picture of the whole assemblage of results, is discussed in section 7.2.1.

6.3 Nora

The site of Nora is a settlement founded by Phoenician people on a peninsula in the south coast of Sardinia around the end of the 8th century BCE, then developed during the Punic and the Roma period (3.2.3). The site code for extracts from Nora is “NRBS”.

6.3.1 Faunal and palaeoenvironmental evidence

With regard to the contextualisation of lipid results, Nora is an interesting site due to the availability of a full catalogue, with a precise and detailed seriation of ceramic types and faunal and environmental data available. But strong limitations to the use of available fauna and environmental evidence exist.

On the one hand, the published faunal data available is unfortunately incomplete. The most important faunal catalogue for the site is contained in the Roman Forum publication (Sorrentino 2009). In that paper, however, there is no minimum number of individuals, no criteria for chronological division is published and one bone is interpreted as roe deer, an animal that is not attested in Sardinia (Sorrentino 2009). From this data it is nevertheless possible to generally state that bovines and sheep/goats were the two main groups of animals at the site, followed by pigs; wild animals, and namely red deer, do not appear to have played a significant role. Some underwater archaeological findings, and especially the recently published content of Phoenician and Punic amphoras, provide additional information about traded fauna (Madrigali-Zara 2018). Some of the amphoras contained animal bones of sheep/goat and cattle, as mentioned in Chapter 2 (2.2.2.4), and the presence of zebu in one of the amphoras suggests trade with North Africa.

On the other hand, palynological data from the Roman Forum excavation is limited to some archaeological layers and contexts, but it provides useful information about the past environment. Based on this data, apparently cereal fields and garrigue (degrading from burnt woods) characterised the area around Nora, and Mediterranean scrub was also present (Miola et al. 2009). Due to a lack of evidence, it is not clear how relevant fruit trees were in the local economy.

Finally, regional archaeological surveys provide additional information about the economy and subsistence practices (Finocchi 2002). Due to geographical reasons, the economy of the settlement is supposed to have always been based on marine resources more than meat (Finocchi 2002: 157). The settlement, as suggested by palynological data, was largely based on agriculture and exploitation of the surrounding hinterland in the Punic period, especially by the 4th century BCE (Finocchi 2002: 180). In the Phoenician period, however, agricultural exploitation was limited, and the settlement appears to have relied on trade, exchange and marine resources (Finocchi 2002: 160-163).

6.3.2 Pottery assemblage and general information about lipid results

A total of 78 samples from Nora were analysed (table 11). All of them come from the excavation of the Roman Forum undertaken by the University of Padova between 1997 and 2006 (excavation area P; fig. 16). They have been selected following the comprehensive catalogue published by Lorenza Campanella (Campanella 2009a; b; c) where every sherd is precisely described and typologically dated. The chronology of each context (layer) has been considered according to the stratigraphy published in Bonetto et al. 2009 (2-18). Vessels are typologically dated between the 8th and the 2nd century BCE. The original plan was to analyse only sherds found in Phoenician and Punic layers, but it has not been possible as sherds were stored by ceramic type and not archaeological layer. Some of the analysed vessels have been found in Roman fills, as indicated by chronology of contexts in table 12, but since organic residues do not come from depositional soil (Heron et al. 1991, see also Chapter 4), these sherds can still provide reliable results. A total of 25 wheelmade cooking pots, 8 handmade cooking pots, 6 casseroles, 24 basins, 6 tripod bowls, 3 baking trays and 6 ovens were analysed.

Table 11 Number of sherds per vessel category, from the site of Nora.

	Wheelmade pots	Handmade pots	Casseroles	Basins and tripod bowls	Baking trays	Ovens	Total
Number of sherds	25	8	6	30	3	6	78

Available information for each sherd from Nora is summarised in table 12. This information includes the excavation area and vessel type/subtype with chronology. Notably, due to time constraints and storage of sherds, the vessels had to be chosen on the basis of typology rather than context, a unique case in this research. For this reason, in comparisons and discussions (chapter 7) chronology of vessels from Nora is based on type: this limitation must be considered in discussing the following results. In the Appendix (table III) analyses undertaken on the sherd, lipid concentration, identified compounds, $\delta^{13}C$ values and identified commodities per each sherd are listed.

6.3.2.1 Quantitative results

The mean lipid concentration and the recovery rate for sherds from Nora are shown in fig. 62. The results provided from three extracts have been discarded due to contamination and not considered in comparisons (highlighted in red in table III). The mean lipid concentration in wheelmade cooking pots is 15 µg/g (standard deviation 13 µg/g, maximum value 56 µg/g), with 79% recovery rate. The mean lipid concentration in handmade cooking pots is 181 µg/g (standard deviation 253 µg/g, maximum value 752 µg/g), with 100% recovery rate. Values are lower than the means obtained from all sherds analysed in the 6 sites involved (*island mean*) in the case of wheelmade cooking pots (73 µg/g) and higher than the island mean for handmade cooking pots (96 µg/g).

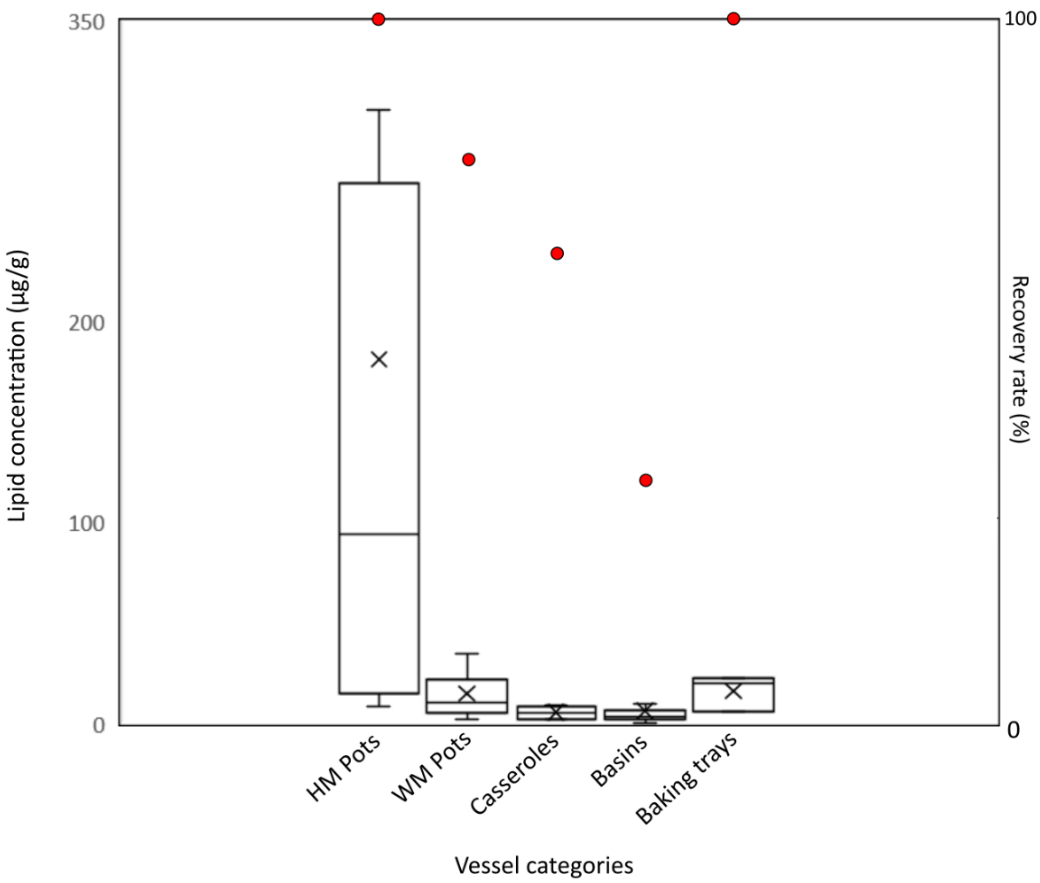


Figure 62. Box plots showing lipid concentrations (X = mean) and recovery rate (red dot) of the analysed extracts coming from the site of Nora, per vessel category. HM pots: 8 extracts; WM pots: 24; casseroles: 6; basins: 29; baking trays: 3.

The mean lipid concentration is 6 µg/g for extract of basins (standard deviation 8 µg/g, maximum value 20 µg/g), with 34.5% recovery rate: this is in line with the island mean (6 µg/g). The mean lipid concentration in extracts of casseroles is 5 µg/g (standard deviation 3 µg/g, maximum value 9 µg/g), lower than the island mean of 27 µg/g. The recovery rate for casseroles extracts is 66.7%. The mean lipid concentration for baking trays is 16 µg/g (island mean 15 µg/g) and the recovery rate is 100%, but the three baking trays analysed are all potentially affected by contamination (6.2.4), suggesting caution is required to interpret this result. Recovery rate for ovens is 0%, the mean lipid concentration of 1 μg/g is in line with the island mean (1.5 μg/g).

In general, contaminants in extracts from Nora, such as phthalates (plasticiser) or squalene (finger lipids arising from handling), are more common than at other sites. This could be due to post-excavation treatments, since sampled vessels from Nora have been stored in plastic bags for up to 23 years, and it is known they were handled and washed by researchers in preparation for their full publication. These possible contaminants are easily recognised, however.

Table 12 List of analysed sherds from Nora, with context, type and chronology

Sample name	Sherd code-details	Context	Chronology (context)	Vessel category-type	Chronology (type)
NRBS1	NR99/PC/5149/CFP/66	Roman Forum – Area P	5th century BCE	P1 pot	7th-first half 6th centuries BCE
NRBS2	NR00/PD/5183/CFP/59	Roman Forum – Area P	1st-2nd centuries AD	P2 pot	Second half 7th century BCE
NRBS3	NR06/PH/11596/CFP/5	Roman Forum – Area P	1st-2nd centuries AD	P2 pot	Second half 7th century BCE
NRBS4	NR99/PC/5134/CFP/118	Roman Forum – Area P	2nd-1st centuries BCE	P2 pot	Second half 7th century BCE
NRBS5	NR99/PC/5149/CFP/63	Roman Forum – Area P	5th century BCE	P2 pot	end 7th -6th centuries BCE
NRBS6	NR01/PD/5218/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	P2 pot	end 7th -6th centuries BCE
NRBS7	NR99/PC/5134/CFP/59	Roman Forum – Area P	2nd-1st centuries BCE	P2 pot	Second half 6th century BCE
NRBS8	NR98/PB/5043/CFP/17	Roman Forum – Area P	1st-2nd centuries AD	P2 pot	End 6th-5th centuries BCE
NRBS9	NR00/PD/5183/CFP/54	Roman Forum – Area P	1st-2nd centuries AD	P2 pot	End 6th-5th centuries BCE
NRBS10	NR98/PB/5057/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	P3 pot	5th-4th centuries BCE
NRBS11	NR99/PB/5123/CFP/1	Roman Forum – Area P	2nd-1st centuries BCE	P5 pot	5th-4th centuries BCE
NRBS12	NR97/PA/5009/CFP/2	Roman Forum – Area P	1st-2nd centuries AD	Tripod bowl	7th century BCE
NRBS13	NR99/PC/5147/CFP/19	Roman Forum – Area P	5th century BCE	Tripod bowl	7th-6th centuries BCE
NRBS14	NR01/PD/5218rip/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	Tripod bowl	7th-6th centuries BCE
NRBS15	NR00/PD/5183/CFP/25	Roman Forum – Area P	1st-2nd centuries AD	BA1 basin	First half 6th century BCE
NRBS16	NR99/PC/5134/CFP/115	Roman Forum – Area P	1st-2nd centuries AD	BA1 basin	7th-first half 6th centuries BCE
NRBS17	NR99/PC/5134/CFP/74	Roman Forum – Area P	1st-2nd centuries AD	BA2 basin	7th century BCE
NRBS18	NR05/PD/5172/CFP/16	Roman Forum – Area P	Late Roman/Early medieval	BA2 basin	7th century BCE
NRBS19	NR06/PI/5335/CFP/13	Roman Forum – Area P	1st-2nd centuries AD	BA3 basin	4th-3rd centuries BCE
NRBS20	NR01/PD/5218rip/CFP/3	Roman Forum – Area P	1st-2nd centuries AD	BA5 basin	7th-6th centuries BCE
NRBS21	NR01/PF/5721/CFP/1	Roman Forum – Area P	2nd-1st centuries BCE	BA6 basin	7th-6th centuries BCE
NRBS22	NR04/PG/11051/CFP/1	Roman Forum – Area P	Late Roman/Early medieval	BA6 basin	8th-7th centuries BCE
NRBS23	NR99/PC/5135/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	BA3 basin	Second half 7th-6th centuries BCE
NRBS24	NR00/PD/5168/CFP/10	Roman Forum – Area P	1st-2nd centuries AD	BA3 basin	Second half 7th-6th centuries BCE
NRBS25	NR06/PG/11380/CFP/2	Roman Forum – Area P	1st-2nd centuries AD	BA8 basin	4th -2nd centuries BCE
NRBS26	NR06/PM/5382/CFP/40	Roman Forum – Area P	1st-2nd centuries AD	BA8 basin	4th-2nd centuries BCE

NRBS27	NR99/PC/5134/CFP/100	Roman Forum – Area P	1st-2nd centuries AD	BA13 basin	7th-5th centuries BCE
NRBS28	NR06/PM/5385/CFP/106	Roman Forum – Area P	1st-2nd centuries AD	Casserole	4th- 3rd centuries BCE
NRBS29	NR99/PC/5130/CFP/13	Roman Forum – Area P	1st-2nd centuries AD	Casserole	First half 5th century BCE
NRBS30	NR00/PB/5196/CFP/2	Roman Forum – Area P	1st-2nd centuries AD	Casserole	End 5th-first half 4th centuries BCE
NRBS31	NR01/PD/5290/CFP/1	Roman Forum – Area P	5th century BCE	"S profile" pot	8th-6th centuries BCE?
NRBS32	NR06/PM/5381/CFP/7	Roman Forum – Area P	5th century BCE	"S profile" pot	8th-6th centuries BCE?
NRBS33	NR99/PC/5148/CFP/10	Roman Forum – Area P	5th century BCE	Baking tray	8th-5th centuries BCE?
NRBS34	NR05/PF/12014/CFP/1	Roman Forum – Area P	7th century BCE	Handmade pot	7th -6th centuries BCE?
NRBS35	NR04/PF/5563/CFP/9	Roman Forum – Area P	7th century BCE	Baking tray	8th-5th centuries BCE?
NRBS37	NR00/PD/5183/CFP/81	Roman Forum – Area P	1st-2nd centuries AD	Tannur	5th -2nd centuries BCE?
NRBS38	NR01/PD/5287/CFP/4	Roman Forum – Area P	2nd-1st centuries BCE	Tannur	5th -2nd centuries BCE?
NRBS39	NR06/PM/5382/CFP/2	Roman Forum – Area P	1st-2nd centuries AD	Tannur	5th -2nd centuries BCE?
NRBS40	NR05/PI/5295/CFP/23	Roman Forum – Area P	Modern age	Tannur	5th-2nd centuries BCE?
NRBS41	NR05/PI/5295/CFP/25	Roman Forum – Area P	Modern age	Tannur	5th -2nd centuries BCE?
NRBS42	NR06/PN/12531/CFP/18	Roman Forum – Area P	Modern age	Tannur	5th -2nd centuries BCE
NRBS43	NR00/PD/5168/CFP/30	Roman Forum – Area P	1st-2nd centuries AD	P2	End 7th-first half 6th centuries BCE
NRBS44	NR98/PB/5057/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	P3 pot	5th-4th centuries BCE
NRBS45	NR00/PD/5167/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	P3 pot	5th-4th centuries BCE
NRBS46	NR00/PD/5235/CFP/2	Roman Forum – Area P	1st-2nd centuries AD	P6 pot	3rd-2nd centuries BCE
NRBS47	NR06/PI/5335/CFP/62	Roman Forum – Area P	1st-2nd centuries AD	P6 pot	3rd-2nd centuries BCE
NRBS48	NR06/OH/11685/CFP/9	Roman Forum – Area P	3rd-5th centuries AD	P6 pot	3rd-2nd centuries BCE
NRBS49	NR06/PM/5376/CFP/6	Roman Forum – Area P	1st-2nd centuries AD	P6 pot	3rd centuries BCE
NRBS50	NR06/PI/5339/CFP/14	Roman Forum – Area P	5th century BCE	P6 pot	3rd centuries BCE
NRBS51	NR06/PG/11331/CFP/8	Roman Forum – Area P	3rd-5th centuries AD	P8 pot	4th-2nd centuries BCE
NRBS52	NR99/PC/5130/CFP/63	Roman Forum – Area P	1st-2nd centuries AD	P8 pot	4th-2nd centuries BCE
NRBS53	NR98/PB/5047/CFP/21	Roman Forum – Area P	1st-2nd centuries AD	P8 pot	4th-2nd centuries BCE
NRBS54	NR00/PB/5196/CFP/3	Roman Forum – Area P	1st-2nd centuries AD	P9 pot	3rd-2nd centuries BCE
NRBS55	NR06/PI/5335/CFP/4	Roman Forum – Area P	1st-2nd centuries AD	P9 pot	3rd-2nd centuries BCE
NRBS56	NR03/PF/5416/CFP/3	Roman Forum – Area P	1st-2nd centuries AD	P9 pot	3rd-2nd centuries BCE
NRBS57	NR98/PB/5117/CFP/1	Roman Forum – Area P	2nd-1st centuries BCE	Casserole	4th century BCE
NRBS58	NR05/PI/5315/CFP/13	Roman Forum – Area P	1st-2nd centuries AD	Casserole	First half 5th centuries BCE
NRBS60	NR04/PG/11052/CFP/1	Roman Forum – Area P	Late Roman/Early medieval	Casserole	3rd-2nd centuries BCE
NRBS61	NR99/PC/5134/CFP/38	Roman Forum – Area P	1st-2nd centuries AD	BA1 basin	7th-first half 6th centuries BCE
NRBS62	NR06/PN/12529/CFP/7	Roman Forum – Area P	1st-2nd centuries AD	BA2 basin	7th-6th centuries BCE
NRBS63	NR02/PF/5907/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	BA6 basin	8th -7th centuries BCE
NRBS65	NR98/PB/5114/CFP/1	Roman Forum – Area	1st-2nd centuries AD	BA7 basin	4th century BCE

		P			
NRBS66	NR98/PB/5115/CFP/5	Roman Forum – Area P	1st-2nd centuries AD	BA7 basin	4th century BCE
NRB67	NR06/PM/5385/CFP/110	Roman Forum – Area P	1st-2nd centuries AD	BA8 basin	4th -3rd centuries BCE
NRBS68	NR05/PG/11215/CFP/5	Roman Forum – Area P	1st-2nd centuries AD	BA9 basin	4th -3rd centuries BCE
NRBS69	NR05/PG/11215/CFP/7	Roman Forum – Area P	1st-2nd centuries AD	BA9 basin	4th -3rd centuries BCE
NRBS70	NR04/PF/5470/CFP/2	Roman Forum – Area P	3rd-5th centuries AD	BA11 basin	3rd-2nd centuries BCE
NRBS71	NR06/PM/5374/CFP/9	Roman Forum – Area P	1st-2nd centuries AD	BA11 basin	3rd-2nd centuries BCE
NRBS72	NR06/PM/5373/CFP/5	Roman Forum – Area P	1st-2nd centuries AD	BA15 basin	4th century BCE
NRBS73	NR97/PA/5014/CFP/8	Roman Forum – Area P	1st-2nd centuries AD	Tripod bowl	7th-first 6th centuries BCE
NRBS74	NR00/PD/5235/CFP/9	Roman Forum – Area P	1st-2nd centuries AD	Tripod bowl	7th-first 6th centuries BCE
NRBS75	NR02/PF/5943/CFP/1	Roman Forum – Area P	1st-2nd centuries AD	Tripod bowl	7th-first 6th centuries BCE
NRBS76	NR01/PD/5218/CFP/27	Roman Forum – Area P	1st-2nd centuries AD	"S profile" pot	8th-6th centuries BCE?
NRBS77	NR01/PD/5289/CFP/7	Roman Forum – Area P	1st-2nd centuries AD	"S profile" pot	8th-6th centuries BCE?
NRBS78	NR05/PI/5298/CFP/8	Roman Forum – Area P	1st-2nd centuries AD	Handmade pot	8th-5th centuries BCE?
NRBS79	NR03/PF/5424/CFP/13	Roman Forum – Area P	4th-2nd centuries BCE	"S profile" pot	8th-6th centuries BCE?
NRBS80	NR00/PD/5246/CFP/8	Roman Forum – Area P	1st-2nd centuries AD	"S profile" pot	8th-6th centuries BCE?
NRBS81	NR06/PI/5335/CFP/31	Roman Forum – Area P	1st-2nd centuries AD	Baking tray	8th-6th centuries BCE

6.3.2 Qualitative results per vessel type

6.3.2.1 Cooking pots

Animal fats

At Nora, biomarkers of animal fat have been detected in 12 cooking pot extracts out of 33. In lipid extracts from wheelmade pots degraded animal fat in low concentration was generally identified (e.g. in fig. 64AB): in these chromatograms typically free fatty acids (C_{14} to C_{18}) alternates with alcohols (especially $C_{16\text{-}20}$). Notably, in 13 cooking pot extracts from Nora, $C_{16:0}$ free fatty acid is dominant over $C_{18:0}$. This lipid distribution seems connected to contamination more than aquatic or plant products processing. Plant specific biomarkers are absent, and in some of the extracts (e.g. fig. 64A) squalene and cholesterol, probably coming from human fingers, are also attested (Hammann et al. 2018). However, this evidence suggests animal product processing as an uncommon activity at the site.

In contrast, some chromatograms of handmade cooking pots provide very different profiles (*n* = 4, half of the total). These extracts show chromatographic profiles consistent with degraded animal fat, with abundant $C_{16:0}$ and $C_{18:0}$ free fatty acids, $C_{18:1}$ monounsaturated free fatty acid, other free fatty acids ($C_{19\text{-}26}$), and $C_{48\text{-}54}$ triacylglycerols (fig. 65; 66A).

Short chain free fatty acids such as $C_{12:0}$ and $C_{14:0}$, possibly denoting the presence of milk in small proportions (up to 20% of the total fatty acid content (Christie 1981; Copley et al. 2003)), have been detected in 7 extracts of cooking pots from Nora (fig. 64A; 66). In two pot extracts C_{31-35} ketones are found, indicating the heating of fatty acids over 300°C (Raven et al. 1997; fig. 66B).

Compound-specific isotope analysis was carried out on a total of 5 cooking pot extracts from Nora (one wheelmade, four handmade). The $\Delta^{13}C$ values, ranging between -3.1 and -1.4‰, are once more consistent with ruminant adipose fat in all cooking pot extracts (fig. 63). A mixture with dairy fats is suggested in only one case (NRBS79, handmade pot, $\Delta^{13}C$ = -3.1‰).

No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in cooking pot extracts from Nora (*n* = 5) containing animal fat.

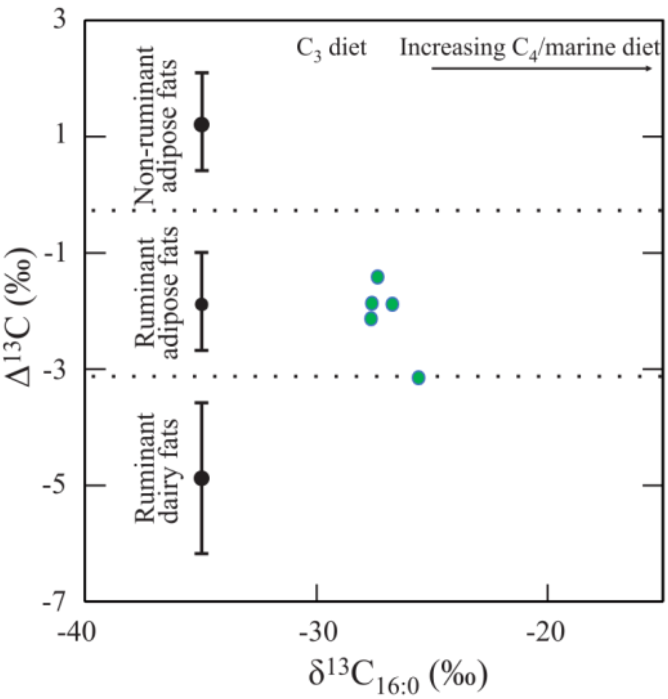


Figure 63. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for pot extracts from Nora. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

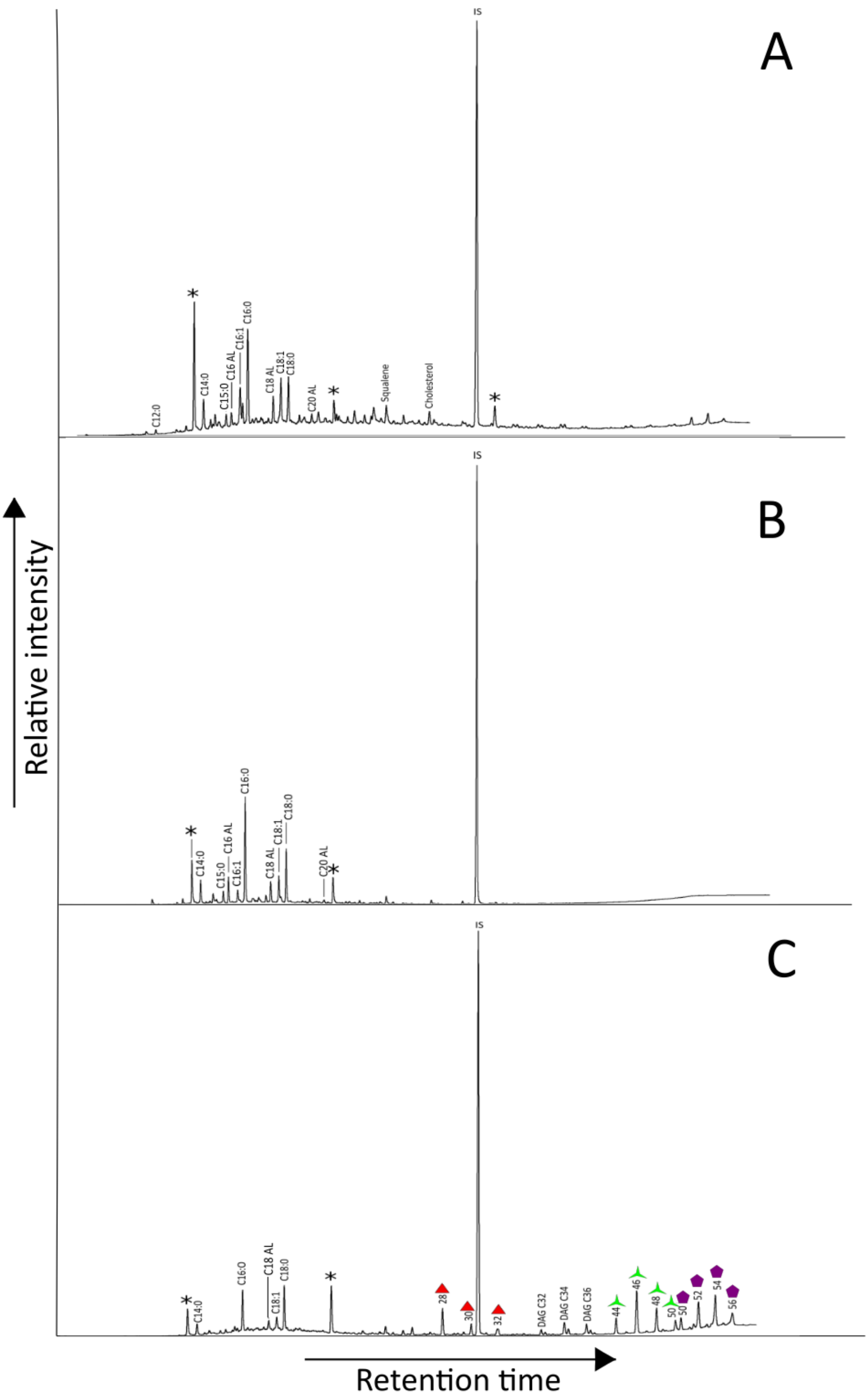


*Figure 64. High temperature gas chromatograms of the extracts NRBS7 (A); NRBS78 (B); NRBS45 (C), indicative of presence of animal fat mixed with beeswax (C) and possibly with plant lipids (A). All chromatograms come from wheelmade pots. IS: internal standard; *: phthalate; AL: alcohol; red triangle: alcohol; green stars: wax esters; purple pentagon: triacylglycerol; DAG: diacylglycerol; with Cn: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

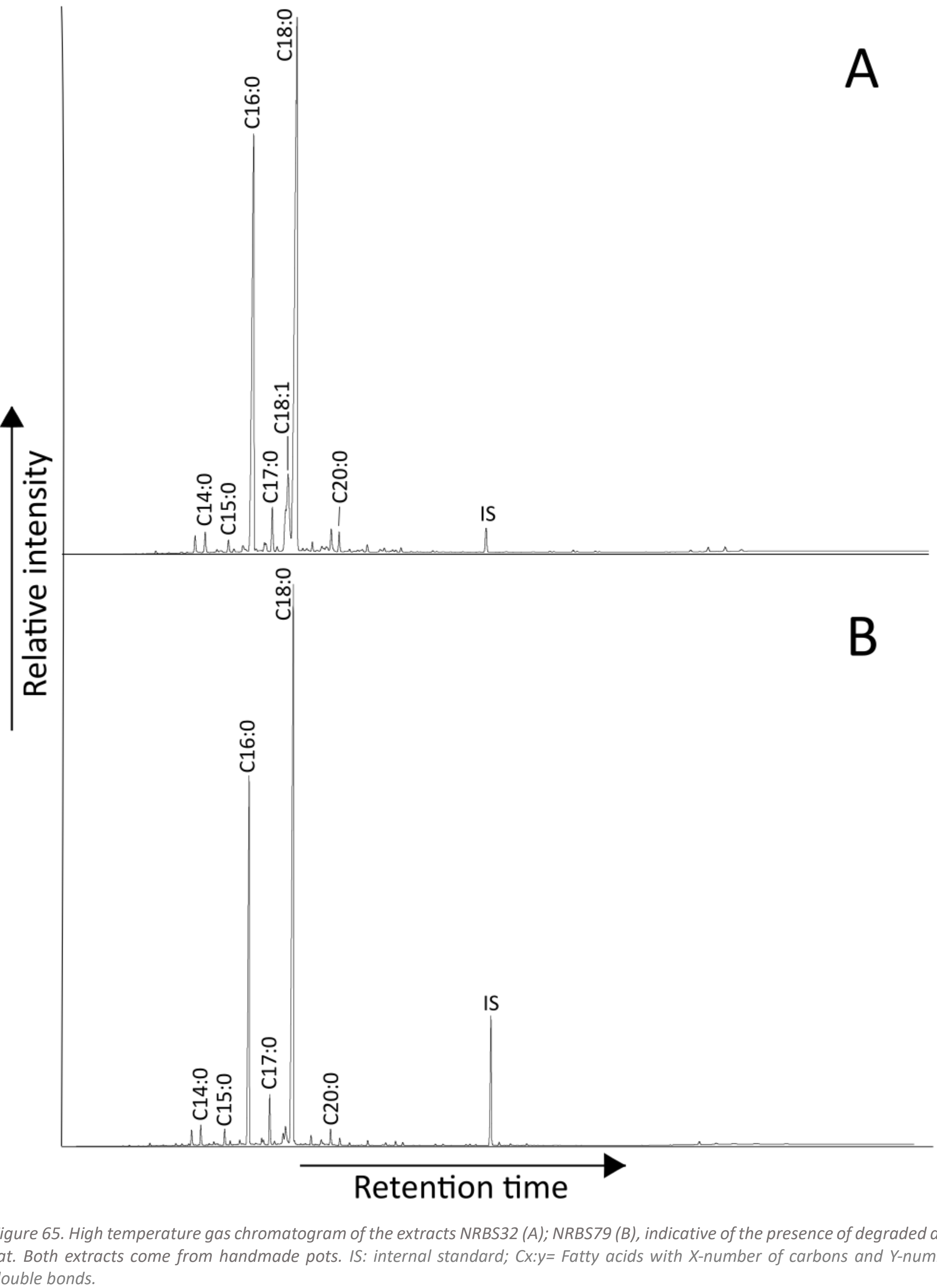


Figure 65. High temperature gas chromatogram of the extracts NRBS32 (A); NRBS79 (B), indicative of the presence of degraded animal fat. Both extracts come from handmade pots. IS: internal standard; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.

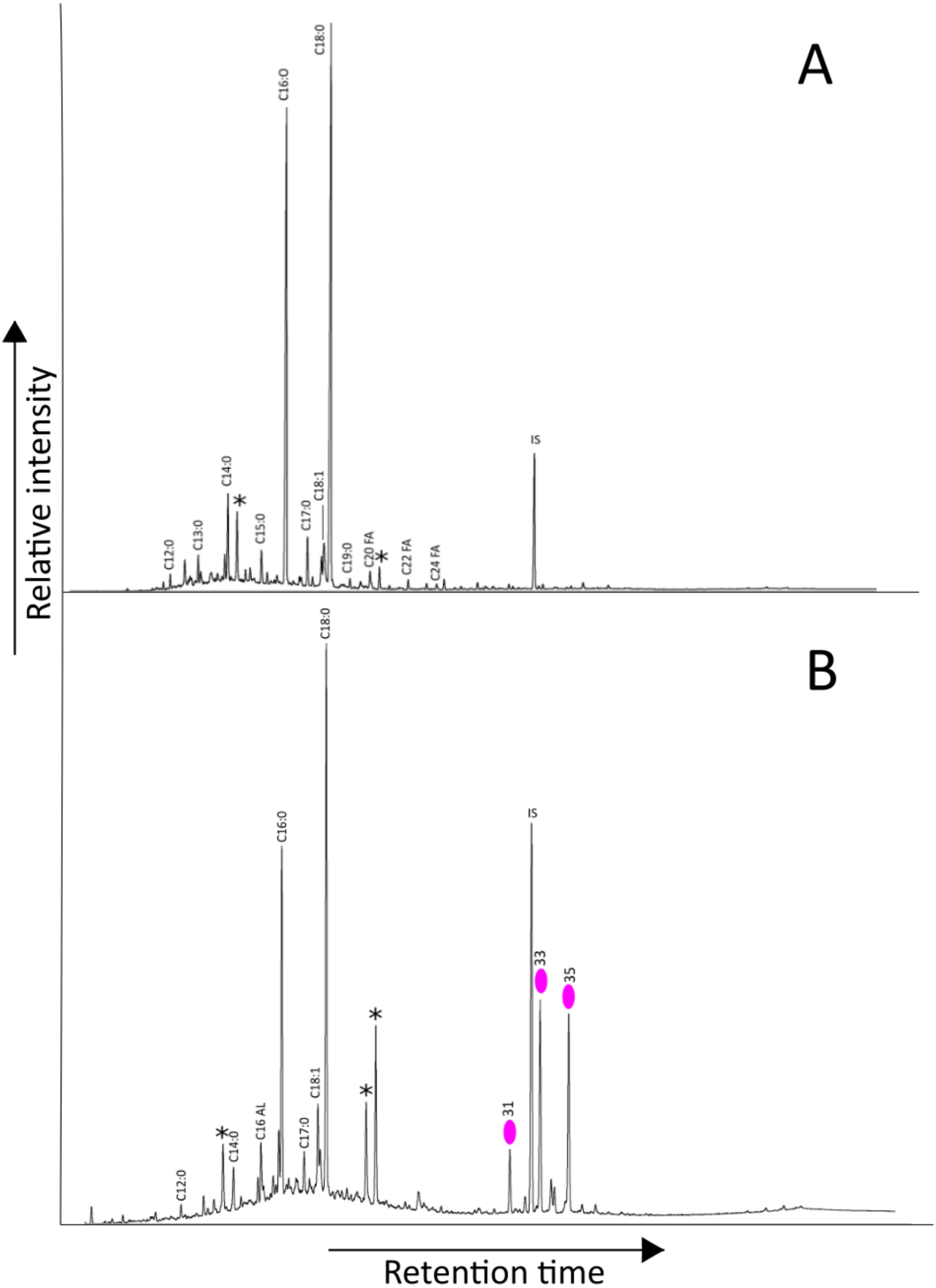


*Figure 66. High temperature gas chromatograms of the extracts NRBS80 (A; handmade pot) and NRBS1 (B; wheelmade pot) with a molecular signature indicative of presence animal fat, also heated over 300°C in chromatogram B. IS: internal standard; AL: alcohol; *: phthalate; FA: fatty acid; pink ellipse: ketone; with Cn: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

Other commodities

In three cooking pot extracts from Nora the presence of beeswax was identified, due to the detection of C_{42-50} wax esters with C_{46} dominating and C_{28-32} even numbered long-chain alcohols, with C_{30} dominating (fig. 64C; 67). The presence of beeswax in these extracts is likely but not definitive due to the lack of alkanes and long-chain fatty acids: the absence of alkanes, however, can be linked with beeswax degradation due to heating (Regert et al. 2001). In all the three extracts biomarkers of animal fats ($C_{16:0}$ and $C_{18:0}$ FFAs, C_{48-54} TAGs) are attested. NRBS10 (see fig. 67), dehydroabietic acid and methyl dehydroabietate have also been detected. These generally indicates presence of resins in the vessel, but the presence of these solely two compounds suggests possible contamination (Colombini et al. 2005; Rageot et al. 2015: 322; see discussion in section 7.1.3).

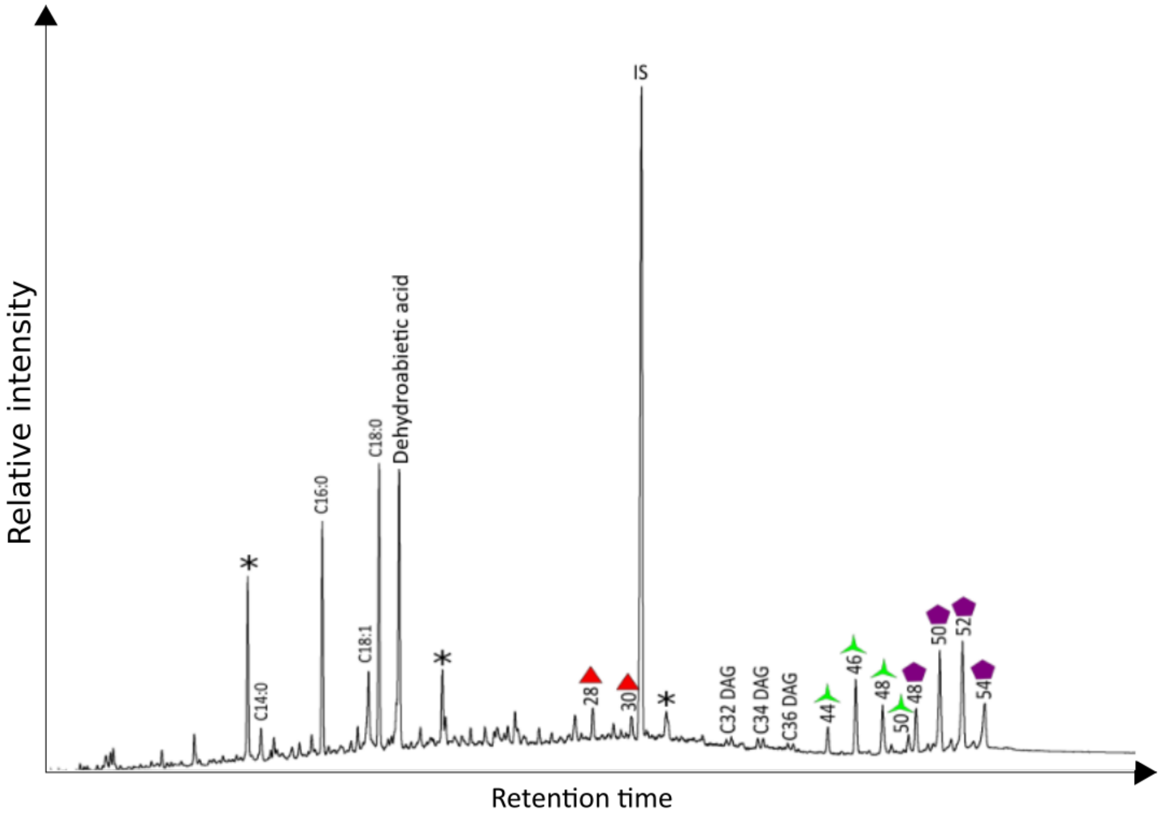


*Figure 67. High temperature gas chromatogram of the extract NRBS10 (wheelmade pot), indicative of a mixture of beeswax and animal fats. IS: internal standard; *: phthalate; red triangle: alcohol; green stars: wax esters; purple pentagon: triacylglycerol; DAG: diacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

The lipid extract NRBS49, shown in figure 68, contains a mixture of animal fat and plant lipids. Plant processing is suggested by the presence of C_{20-24} free fatty acids, C_{24-28} alcohols and C_{25-31} alkanes (Evershed et al 1991; Dunne et al. 2016), while the presence of $C_{16:0}$ and $C_{18:0}$ FFAs suggests animal product processing. It has not been possible to further define any additional detail or interpretation (e.g. plant species) for this extract.

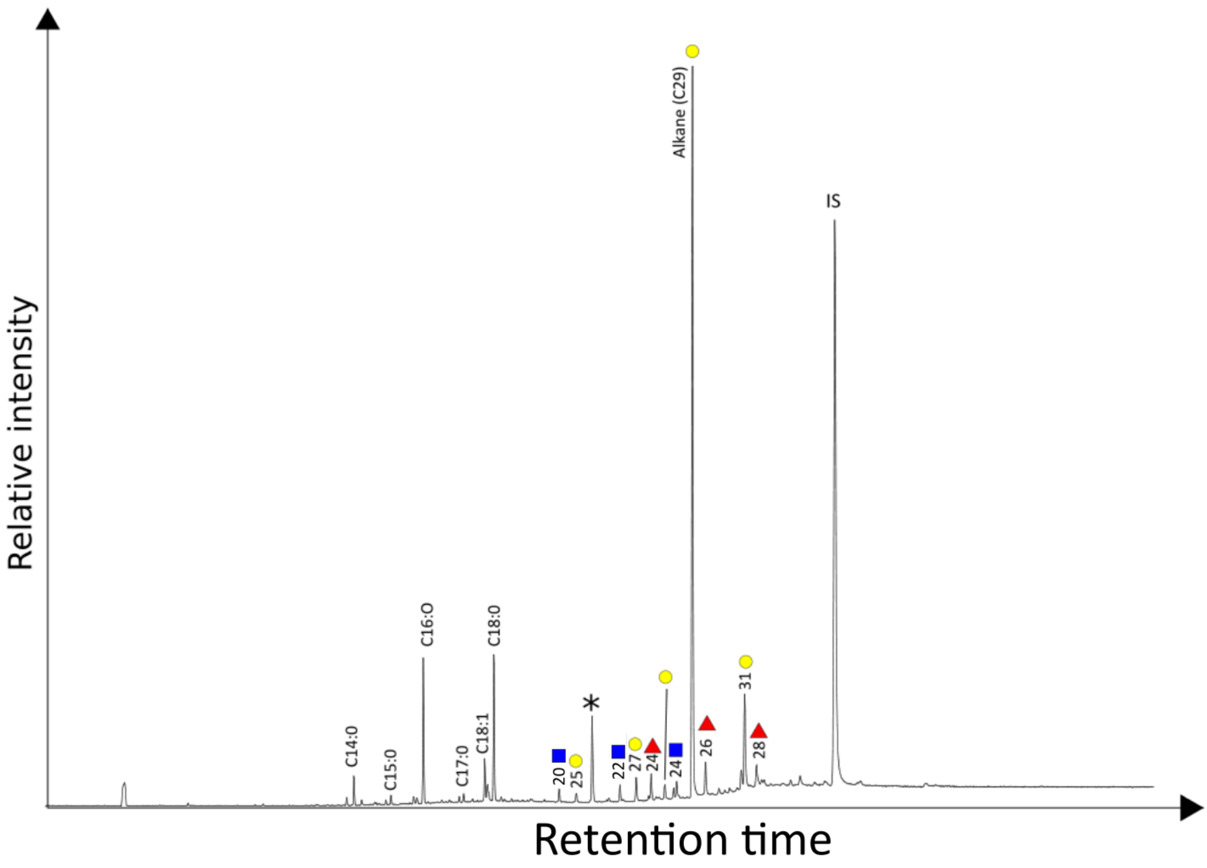


*Figure 68. High temperature gas chromatogram of the extract NRBS49 (wheelmade pot), indicative of leafy plants or fruit processing. IS: internal standard; *: phthalate; red triangle: alcohol; yellow circle: alkane; blue square: fatty acid; with* N: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.3.2.2 Basins and tripod bowls

The qualitative results in basins from Nora generally indicate that basins were not used to process animal products. Eight basin extracts out of 25 and two tripod bowl extracts out of 5 contained more than 5 µg/g of lipids. Several of the extracts contained fatty acids (typically C_{14-20}, $C_{16:0}$ dominating) in low concentrations, phthalates and alcohols (typically C_{16-20}, e.g. in fig. 69). These compounds could broadly suggest plant lipid processing, but contamination seems more likely as alcohols in extracts derived from plant lipids are normally in the C_{24-34} range (Tulloch 1976). Unfortunately, more detailed identification of commodities is not possible in these cases (*n* = 8).

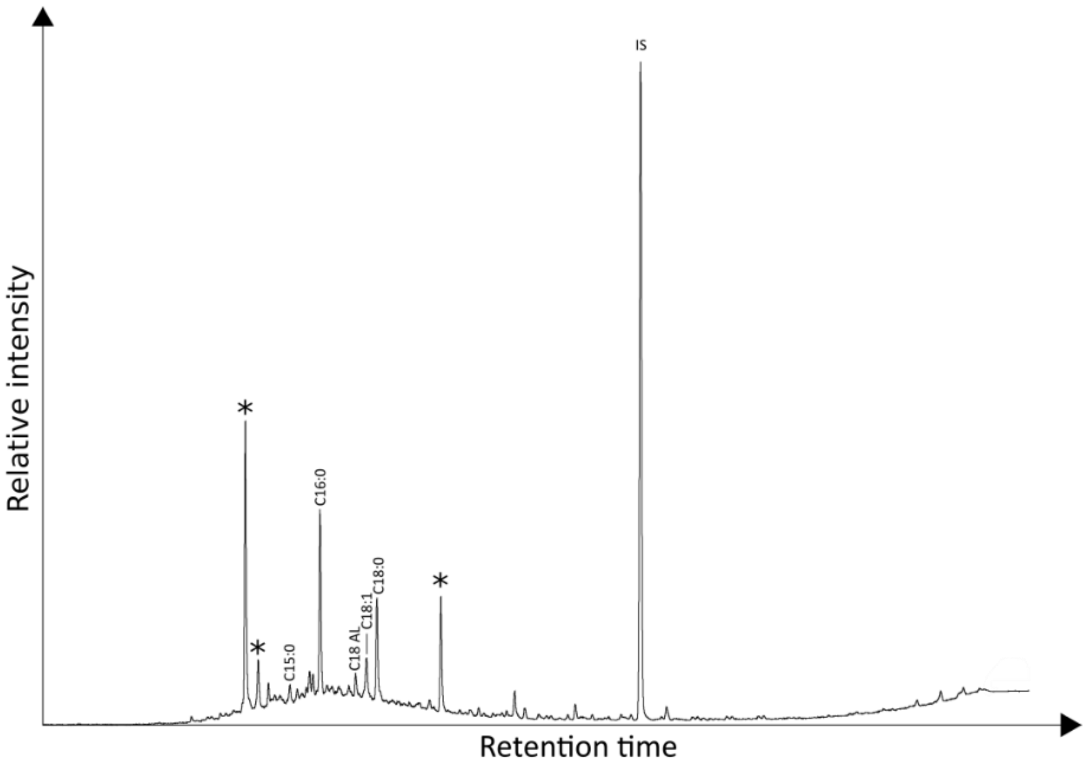


*Figure 69. High temperature gas chromatogram of the extract NRBS66 (basin), indicative of degraded animal fat. Contamination possible. IS: internal standard; AL: alcohol; *: phthalate; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

Two chromatograms of basins extracts show the distinctive lipid profile of beeswax (Roffet-Salque et al. 2015). In extract NRBS63 (fig. 70B) C_{40-50} wax esters, long-chain alcohols (even numbered, C_{24} to C_{34}) and alkanes ($C_{27,29,31}$), distinctive of beeswax processing, are attested (Roffet-Salque et al. 2015). In NRBS22 (fig. 70A), the chromatographic profile is less distinctive, due to the lower concentration of alcohols and alkanes, and the presence of squalene, suggesting partial contamination. However, despite concentration being low, beeswax can still be identified as present in the vessel according to the compounds identified (Regert et al. 2001). Both basins are grouped in the same subtype (BA6, following Campanella 2009b), i.e. basins with a re-entrant bulged and curved rim (*orlo ingrossato e rientrante*). This suggests a possible connection between these basins and beeswax, as it will be discussed in sections 7.2.2 and 7.1.2.

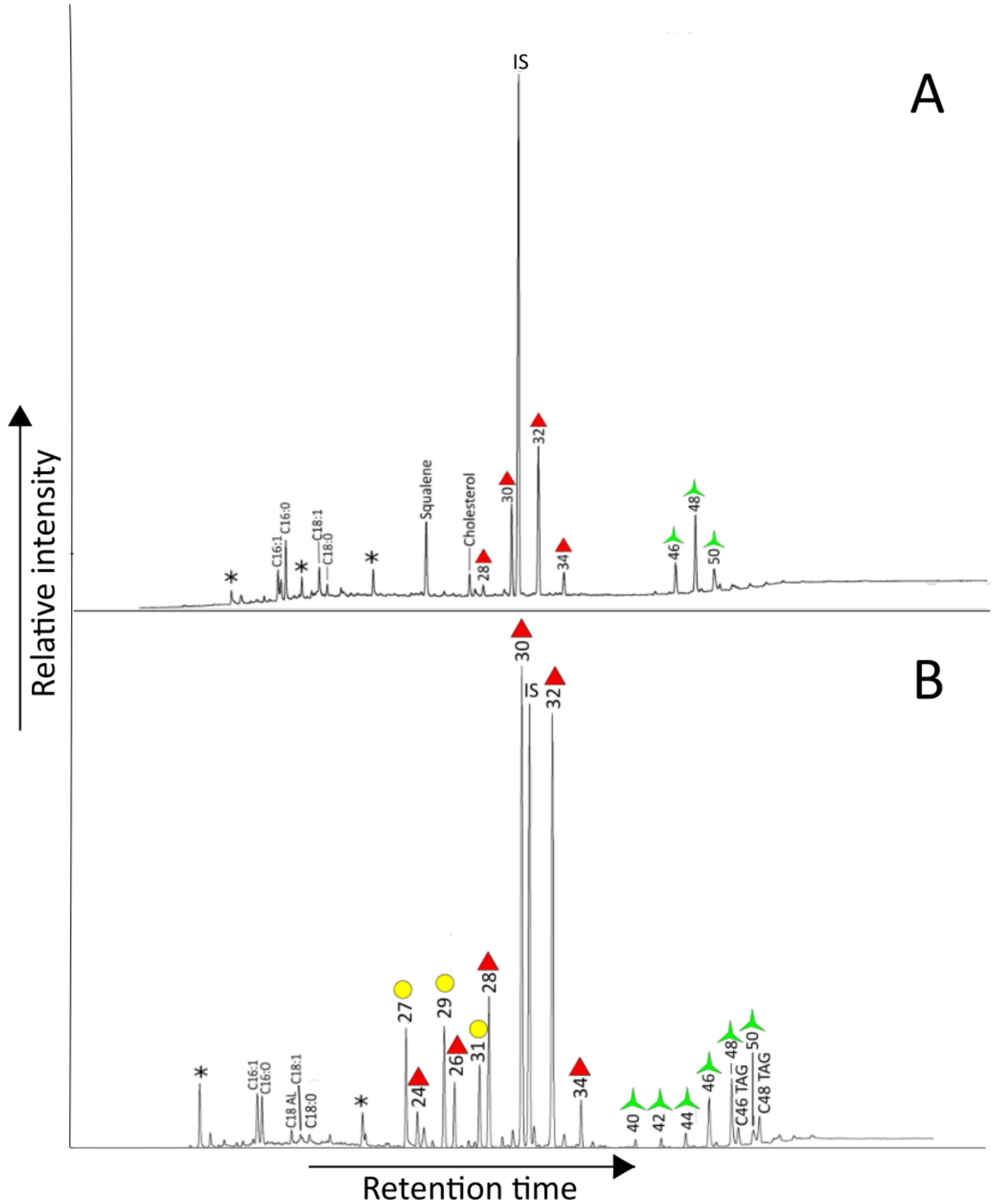


*Figure 70. High temperature gas chromatograms of the extracts NBRS22 (A); NRBS63 (B) indicative of the presence of beeswax (very low concentration in A). Both extracts come from basins. IS: internal standard; *: phthalate; red triangle: alcohol; yellow circle: alkane; green star: wax esters; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.3.2.3 Casseroles

The lipid extracts from casseroles in Nora are in general poorly concentrated. When containing more than 5 µg/g (*n* = 4), in three cases only C_{16-18} FFAs and phthalates are attested. The chromatogram showing the richest lipid assemblage is shown in figure 71. Free fatty acids (from C_{12} to $C_{20,}$ C_{18} dominating), C_{18} alcohol, alkanes (C_{27-31}), and plasticisers are attested in the extract. Animal fat is identified in this chromatogram (Christie 1978), but low concentration makes every interpretation labile.

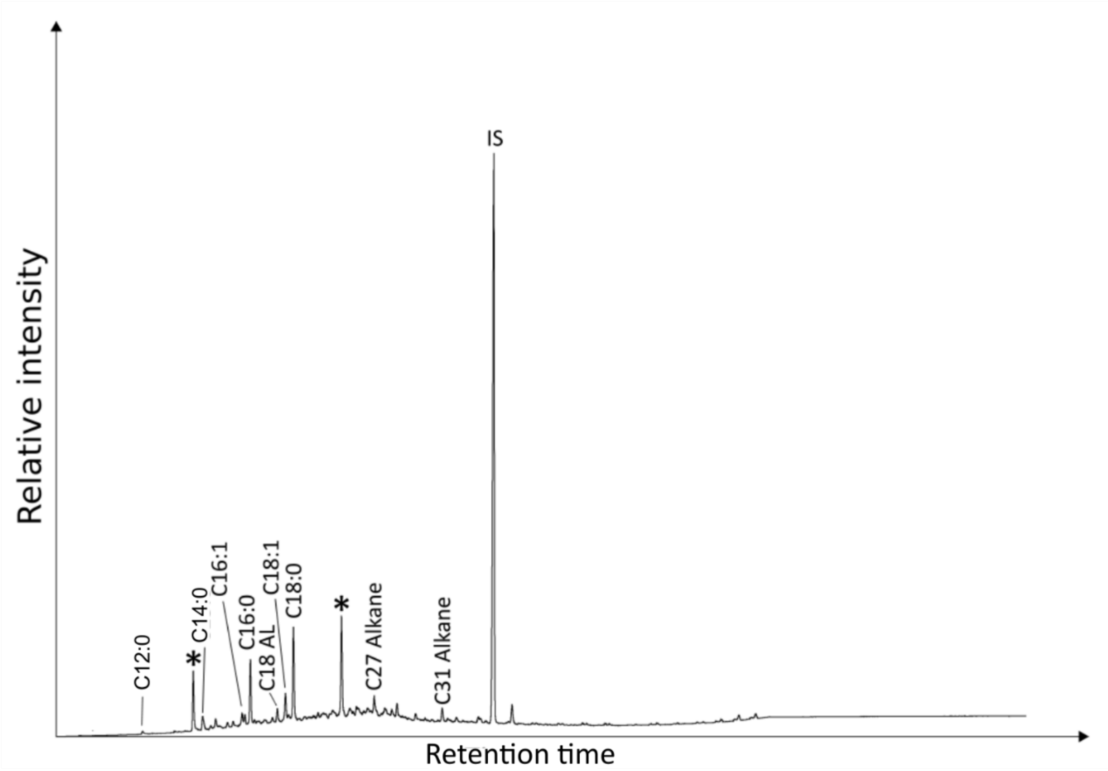


Figure 71. High temperature gas chromatogram of the extract NRBS29 (casserole), showing a very low concentration of animal fat (or contamination). IS: internal standard; AL: alcohol with Cn: *acyl carbon atoms number; *: phthalate; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.3.2.4 Baking trays

Three extracts of baking trays have been analysed from Nora. In the case of NRBS81 (fig. 72A) free fatty acids ranging from C_{12} to C_{20} ($C_{16:0}$ dominating), monounsaturated fatty acids $C_{16:1}$ and $C_{18:1}$, alcohols (C_{18-20}) and alkanes (C_{20}) have been detected together with phthalates from storing bags. Despite a probable external contribution, the combination of compounds suggests the processing of animal and plant products. Contamination is likely in the other extracts. The results of the extract NRBS35 (fig. 72B) has been discarded and excluded from comparisons (see table III, Appendix) due to the presence of short-chain TAGs such as tricaprylin (C27 TAG), commonly used in home products such as cleaners.

6.3.2.5 Ovens

Extracts of ovens from Nora (*n* = 6) contained no lipids.

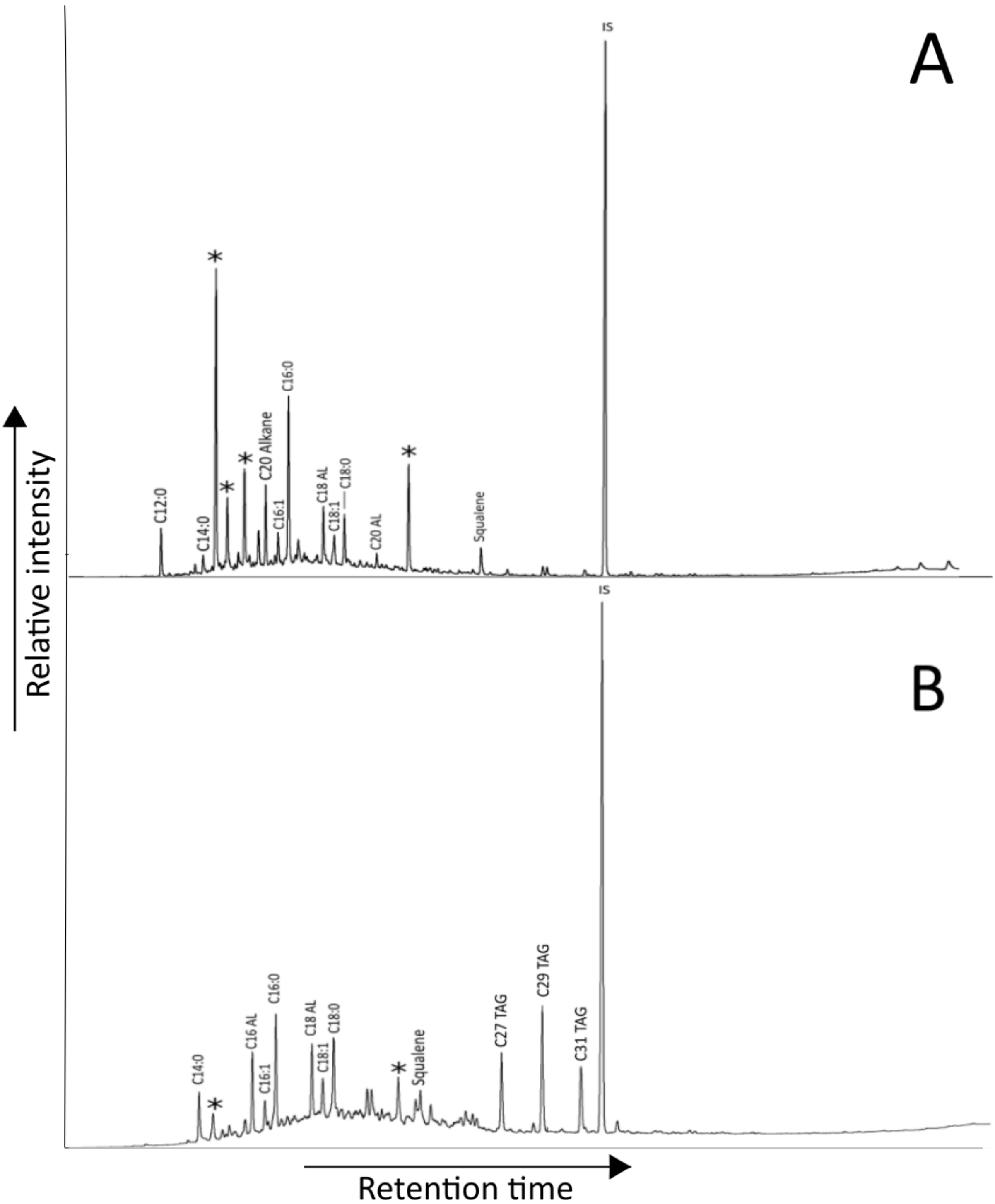


Figure 72. High temperature gas chromatograms of the extracts NRBS81 (A); NRBS35 (B). Both extracts come from baking trays. Animal fat is present but contamination is possible (A) or very probable (B). IS: internal standard; AL: alcohol; TAG: tracylglycerol; with Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.3.2.6 Chronological pattern

No chronological pattern among the extracts from Nora has been identified.

6.3.3 Summary

Nora represents a very interesting site due to the availability of a full ceramic catalogue, so a precise and detailed seriation of ceramic types. Faunal and environmental results are also available (see 6.3.1). However, as explained above, this sample set has also some limitations: for technical reasons - related to time, availability of vessels and organisation of storage rooms - sherds had to be chosen on the base of typology, not context (6.3.2).

Animal products seem to have not represented an important element in the diet of Phoenician and Punic Nora, or at least they were not commonly processed in the vessels analysed. Animal fats are not only absent in basins, tripod-bowls and in the majority of casseroles, but also in the large majority of cooking pots (comparison with other sites per vessel category in section 7.2).

When animal fats are attested, they are proved to derive predominantly from ruminant adipose products. Some dairy fat, however, seems to have been processed in eight extracts in small proportions, according to the detection of short chain fatty acids denoting the composition of milk fat (Copley et al. 2003). These results are consistent with faunal evidence, showing cows and ovicaprines as largely dominant over pigs (see 6.3.1, deer being not relevant at all), and are compared with the results from other sites in section 7.1.1.2. Animal products, according to the available sample, are processed largely in indigenous handmade cooking pots in the site. Not much is known about the role and presence of indigenous people and culture in Phoenician and Punic Nora (Bonetto 2014), but, according to the available evidence (burials, pottery assemblages) it is very likely that an indigenous population existed and contributed to the life of the settlement. Further discussion on wheelmade and handmade pots possible differences in use in 7.2.1.

Other commodities deserving attention in the case of Nora are leafy plants, beeswax and aquatic products. Biomarkers of leafy plants have been detected in one cooking pot extract, while in two more cooking pot extracts the identification of plant waxes is possible, but degraded beeswax appears as a more likely identification based on the lipid composition. Beeswax is attested in a minority of pots (two extracts, probably three) and in one subcategory of basins (two extracts). Beehive and plant products appear as commodities commonly processed at the site, but evidence allowing to push interpretation further is lacking on a site basis. Issues related to these commodities are discussed in section 7.1.2 and 7.1.3 together with results from other sites. Finally, the lack of aquatic biomarkers in Nora is particularly surprising, being a site located on a peninsula, clearly sea-related and where fishing has always been considered as a relevant activity (as partially confirmed also by faunal evidence [Sorrentino 2009]). The significance of this absence is discussed in section 7.1.1.4.

6.4 Olbia

Olbia, located on the homonymous gulf in the north-east of the island, was a Phoenician and then Greek settlement between the 7th and 6th centuries BCE, completely rebuilt and redeveloped in the 4th century BCE and inhabited until today (see 3.2.4). The site codes for extracts from Olbia are two: "OM" for the ex-Mercato excavation, and "OLB" for other excavation areas.

6.4.1 Faunal and palaeoenvironmental evidence

Extensively published faunal or environmental studies are absent for Olbia. Faunal data have been analysed only in two small contexts (Manconi 1990; 2000b; Wilkens 2000). Data from the storage room of via delle Terme (Wilkens 2000) have been described in detail in Chapter 2 (2.2.2.6), since they are among the most detailed data about fish products from the whole island for the Phoenician and Punic period. The stored amphoras contained bones of hundreds of fishes from the gulf, and among them 321 *Centracanthus cirrus* (curled picarel) and 46 *Mugil auratus* (golden grey mullet). The other faunal remains analysed and published come from a sacred area located in Corso Umberto (Manconi 1990). In this context only 16 fragments come from Punic layers: ovicaprines and bovines are the most numerous (6 fragments each) followed by pigs, red deer and horses (2 fragments each).

Despite being limited to a few contexts and remains, the available evidence (Manconi 2000, Wilkens 2000), published and unpublished, allows archaeologists to outline a general picture of the economy and subsistence practices in the Punic city, as portrayed by Cavaliere (2010b). The settlement was probably surrounded by woods and natural vegetation, as established by the numerous wild animal remains found in dumps in the urban centre (Cavaliere 2010b: 1745). The economy was mainly agropastoral, but hunting was often practised, and fishing is assumed to have been a relevant part of local economy. The available data is limited, so that it is not easy to expand upon these general statements. However, discussions with archaeologists who have been involved in nearly every excavation in the city in the last thirty years have enabled me to contextualise results based on the available information.

6.4.2 Pottery assemblage and general information about lipid results

A total of 83 sherds from Olbia have been analysed (table 13). Due to the nature of the archaeological record of the settlement (see 3.2.4), nearly all of them (n = 80) come from the Punic phase. In particular (n = 77) they come from a domestic context named "ex Mercato", dated between the 4th and the 2nd centuries BCE (Pisanu 2006; sample name: OM). The sherds have been selected together with excavators Rubens D'Oriano and Giuseppe Pisanu, and they are precisely dated based on the archaeological context and comparisons with published materials (Cavaliere 2010a, b). From the "ex Mercato" excavation, 50 cooking pots, 8 handmade cooking pots, 9 casseroles and 10 basins have been analysed. A total of 3 cooking pots, 2 basins and 1 baking trays from other excavated contexts in the city has been analysed (sample name: OLB; details in the Appendix, table IV). These targeted contexts are: the closed context of Via Cavour - a filled pit excavated into the rock – being the only archaic context excavated in the city; and the Punic phases of the context of via de Filippi, offering materials from the Punic to the Roman period (see D'Oriano 2017 with references).

Table 13 Number of sherds per excavation area and vessel category, from the site of Olbia

Number of sherds	Wheelmade pots	Handmade pots	Casseroles	Basins	Baking trays	Total
ex Mercato (4th -2nd centuries BCE)	50	8	9	10	0	77
Via Cavour (7th – 6th centuries BCE)	1	0	0	2	0	3
Via de Filippi (3rd – 2nd centuries BCE)	1	1	0	0	1	3

Available information for each analysed sherd from Olbia is summarised in table 14. This information includes excavation context with chronology and vessel type. In the Appendix (table IV) analyses undertaken, lipid concentration, identified compounds, $\delta^{13}C$ values and identified commodities for each sherd are listed.

Table 14 List of analysed sherds from Olbia, with context, type and chronology of context.

Sample name	**Context**	**Chronology**	**Vessel category-type**
OLB1	Via de Filippi	3rd-2nd centuries BCE	Baking tray
OLB2	Via de Filippi	3rd-2nd centuries BCE	Handmade pot
OLB3	Via de Filippi	3rd-2nd centuries BCE	Wheelmade pot, bottom
OLB4	Via Cavour	7th-6th centuries BCE	Wheelmade pot
OLB5-6	Via Cavour	7th-6th centuries BCE	Corynthian basins
OLB7	Via de Filippi	4th century BCE	Clay matrix
OM1	Ex Mercato	3rd century BCE	Basin
OM2	Ex Mercato	2nd century BCE	Wheelmade pot
OM3	Ex Mercato	2nd century BCE	P6 pot
OM4	Ex Mercato	4th-3rd centuries BCE	"Ear" pot (handmade)
OM5	Ex Mercato	4th-3rd centuries BCE	P6 pot
OM6	Ex Mercato	4th-3rd centuries BCE	P6 pot
OM7	Ex Mercato	4th-3rd centuries BCE	Wheelmade pot
OM8	Ex Mercato	2nd century BCE	Casserole
OM9	Ex Mercato	2nd century BCE	Wheelmade pot
OM10	Ex Mercato	2nd century BCE	Wheelmade pot, bottom
OM11	Ex Mercato	2nd century BCE	Wheelmade pot
OM12	Ex Mercato	2nd century BCE	Wheelmade pot
OM13	Ex Mercato	2nd century BCE	Casserole
OM14	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Basin
OM15	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM16	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM17	ex Mercato	End 4th – turn of 3rd centuries BCE	Basin
OM18	ex Mercato	End 4th – turn of 3rd centuries BCE	P6 pot
OM19	ex Mercato	End 4th – turn of 3rd centuries BCE	Casserole
OM20	ex Mercato	End 4th – turn of 3rd centuries BCE	P6 pot
OM21	ex Mercato	3rd century BCE	Basin
OM22	ex Mercato	3rd century BCE	Basin
OM23	ex Mercato	3rd century BCE	Wheelmade pot
OM24	ex Mercato	End 3rd-turn of 2nd centuries BCE	Wheelmade pot

OM25	ex Mercato	End 3rd-turn of 2nd centuries BCE	Wheelmade pot
OM27	ex Mercato	End 4th – turn of 3rd centuries BCE	Basin
OM28	ex Mercato	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM29	ex Mercato	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM30	Ex Mercato	First half 3rd century BCE	Wheelmade pot
OM31	ex Mercato	2nd century BCE	Wheelmade pot
OM32-35	ex Mercato	End 4th – turn of 3rd centuries BCE	“Ear” pot, handmade
OM36	ex Mercato	End 4th – turn of 3rd centuries BCE	Greek style pot (chytra)
OM37	ex Mercato, dump	End 4th – turn of 3rd centuries BCE	Basin
OM38	ex Mercato	End 4th – turn of 3rd centuries BCE	“S profile” pot?
OM39	ex Mercato	2nd century BCE	Casserole
OM40	ex Mercato	2nd century BCE	“Ear” pot, handmade
OM41	ex Mercato, dump	End 4th-3rd centuries BCE	Jug
OM42	ex Mercato	End 4th-3rd centuries BCE	“Ear” pot, handmade
OM43	ex Mercato	End 4th-3rd centuries BCE	Casserole
OM44-46	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM47	ex Mercato	End 4th-3rd centuries BCE	“Ear” pot, handmade
OM48	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM49	ex Mercato	End 4th-3rd centuries BCE	Casserole
OM50	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM51	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM52	ex Mercato	End 4th-3rd centuries BCE	Casserole
OM53	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM54	ex Mercato	End 4th-3rd centuries BCE	Casserole
OM55	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM56	ex Mercato	End 4th-3rd centuries BCE	Wheelmade pot
OM57	ex Mercato	End 4th-2nd centuries BCE	Wheelmade pot
OM58	ex Mercato	End 4th-2nd centuries BCE	Wheelmade pot
OM59	ex Mercato	End 4th-2nd centuries BCE	Wheelmade pot
OM60	ex Mercato	3rd-2nd centuries BCE	Wheelmade pot
OM61	ex Mercato	3rd-2nd centuries BCE	Wheelmade pot
OM62	ex Mercato, dump	End 4th – turn of 3rd centuries BCE	Basin
OM63	ex Mercato, dump	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM64	ex Mercato, dump	End 4th – turn of 3rd centuries BCE	Basin
OM65	ex Mercato, dump	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM67	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM68-69	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Casserole
OM70	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Wheelmade pot
OM71-81	ex Mercato, pit	End 4th – turn of 3rd centuries BCE	Wheelmade pots

6.4.2.1 Quantitative results

The mean lipid concentration and the recovery rate of sherds deriving from the area of Olbia "ex Mercato", per vessel category, are shown in fig. 73. The lipid concentration in this context was far lower than at the other sites under investigation. The mean lipid concentration is 18 µg/g for cooking pots (standard deviation 54 µg/g, maximum value 165 µg/g), with 38% recovery rate. The mean lipid concentration is 19 µg/g for wheelmade cooking pots (island mean is 73 µg/g) and 15 µg/g for handmade cooking pots (island mean 96 µg/g). The mean lipid concentration is 1.3 µg/g for basins (island mean 6 µg/g) and 0.4 µg/g for casseroles (island mean 27 µg/g). In both cases recovery rate is 0%. Lipid preservation is thus generally poor at the site compared to the island mean.

Notably, it seems that these poor preservation conditions primarily affected the Via del Mercato excavation but not other areas of the city. The six sherds sampled from other contexts (three cooking pots, one baking tray and two basins) provided lipid concentrations more aligned with the general trends: 34.7 µg/g for the tray, 42 µg/g for pots, 3.6 µg/g for basins (one of the basins showed evidence of contamination). Despite the different number of samples, this data suggests that only a portion of Olbia is affected by unfavourable organic preservation conditions.

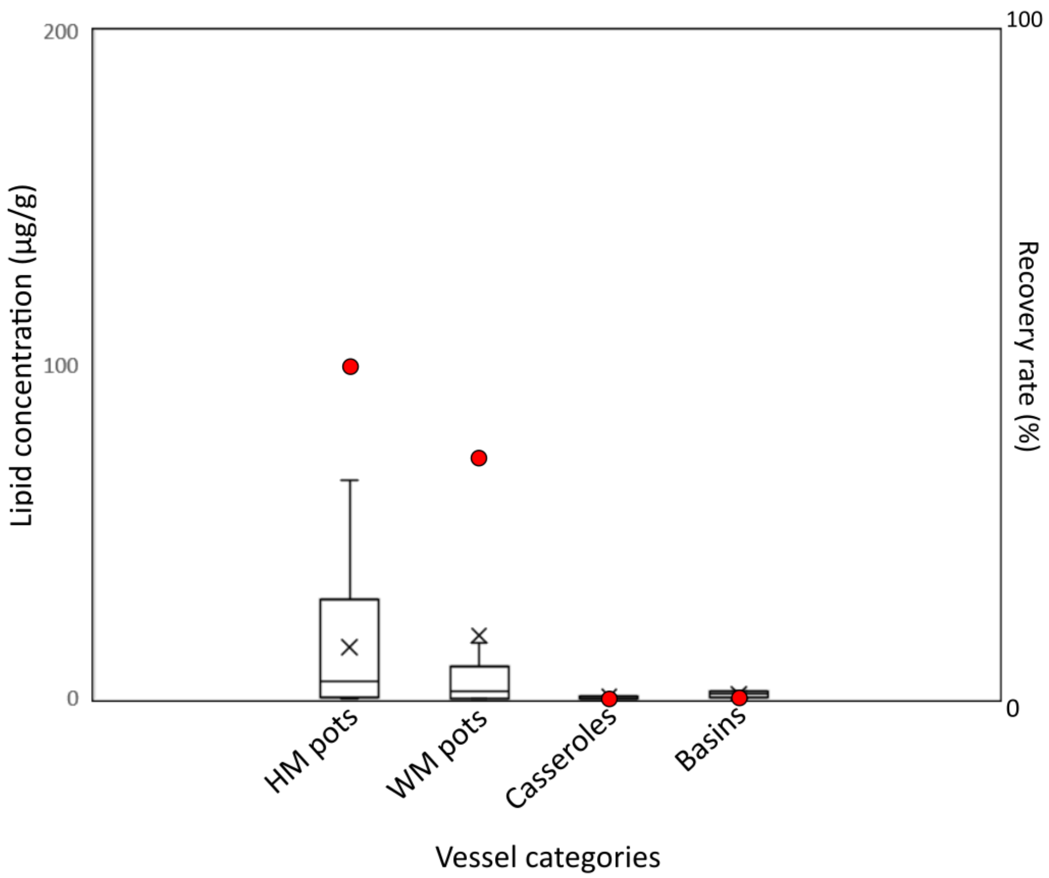


Figure 73. Box plots showing lipid concentration (X = mean) and recovery rate (red dot) of the analysed extracts coming from the context of Olbia "ex Mercato", per vessel category. HM pots: 8 samples; WM pots: 50; casseroles: 9; basins: 9.

This lower lipid preservation is probably due to environmental conditions, but no clear hypothesis exists to justify this peculiarity. Olbia, in contrast to other settlements under investigation and other parts of Sardinia, is founded on a soil constituted by granite, degraded and crumbled along the centuries (Carmignani et al. 2008). It is unclear, basing on the existing bibliography, if the granite matrix could have in some way impacted on lipid preservation. Poor lipid preservation could also be due to other reasons, more difficult to be identified. As mentioned, it seems that these poor preservation conditions primarily affected the Mercato excavation (77 sherds analysed) but not other areas of the city (6 sherds analysed). Sherds sampled from other contexts provided lipid concentrations more aligned with the general trends. But existing evidence hinders to state how it could have happened. The excavators explained that "soil was similar in all contexts but in the Via del Mercato one it was darker. Ditches there have been also used as dumps, so that it became richer in organic contribution" (R. D'Oriano, *pers. comm.*). This is insufficient to state any explanation. Due to the poor and unusual lipid preservation, little can be stated about Olbia results, making further intra-site interpretation or comparison with the other sites more complex and tentative, as it will be discussed in Chapter 7.

6.4.3 Qualitative results per vessel type

6.4.3.1 Cooking pots

In Olbia, the majority of cooking pots provided no or very little lipid (see Appendix, table IV). Identified compounds in pot extracts where lipid concentration is between 5 and 10 µg/g (*n* = 10) are typically $C_{16:0}$ and $C_{18:0}$ FFAs and $C_{18:1}$ monounsaturated free fatty acid, as in the chromatogram shown in figure 74. Degraded animal fat can be identified in these chromatograms.

However, a minority of cooking pot extracts provided relatively high lipid concentrations. In most of the pots containing significant concentration of lipids (more than 10 µg/g, *n* = 10) only degraded animal fat was preserved (fig. 76), typically with C_{14-20} FFAs, where $C_{16:0}$ and $C_{18:0}$ free fatty acids dominate, $C_{18:1}$ monounsaturated free fatty acid, C_{32-36} diacylglycerols and C_{48-54} triacylglycerols. The lipid concentration and preservation largely varies (see examples in fig. 76). In three extracts containing degraded animal fat LCFAs are attested, from C_{20} to C_{26} carbon atoms (see fig. 74B and 76A). As mentioned, these LCFAs likely originated directly from animal fats, incorporated via routing from the ruminant animal's plant diet (Whelton et al. 2018; Halmemies-Beauchet-Filleau et al. 2013; 2014).

Compound-specific stable carbon isotope analysis was carried out on 10 cooking pot extracts from Olbia. Nine of the ten contained ruminant carcass fat (fig. 75). The $\Delta^{13}C$ values ranges from -3.1 and 0.2‰. Isotope values in one pot extract are consistent with non-ruminant product processing ($\Delta^{13}C$ = 0.2‰). Mixed carcass and dairy fat was likely processed in another cooking pot (OLB3, wheelmade pot, $\Delta^{13}C$ = -3.1‰), but the presence of oil (with $C_{16:0}$ fatty acids more abundant than $C_{18:0}$) cannot be excluded.

No aquatic biomarkers ($\geq C_{20}$ APAAs; IFAs, including TMTD; DHYAs) have been found in extracts of cooking pots containing animal fat (*n* = 10) from Olbia.

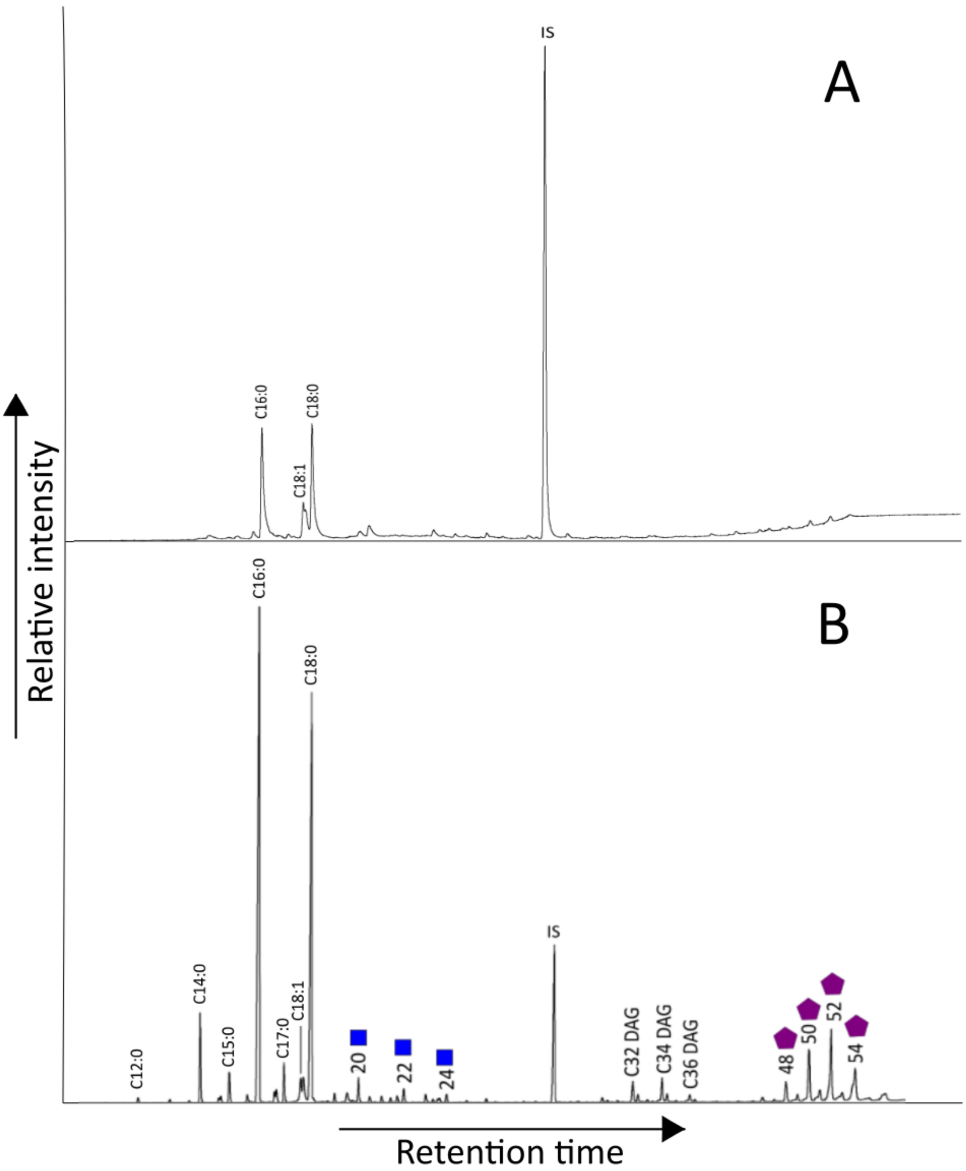


Figure 74. High temperature gas chromatogram of the extracts OM45 (A, wheelmade pot) and OLB3 (B, wheelmade pots), indicating presence of degraded animal fat. IS: internal standard; blue square: free fatty acid; DAG: diacylglycerol; purple pentagon: triacylglycerol; with Cn: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.

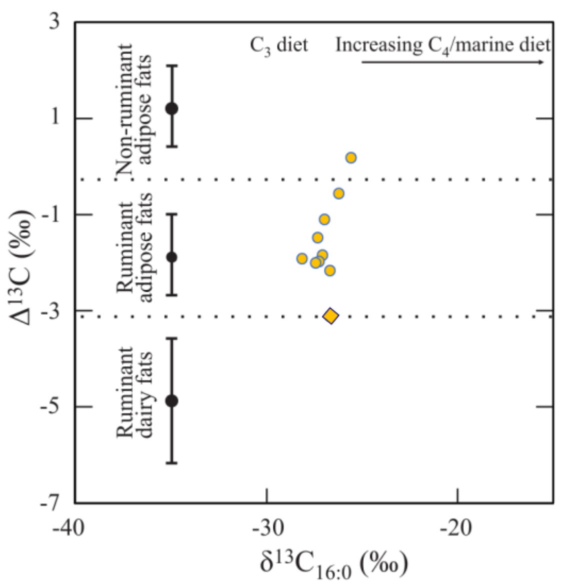


Figure 75. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for pot extracts from Olbia. Extracts possibly not containing exclusively animal fat are indicated with a square. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

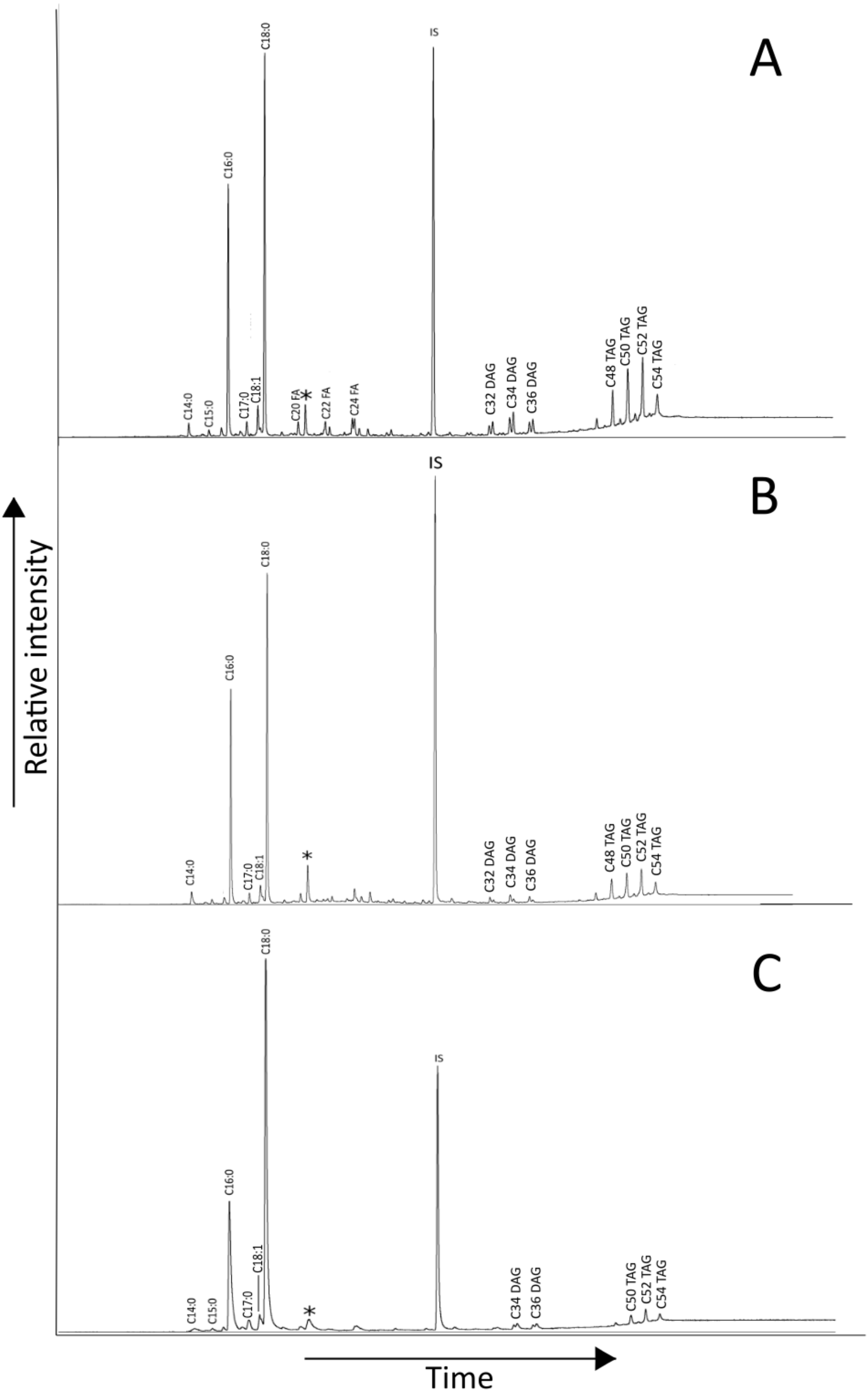


*Figure 76. High temperature gas chromatograms of the extracts OM2 (A, wheelmade pot); OM12 (B, handmade pot); OM73 (C; wheelmade pot), indicative of presence of degraded animal fat. IS: internal standard; *: phthalate; FA: free fatty acid; DAG: diacylglycerol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

In three cooking pot extracts (e.g. fig. 77; 94A), beeswax was identified as indicated by the presence of $C_{42\text{-}50}$ wax esters, $C_{26\text{-}32}$ long-chain alcohols (C_{30} dominating), long-chain free fatty acids (typically $C_{20\text{-}24}$) and $C_{27\text{-}31}$ alkanes (Roffet-Salque et al. 2015). In all the three extracts beeswax was mixed with animal fats, as attested by the presence of $C_{14\text{-}18}$ FFAs and $C_{48\text{-}54}$ TAGs (Evershed et al. 2002).

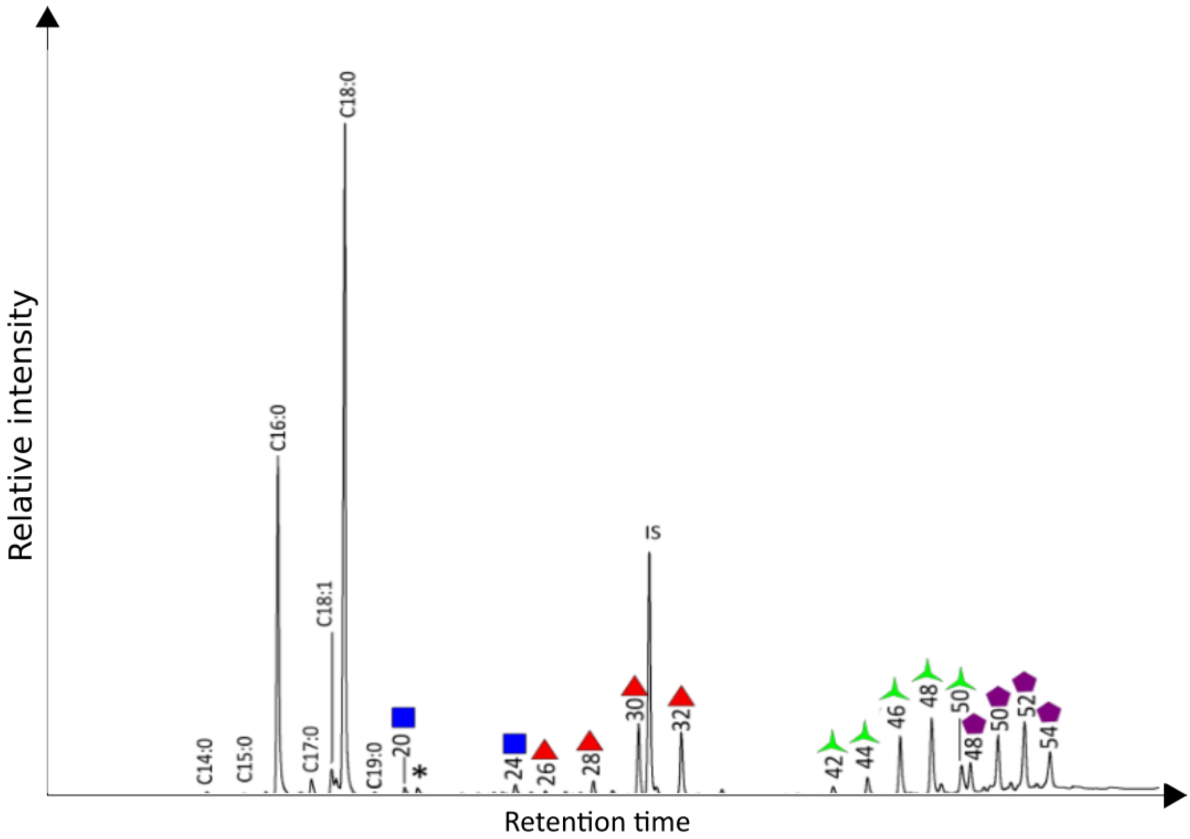


*Figure 77. High temperature gas chromatogram of the extract OM42 (handmade pot). IS: internal standard; *: phthalate; red triangle: alcohol; blue square: fatty acid; green star: wax esters; TAG: triacylglycerol; with* N: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

In the extract OM50 (fig. 78) the lipid distribution could be broadly linked to plant waxes due to the presence of $C_{20\text{-}32}$ LCFAs with C_{30} dominating, $C_{26\text{-}34}$ alcohols with C_{32} dominating, $C_{27\text{-}31}$ alkanes and wax esters $C_{44\text{-}46}$ in low concentration. A more precise identification of plant species is not possible in this case (Tulloch 1976; Copley et al. 2005b).

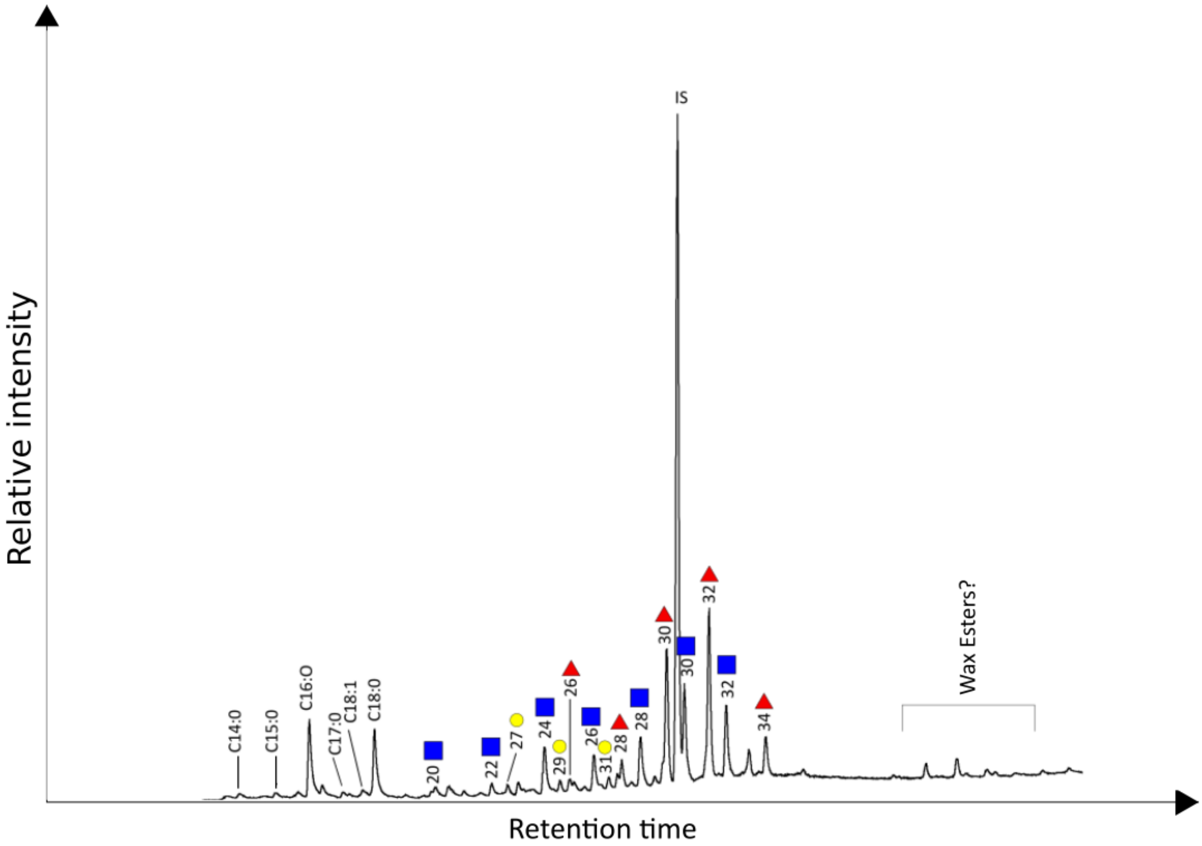


*Figure 78. High temperature gas chromatogram of the extract OM50 (wheelmade pot), indicative of presence of leafy plants. IS: internal standard; *: phthalate; red triangle: alcohol; yellow circle: alkane; blue square: fatty acid; with* N *carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.4.2.2 Basins

Extracts of basins from Olbia analysed (*n* = 10) contained no lipids.

6.4.2.3 Casseroles

Extracts of casseroles from Olbia analysed (*n* = 9) contained no lipids.

6.4.2.4 Baking trays

The only baking tray extract analysed from Olbia (OLB1, fig. 79), represents an exception compared to other baking tray extracts. Together with animal fat (saturated free fatty acids C_{14} to C_{18}, monounsaturated $C_{18:1}$, C_{50-54} triacylglycerols (Mottram et al. 1999)) and dehydroabietic acid, possibly indicating coniferous plant resins ((Colombini et al. 2005)), beeswax has been detected, indicated by the presence of C_{42-48} wax esters with C_{46} dominating, long-chain alcohols (C_{24-32}), long-chain fatty acids (C_{20-26}) and C_{27-31} alkanes (Roffet-Salque et al. 2015). No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in the tray.

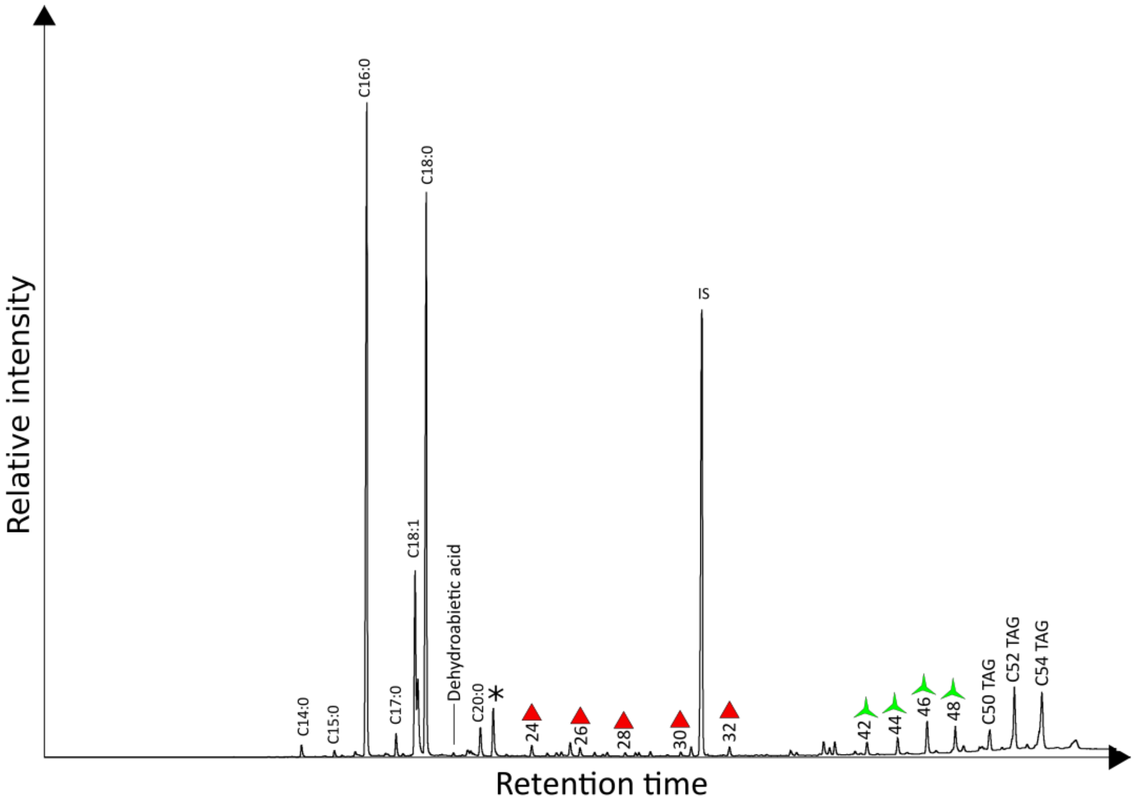


*Figure 79. High temperature gas chromatogram of the extract OLB1 (baking tray), indicative of animal fat mixed with beeswax. IS: internal standard; *: phthalates; TAG: triacylglycerol; red triangles: alcohols; green stars: wax esters; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.4.2.6 Chronological pattern

No chronological pattern among the extracts from Olbia has been detected.

6.4.4 Summary

In Olbia, 83 sherds have been analysed, but poor lipid preservation precluded broad interpretations regarding culinary practices in the site. As a settlement inhabited by Phoenicians, Greeks and then refounded in the 4th century by Carthage (probably with the contribution of both people from the hinterland and North African migrants, see 3.2.4), a different use of some vessel categories would be possible, as it would be possible a difference in diet. But unfortunately it cannot be established or argued on the basis of the results obtained, since poor lipid concentration appears due to environmental reasons.

The results for cooking pots are qualitatively consistent with other sites: animal products are the most attested commodity, and the large majority of them has ruminant carcass origin. The presence of beeswax in five of the cooking pot extracts seems to be meaningful, being the general lipid preservation quite poor (comparison with other sites in section 7.1.2). The lack of lipids in basins may be in part due to the localised environmental conditions, but it supports the generally poor lipid concentration of basins (comparison with other sites in section 7.2.2). The lack of lipids in casseroles, in contrast, is an exception in the general picture. In Olbia, less lipids are found in casseroles compared to basins, this being a unique case in my study: it could be random, or it could be due to a different use of casseroles (and possibly basins) in Olbia compared to other Punic sites in the island. This evidence is discussed in section 7.2.3.

Finally, the lack of aquatic biomarkers is particularly surprising for Olbia, a city totally projected on the sea and an archaeological context where fish bones have been detected and studied (Wilkens 2000). This data is discussed in Chapter 7 (7.1.1.4).

6.5 Sant'Antioco

Sant'Antioco, known as *Sulky* (SLK) in the Phoenician language, is a Phoenician and Punic settlement founded in the 8th century BCE on the island of Sant'Antico, south-west Sardinia. It was the most important settlement of Phoenician Sardinia, possibly having urban status. The area has been inhabited until today (see 3.2.5). The site code for extracts from Sant'Antioco is "SAC".

6.5.1 Faunal and palaeoenvironmental evidence, past lipid evidence

Sant'Antioco/Sulky is one of the most investigated settlements in Phoenician and Punic Sardinia. Robust faunal data is available from different excavation areas (Wilkens 2005, 2008; Carenti 2013, 2016). Since some of this faunal data is among the most relevant for the whole Phoenician and Punic Sardinia, it has been already described and discussed in Chapter 2. To summarise, the most comprehensive data about avifauna come from Sant'Antioco (Carenti 2016), revealing that chicken started to be highly dominant compared with other birds since the 3rd century BCE (2.2.2.4). A detailed study about fish and fishery resources have also been published for Sant'Antioco and discussed above (2.2.2.6). It offered a complex view of sea exploitation in the settlement, identifying gilthead seabream and Mediterranean mussels (*Mytilus galloprovincialis)* as the most relevant species. This also indicates the existence and exploitation of lagoon environments (Carenti 2013). Other relevant information for animal consumption and exploitation in Sardinia come from Sant'Antioco: the most relevant evidence of dog, dormouse (2.2.2.4) and cuttlefish consumption (2.2.2.6) come from this settlement.

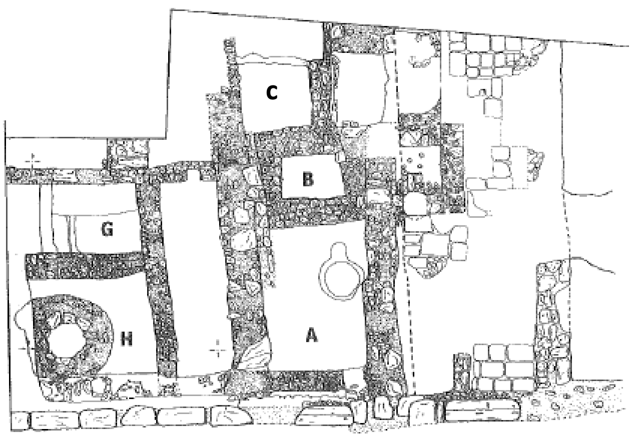


Figure 80. The archaeological area of Cronicario in Sant'Antioco, from Campanella 2008. The targeted context (US 500) is located in room B.

For the aims and focus of this project, two contexts in which faunal remains have been studied and published are of particular interest. The first is the urban dump (US 500) in the area of Cronicario (fig. 80). Ceramic sherds analysed for this project come from this landfill for the vast majority (93%). Faunal evidence was studied and published (Wilkens 2008). Results are summarised in table 15. In the opinion of the archaeozoologist who published the faunal assemblage, this context of limited usefullness to understand culinary practices. In fact, in dump US 500 dietary remains are mixed with animal bones related to craftmanship (Wilkens 2008: 249). Based on the number of fragments (NISP), ovicaprines constitute more than the 35% of the assemblage, with bovines as the second group (26%) and pigs as the third (17%). Red deer is the fourth group here (11%) but the author explicitly says that most of the identified fragments were not related to diet, since they are antlers used for tool production (Wilkens 2008: 252).

Table 15 Number of fragments (NISP) of faunal remains recovered in two different contexts from the Cronicario area in Sant'Antioco. US 500 (from Wilkens 2008, tabella 1) and Room IIF (from Carenti and Wilkens 2006, tabella 5 and 6).

	US 500 (dump, 5th century BCE)		Room IIF (Phoenician phase)		Room IIF (Punic phase)	
	No. Fragments	%	No. Fragments	%	No. Fragments	%
Shellfish	17		198		779	
Sea urchin (*Paracentrotus lividus)*			76		2	
Crab					10	
Fish	1		340		385	
Bird			19		100	
Rodents			12		43	
Mongoose	1	0.32				
Prolagus sardus			2	3.70		
Dog	5	1.60	1	1.85	4	1.19
Pig	58	18.64	20	37.03	76	22.75
Red deer	36	11.57				
Cattle	82	26.36	10	18.51	39	11.67
Muflon (*ovis musimon)*	5	1.60				
Sheep	26	8.36			26	7.78
Goat	18	5.78			3	0.89
Ovicaprine (sheep/goat)	79	25.40	21	38.88	186	55.68
Donkey	1	0.32				

The second context is Room IIF, very close to the landfill US 500. The faunal remains found here are food leftovers, offering a more precise picture of animal consumption in the settlement (Carenti and Wilkens 2006: 179). Faunal remains identified in Room IIF are summarised in table 15. The assemblage is constituted mainly by molluscs, fishes and domestic animals. The authors do not deal in depth with fish and shellfish, but they state that the most numerous shellfish had culinary purposes: gasteropods as *patellae, trochidae* (top-snails), clams (*Venerupis decussata; Glycymeris).* Regarding domestic animals, basing the number of fragments (NISP) the amount of pigs (37%) and ovicaprines (39%) was nearly the same in the Phoenician phase. Bovines follows as the third group (18,5%). In the Punic phase ovicaprines become largely predominant, constituting 64% of domestic animals remains, followed by pigs (23%) and bovines (12%).

The authors conclude their study stating that marine resources were collected mainly for culinary practices and played a relevant role in the diet, despite fishing appearing as a secondary activity in the life of the settlement. Hunting, on the contrary, appears as an irrelevant activity in Sant'Antioco, based on faunal evidence (Carenti and Wilkens 2006: 181).

Detailed palaeobotanical studies are absent for Sant'Antioco. Faunal evidence, however, suggests the existence and exploitation of lagoon environments around the settlement.

In addition, in Sant'Antioco Phoenician and Punic cookware has been targeted by organic residue analysis in the past (see Chapter 4, section 4.4). Using GC-MS, Pecci (2008) analysed eight sherds from seven vessels that came from the urban dump US 500 (the same context targeted in the present research). She identified lipids, and specifically $C_{16:0}$ and $C_{18:0}$, in every vessel; unfortunately, GC-C-IRMS was not undertaken. Hence, the distinction between ruminant and non-ruminant fats, dairy and carcass fats, and aquatic and terrestrial fats has been tentative, and based on the absence or presence of other lipids. The results are summarised below in table 16, following the information given in the paper. The author states that every vessel was coated with *Pinacia* resin, despite biomarkers used being explicitly declared only in 4 cases. Two vessels are said to contain beehive products, which may indicate beeswax (long-chain alcohols and fatty acids were used as biomarkers). These results, in the opinion of the author, suggest widespread waterproofing technology. Animal fats ($C_{16:0}$ and $C_{18:0}$ FFAs as biomarkers) are detected in all analysed vessels. These data, whilst limited, provide directly relevant comparative data for the present study (see sections 7.1.1, 7.1.2).

Table 16 Results of organic residue analysis on cookware undertaken in Sulky/Sant'Antioco, SU 500 (urban dump) before the current research. Reworked from Pecci 2008 (table 1 and table 2 and text).

Context and paper	Sample number	Shape and chronology	Identified compounds	Identified commodities
Cronicario, US 500 (Pecci 2008)	732 A	Cooking pot, second/third quarter 4th century BC	$C_{16:0,\ 18:0}$ FFAs; cholesterol; dehydroabietic, abietic, 7-oxodehydroabietic acids; LCFAs; long-chain alcohols.	Animal fats (non ruminant?) *Pinaceae* (tar?) Mineral wax Beeswax/honey
Cronicario, US 500 (Pecci 2008)	286	Cooking pot, half 3rd century BC	$C_{15:0\text{-}18:0}$ FFAs; cholesterol; dehydroabietic acid.	Animal fats (ruminant?) *Pinaceae* resin
Cronicario, US 500 (Pecci 2008)	313B	Cooking pot, end 4th – beginning 3rd century BC	$C_{16:0,\ 18:0,\ 20:0,\ 22:0}$ FFAs; $C_{18:1,\ 22:1}$ monounsaturated FAs; cholesterol; C_{16} alcohol; dehydroabietic acid (?).	Animal fats (fish?) Vegetal fats? *Pinaceae* resin
Cronicario, US 500 (Pecci 2008)	212	Casserole, end 5th – 4th century BC	$C_{15:0\text{-}18:0}$ FFAs; cholesterol; $C_{18:1}$ monounsaturated FA; dehydroabietic acid.	Animal and vegetal fats (Oils?) *Pinaceae* resin
Cronicario, US 500 (Pecci 2008)	214	Casserole, end 5th – 4th century BC	$C_{16:0,\ 18:0}$ FFAs; dehydroabietic acid; 7-oxodeidroabietic acid.	Animal fats (non ruminant?) *Pinaceae* resin
Cronicario, US 500 (Pecci 2008)	215	Casserole, end 5th – 4th century BC	$C_{7:0,\ 8:0,\ 9:0,\ 10:0,\ 12:0,\ 14:0,\ 16:0,\ 18:0}$ FFAs; $C_{20:0}$, $C_{20:1}$, $C_{21:0}$, $C_{21:1}$, $C_{22:0}$, $C_{22:1}$ fatty acids; C_{16} alcohol; dehydroabietic acid (?)	Animal fats (non ruminant + dairy fats? Fish?) Vegetal fats (Oils?) *Pinaceae* resin
Cronicario, US 500 (Pecci 2008)	477A/477B	Baking tray, half 8th – half 7th century BC	$C_{15:0\text{-}18.0}$ FFAs; $C_{20:1,\ 22:1}$ monounsaturated fatty acids; C_{16} alcohol, dehydroabietic acid (?)	Animal fats (mixed) *Pinaceae* resin

6.5.2 Pottery assemblage and general information about lipid results

A total of 27 vessels (30 sherds) have been analysed from Sant'Antioco (table 17). Despite the site being one of the most investigated in Phoenician and Punic Sardinia, only one context has been targeted in this project, due to time constraints and availability of permissions. Analysed pottery, in fact, come from a well-investigated urban dump (US 500) in the area of Cronicario, except two fragments found in rooms surrounding the dump (fig. 80): all contexts are dated to the 5th century BCE. Materials from this dump were fully published by Campanella (2008). The ceramic catalogue by Campanella (2008) was used to select the pottery to be sampled. As it is only one stratigraphic unit and from one century, it was decided to include only a limited number of sherds.

The selected assemblage includes 19 wheelmade cooking pots, six basins, six casseroles, one handmade cooking pot and one baking tray. Three of the pots have been sampled in two different places (rim and bottom) to obtain information about lipid preservation and concentration in different areas of the vessel. This is potentially useful to comprehend more about vessel use and culinary practices (Charters et al. 1993).

Table 17 Number of sherds per vessel category, from the site of Sant'Antioco.

	Wheelmade pots	Handmade pots	Casseroles	Basins	Baking trays	Total
Number of sherds	13 (3)	1	6	6	1	27 (3)

The available information for each sherd from Sant'Antioco are summarised in table 18. This information includes context and vessel type/subtype with chronology. In the Appendix (table V), analyses undertaken, lipid concentration, identified compounds and identified commodities per each sherd are listed.

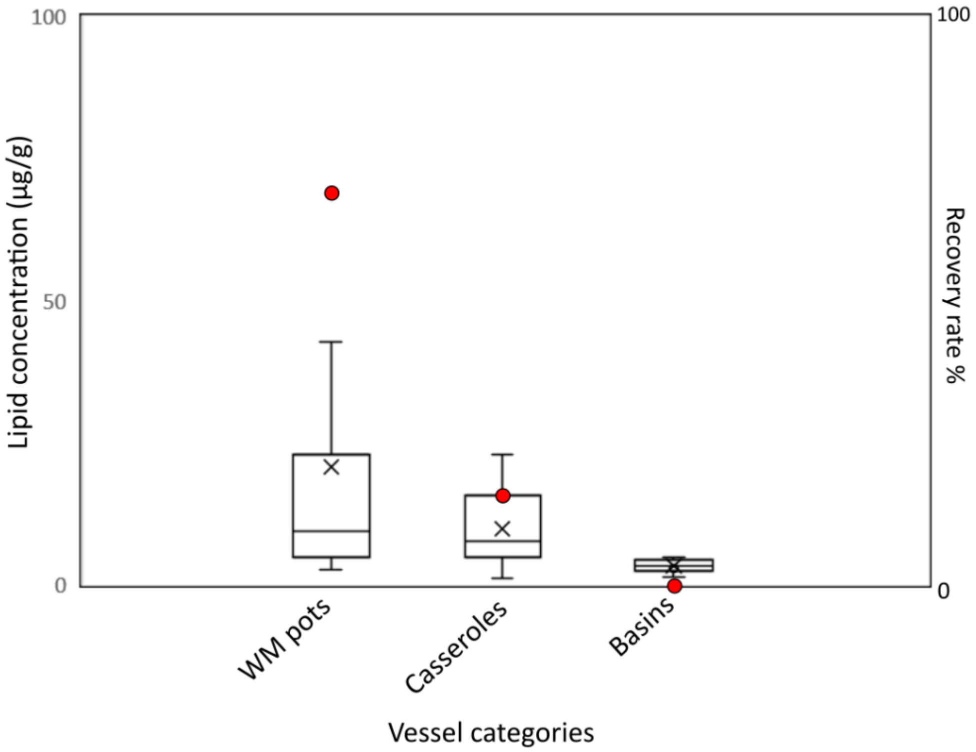


Figure 81. Box plots showing lipid concentration (X = mean) and recovery rate (red dot) of the analysed extracts coming from Sant'Antioco, per vessel category. WM pots: 12 samples; casseroles: 6; basins: 6.

6.5.2.1 Quantitative results

The mean lipid concentration and the recovery rate of the sherds coming from Sant'Antioco (US 500) are shown in fig. 81. The mean lipid concentration in wheelmade cooking pots is 21 µg/g, with standard deviation 31 µg/g, maximum value 113 µg/g and recovery rate 69%. This mean lipid concentration is lower than the island mean (73 µg/g). The only handmade cooking pot analysed has a concentration of 588 µg/g, far higher than the island mean (96 µg/g). The mean lipid concentration is 3 µg/g in basins, with 1 µg/g standard deviation and 0% recovery rate, while in casseroles it is 10 µg/g (standard deviation 8 µg/g, recovery rate 83%). Both values are lower than the island means (respectively 6 µg/g and 27 µg/g). The only baking tray analysed has a concentration of 31 µg/g, higher than the island mean (15 µg/g). Comparisons with island means are not statistically significant.

Table 18 List of analysed sherds from Sant'Antioco, with context, type and chronology

Sample name	Sherd code-details	Context	Chronology (context)	Vessel category-type	Chronology (type)
SAC1	17202 VANO A/369B/C.1269	Cronicario (Room A)	5th century BCE	Baking tray	8th-5th centuries BCE?
SAC17	17296 VANO C/547/C.1269	Cronicario (Room C)	5th century BCE	"S profile" pot	8th-6th centuries BCE
SAC29	13896/3133/26CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC30	13870/3107/27CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC31	13889/3126/22CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC32	14155/3412/42CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC33	13888/3125/21CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC34	13893/3130/29CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC35	13871/3108/30CRON	Cronicario (SU 500)	5th century BCE	Casserole	5th century BCE
SAC46	13876/3113/24CRON	Cronicario (SU 500)	5th century BCE	P2 pot	6th century BCE
SAC50	13798/3027/6CRON	Cronicario (SU 500)	5th century BCE	Basin BA6	7th-6th centuries BCE
SAC51	13804/3033/15CRON	Cronicario (SU 500)	5th century BCE	Basin BA7	5th-4th centuries BCE
SAC54	10992/3168/L331-b7	Cronicario (SU 500)	5th century BCE	Basin BA7	5th-4th centuries BCE
SAC55	13913/3152/4CRON	Cronicario (SU 500)	5th century BCE	Basin BA6	7th-6th centuries BCE
SAC57	13916/3155/16CRON	Cronicario (SU 500)	5th century BCE	Basin BA7	5th-4th centuries BCE
SAC58	13997/3559/22CRON	Cronicario (SU 500)	5th century BCE	Basin BA7	5th-4th centuries BCE
SAC63A	13817/3046/36	Cronicario (SU 500)	5th century BCE	P5 pot, rim	5th-4th centuries BCE
SAC63B	13817/3046/36	Cronicario (SU 500)	5th century BCE	P5 pot, bottom	5th-4th centuries BCE
SAC66A	14160/3418/37	Cronicario (SU 500)	5th century BCE	P5 pot, rim	5th-4th centuries BCE
SAC66B	14160/3418/37	Cronicario (SU 500)	5th century BCE	P5 pot, bottom	5th-4th centuries BCE
SAC72	14001/3563/39	Cronicario (SU 500)	5th century BCE	P6 pot	5th-4th centuries BCE
SAC73	13867/3104/30	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC75	13862/3099/22	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC76	14169/3431/44	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC77	13794/3023/17	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC78	13922/3161/47	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC79	13858/3095/9	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE
SAC85A	14165/3425/38	Cronicario (SU 500)	5th century BCE	P5 pot, rim	5th-4th centuries BCE
SAC85B	14165/3425/38	Cronicario (SU 500)	5th century BCE	P5 pot, bottom	5th-4th centuries BCE
SAC89	13850/3087/31	Cronicario (SU 500)	5th century BCE	P5 pot	5th-4th centuries BCE

6.5.3 Qualitative results per vessel type

6.5.3.1 Cooking pots

In most of the cooking pot extracts from Sant'Antioco containing more than 5 µg/g lipids (*n* = 10), identified compounds are consistent with degraded animal fat. Palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) FFAs dominate the chromatographic profile and $C_{18:1}$ fatty acid is always present.

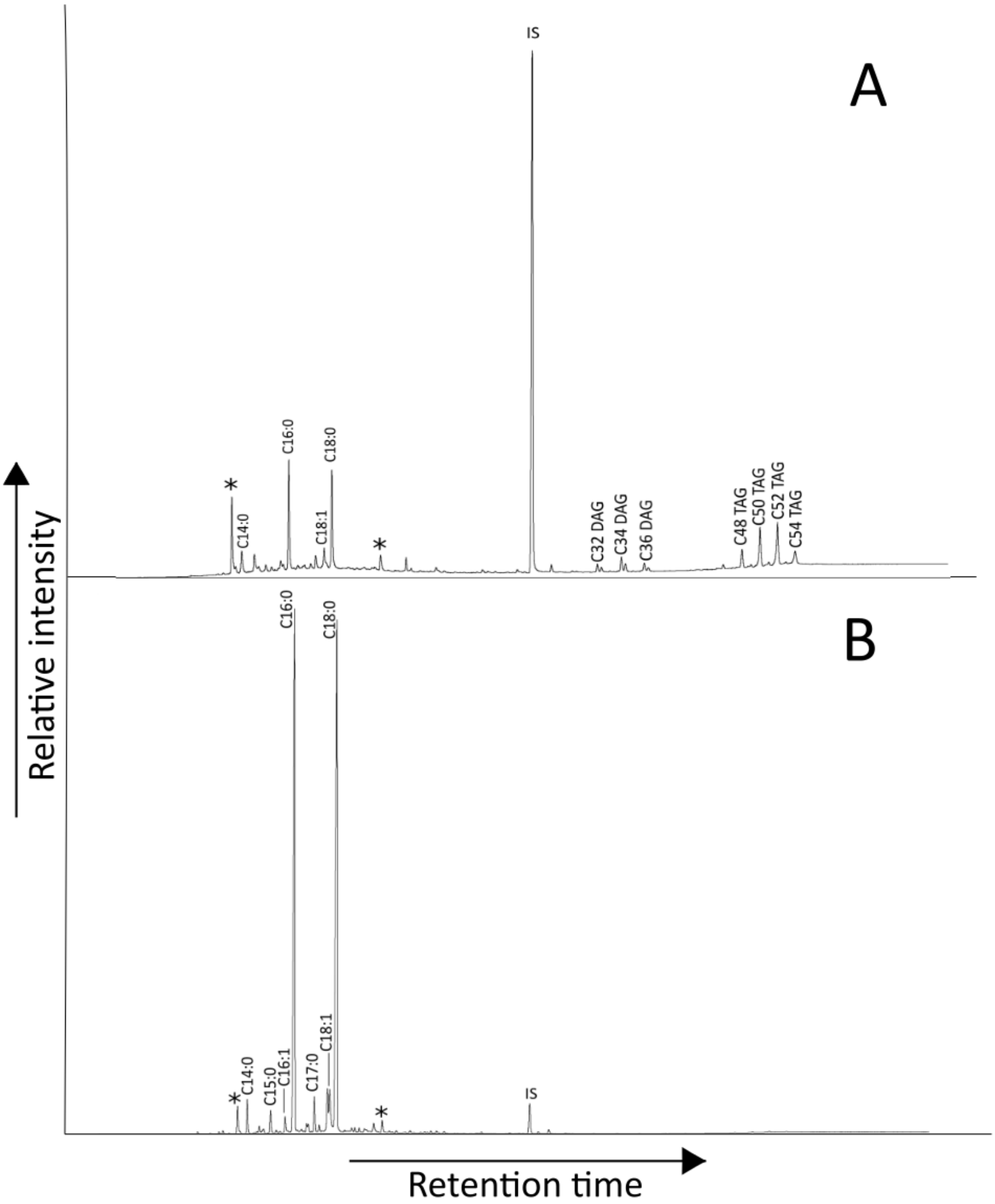


*Figure 82. High temperature gas chromatogram of the extracts SAC79 (A, wheelmade pots) and SAC17 (handmade pot), indicative of the presence of degraded animal fat. IS: internal standard; *: phthalate; DAG: diacylglycerol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

In two extracts (e.g. fig. 82A) C_{32-36} DAGs and C_{48-54} TAGs are present. In four extracts $C_{15:0}$ and $C_{17:0}$ FFAs are detected, suggesting the processing of ruminant fat (Mottram et al. 1999; Evershed et al. 2002). In one extract short chain free fatty acids ($C_{12:0}$ and $C_{14:0}$), present in low concentrations in adipose fat but denoting the composition of milk, are attested. These can denote the presence of milk in small proportions (up to 20% of the total fatty acid content (Christie 1981; Copley et al. 2003)). Extracts of cooking pots containing animal fat are generally poorly concentrated (less than 30 µg/g), suggesting that animal product processing was not common in these vessels, but two exceptions exist, with lipid concentration over 100 µg/g, as the extract shown in fig. 82B.

In one cooking pot extract beeswax was identified mixed with animal fats (fig. 83), as testified by the presence of C_{40-50} wax esters (C_{46} dominant), C_{24-34} even numbered alcohols (C_{30} dominant) and C_{27-31} odd numbered alkanes (C_{27} dominant (Roffet-Salque et al. 2015)).

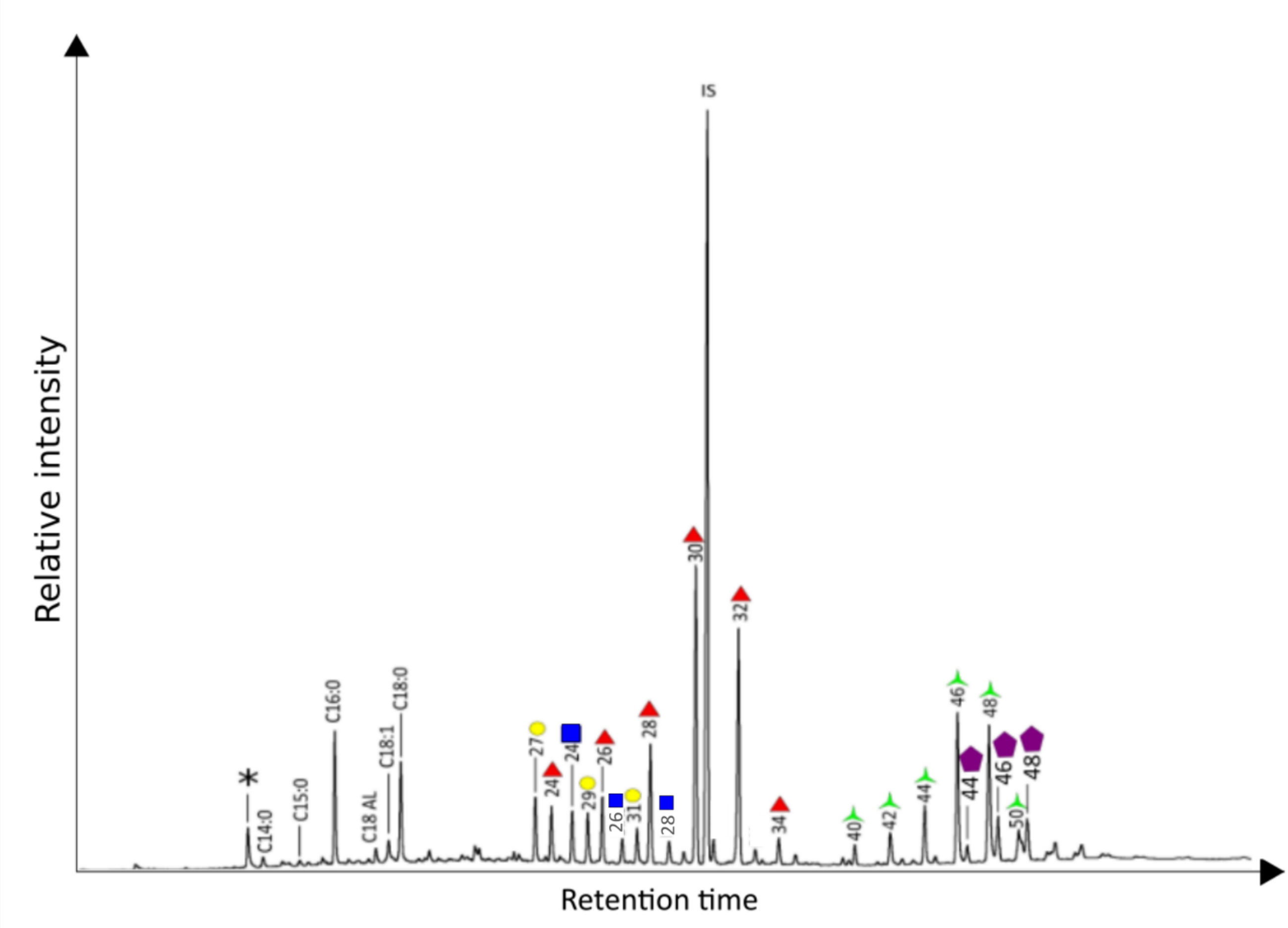


*Figure 83. High temperature gas chromatogram of the extract SAC46 (wheelmade pot), indicative of mixture of animal fat and beeswax. IS: internal standard; *: phthalates; red triangles: alcohols; blue squares: fatty acids; yellow circle: alkanes; green stars: wax esters; purple pentagons: triacylglyceroles; with N: acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.5.3.2 Basins

No extract of basin from Sant'Antioco analysed (n = 6) contained lipids.

6.5.3.3 Casseroles

Five out of six extracts of casseroles analysed contain lipids. Two of them appear very likely contaminated due to the anomalous chromatographic profile and the results have been therefore discarded (see Appendix, table V): the two sherds were stored in the same plastic bag.

In three extracts degraded animal fat has been identified, as testified by the presence of $C_{16:0}$ and $C_{18:0}$ FFAs and $C_{18:1}$ monounsaturated fatty acid (Mottram et al. 1999). In the case of SAC33 shown in figure 84, C_{32-36} DAGs and C_{48-54} TAGs have also been identified.

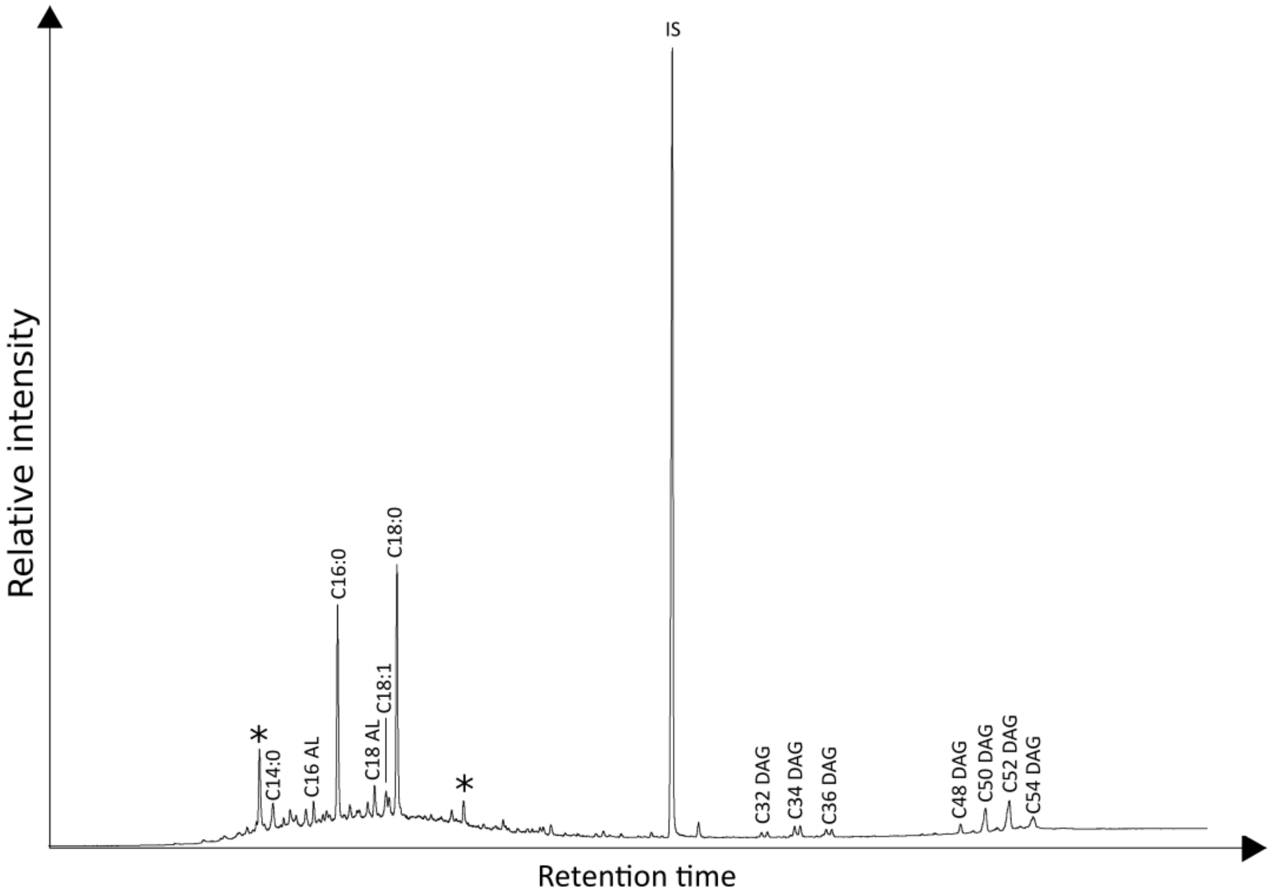


*Figure 84. High temperature gas chromatogram of the extract SAC33 (casserole), indicative of degraded animal fat. IS: internal standard; *: phthalates; AL: alcohol; DAG: diacylglycerol; TAG: triacylglycerol; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.5.3.4 Baking trays

The chromatogram of the only baking tray extract analysed is shown in figure 85. Free fatty acids $C_{14:0}$, $C_{16:0}$ and $C_{18.0}$; alcohols $C_{14, 16, 20}$ and phthalates are identified. The lipid distribution, with the presence of squalene and cholesterol possibly transferred from human fingers (Hammann et al. 2018), suggests a likely contamination.

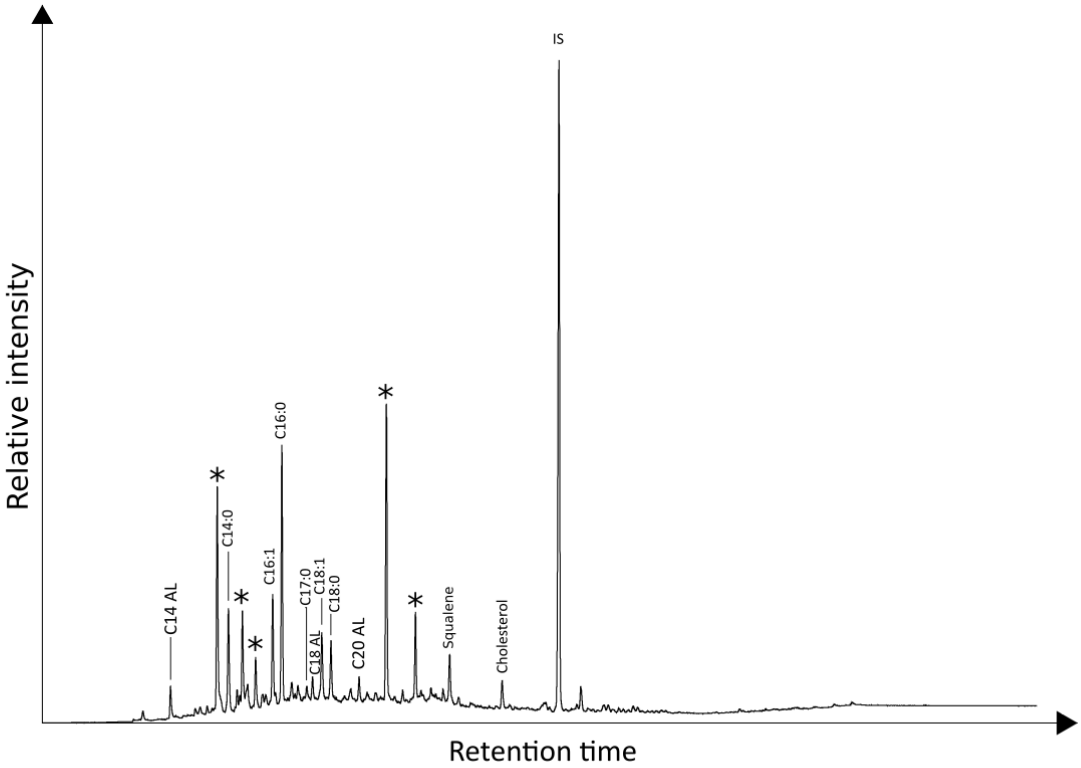


*Figure 85. High temperature gas chromatogram of the extract SAC1 (baking tray), indicative of mixed animal fat and contaminants. IS: internal standard; *: phthalate; AL: alcohols with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.5.3.5 Chronological patterns

In the case of Sant'Antioco only one chronological phase and one context was investigated, so that no chronological patterns among the assemblage investigated from Sant'Antioco have been identified.

6.5.4 Summary

The analyses undertaken on sherds from Sant'Antioco, and namely from the dump US 500, enriched our knowledge of culinary practices in the settlement at least in the 5^{th} century BCE.

Animal fat has been detected in 10 cooking pot extracts, attesting animal products processing. However, only in two of them lipid concentration overcome 30 µg/g, suggesting that animal products were only rarely cooked and consumed. In fact, fabric does not seem to justify these differences, as it is discussed in Chapter 7 (7.2.1). Notably, the most concentrated cooking pot (587 µg/g) is a handmade pot connected with indigenous ceramic traditions. The possible significance of this result is further discussed in section 7.2.1.

Basin extracts contained no lipids. In casserole extracts, when containing lipids, poorly concentrated animal fats are identified. The only baking tray extract seems to have contained lipid-poor commodities and it seems to be contaminated. The number of sherds analysed per vessel category hinders more detailed in-site interpretations. All these results coming from basins, casseroles and baking trays are compared with the island trends in section 7.2

It is worth noting that, differently from past analyses on cooking ware from Sant'Antioco (6.5.1), biomarkers of resins have not been identified in the extracts: this evidence is further discussed in section 7.1.3.

6.6 Genuri – San Marco

The Punic age settlement of Genuri-San Marco, located in the region of Marmilla, middle of Sardinia, was built around a Bronze Age nuraghe (fig. 19) and inhabited between the 4th and the 2nd centuries BCE. Based on available evidence, it appears likely founded by local people who adopted Punic pottery (see 3.2.6). The site code for extracts from Genuri San Marco is "GSM".

6.6.1 Faunal and palaeoenvironmental data

The only faunal and palaeobotanical investigations undertaken for the Nuraghe San Marco in Genuri refer to the Bronze Age phase (Cocco et al. 2015). A pit, sealed around the 12th century BCE, was investigated revealing both faunal and palaebotanical remains. Pigs and ovicaprines are the most attested animal species. The pit was found to contain a relevant amount of grape seeds (95% of the total of seeds), suggesting an economy based on vine cultivation. Wheat, legumes and wild fruits have been identified (Cocco et al. 2015). All these data, however, are of limited use for the current research, because the pit was sealed centuries before the Punic reoccupation of the area.

For the Punic phase, faunal and palaeobotanical information is lacking. As confirmed by the *Soprintendenza* officials none of the hundreds of animal bones collected have been published, hindering any site-based interpretation. Not much can be stated about the ancient environment in the Punic period. The settlement is located at the base of an upland (*altipiano)* and it was inhabited continuously up to the Medieval times. In the opinion of the excavators, this suggests that it had an agricultural purpose related to the commercial exploitation of surrounding fertile lands (Atzeni et al. 2016: 181).

6.6.2 Pottery assemblage and general information about lipid results

A total of 27 extracts have been analysed from the Punic settlement located around the Nuraghe San Marco at Genuri (4th–3rd century BCE; fig. 19). All analysed sherds come from contexts dated in the 4th-3rd centuries BCE. A total of five wheelmade cooking pots, 13 handmade cooking pots, eight basins and one casserole has been analysed (table 19).

Table 19 Number of sherds per vessel category, from the site of Genuri – nuraghe San Marco

	Wheelmade pots	Handmade pots	Casseroles	Basins	Total
Number of sherds	5	13	1	8	27

Available information for each analysed sherd from Genuri-San Marco is summarised in table 20. This information includes excavation area, vessel type and chronology of context. In the Appendix (table VI) analyses undertaken, lipid concentration, identified compounds, $\delta^{13}C$ values and identified commodities per each sherd are listed.

6.6.2.1 Quantitative results

The mean lipid concentration and the recovery rate for extracts of sherds coming from the nuraghe San Marco at Genuri are shown in fig. 86. The mean lipid concentration is 20 µg/g for cooking pots (standard deviation 28 µg/g). The maximum value is 114 µg/g. The mean is 30 µg/g for wheelmade cooking pots, 15 µg/g for handmade cooking pots. The recovery rate in pots is 47%. The mean lipid concentration is 2 µg/g for basins (recovery rate 0%). The only casserole analysed has a lipid concentration of 169 µg/g. The values are lower than the island means for cooking pots (73 µg/g for wheelmade pots, 96 µg/g for handmade pots) and basins (6 µg/g) but the comparisons are not statistically significant.

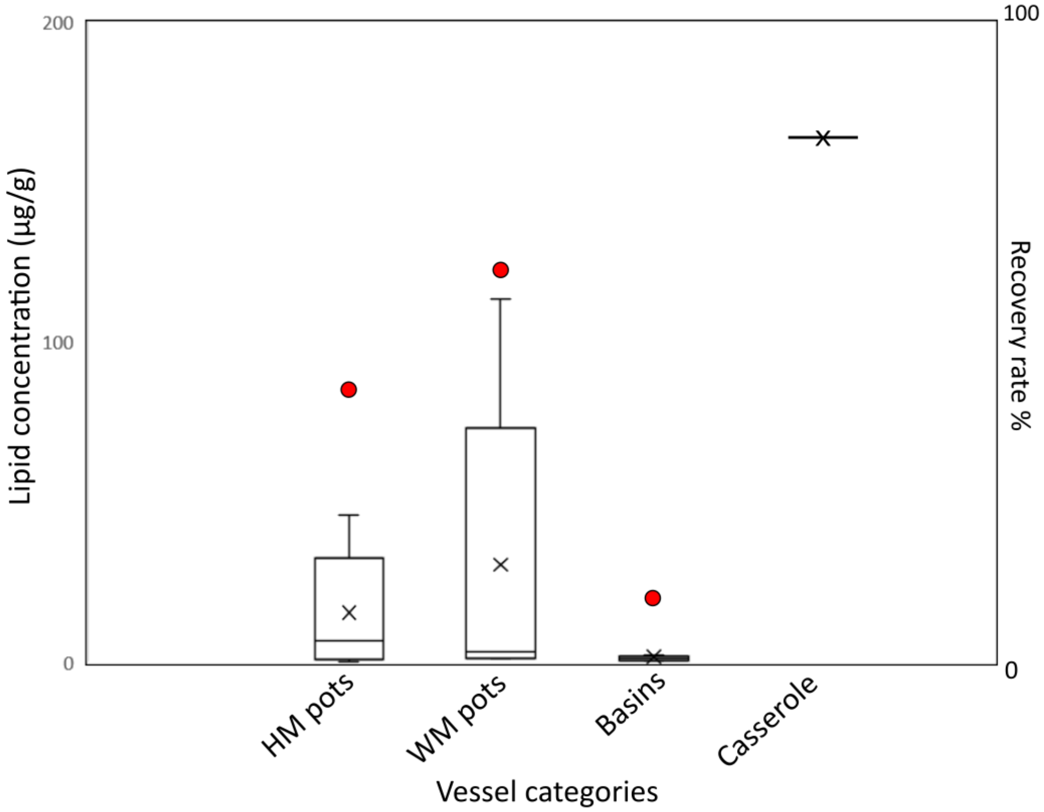


Figure 86. Box plots showing lipid concentration (X = mean) and recovery rate (red dot) of the analysed extracts coming from Genuri – nuraghe San Marco, per vessel category. HM pots: 13 samples; WM pots: 5; basins: 8; casserole: 1.

With such a small number of sherds, no relevant insight about lipid preservation and site-based interpretation was obtained. Lipid results, however, offer a good comparison for results from S'Urachi, because nuraghe San Marco was a site inhabited by indigenous people who adopted Punic pottery.

Table 20 List of sherds from Genuri-Nuraghe San Marco, with context, type and chronology of context.

Sample name	Sherd code-details	Context	Chronology	Vessel category-type
GSM1	US206 00.E/F/G.15 2/07/2008	Punic settlement around the nuraghe	4^{th}-3^{rd} centuries BCE	Basin
GSM2	US 449 99.H/I-15 23/10/2008	Punic settlement around the nuraghe	4^{th}-3^{rd} centuries BCE	Basin
GSM3	US30 L6M6 30/11/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM4	US30 M7 7/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM5	US30 L6I6 13/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM7	US30 L7I7 7/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM8	US30 L7 5/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Casserole
GSM9	US30 L7 5/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Wheelmade pot
GSM10	US30 H6 7/6/2002	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM11	US29 L7 7/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Wheelmade pot
GSM12	US30 I6 4/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM13	US29 L7 7/11/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM14	US29 L7 7/11/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM15	US29 L7 3/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM16	US30 G7 17/6/2002	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM18	US29 L7 27/11/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM19	US30 L6 3/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM20	US30 L6 3/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Wheelmade pot
GSM21	US30 L6 3/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Wheelmade pot
GSM22	US30 L6 5/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM23	US30 L6 5/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Basin
GSM25	US30 L7I7 6/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM26	US30 L7I7 6/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Wheelmade pot
GSM27	US30 L7I7 6/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM28	US30 M7 4/12/2001	Punic settlement around the nuraghe, fill	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM29	US28 M7 31/10/2001	Floor close to the nuraghe wall	4^{th}-3^{rd} centuries BCE	Handmade pot
GSM30	US27 L7 31/10/2001	Floor close to the nuraghe wall	4^{th}-3^{rd} centuries BCE	Handmade pot

6.6.3 Qualitative results per vessel type

6.6.3.1 Cooking pots

In most of the cooking pot extracts from Genuri-San Marco containing more than 5 µg/g lipids (*n* = 9), identified compounds are consistent with degraded animal fat. Palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) FFAs dominate the chromatographic profile and $C_{18:1}$ monounsaturated fatty acid is always attested. In five extracts $C_{15:0}$ and $C_{17:0}$ FFAs are detected, suggesting the processing of ruminant fats (Mottram et al. 1999; Evershed et al. 2002). In two extracts (e.g. fig. 88A) C_{32-36} DAGs and C_{48-54} TAGs are attested.

In one extract (fig. 88A) short chain free fatty acids ($C_{12:0}$ and $C_{14:0}$), present in low concentrations in adipose fat, are attested. These denote a contribution from milk (Christie 1981) and they can account for a dairy fat contribution in up to 20% total fatty acid moiety (Copley et al. 2003). However, origin of the animal fat in this extract was predominantly ruminant adipose, according to stable carbon isotope values (see below). In the same extract LCFAs up to C_{22} carbon atoms are identified, together with C_{20-26} even numbered alcohols. These LCFAs and alcohols likely originated directly from animal fat, incorporated via routing from the ruminant animal plant diet (Whelton et al. 2018; Halmemies-Beauchet-Filleau et al. 2013; 2014).

Compound-specific stable carbon isotope analysis was carried out on 2 cooking pot extracts from Genuri San Marco containing animal fat (fig. 87). One of them comes from a handmade pot, and the isotope value ($\Delta^{13}C$ = -3.6‰) is consistent with ruminant dairy fat. The second comes from a wheelmade pot, $\Delta^{13}C$ = -2.0‰, consistent with ruminant adipose fat.

No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD) have been found in extracts of cooking pots containing animal fats (*n* = 2) from Genuri-San Marco.

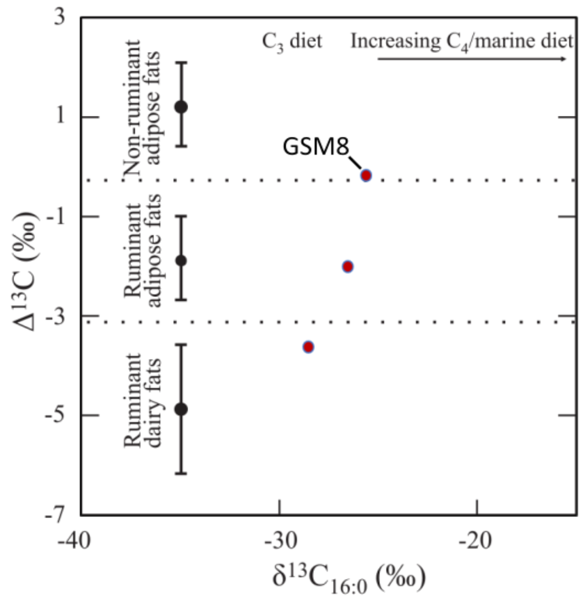


Figure 87. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for extracts from Genuri San Marco. GSM8: casserole. Other extracts: pots. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

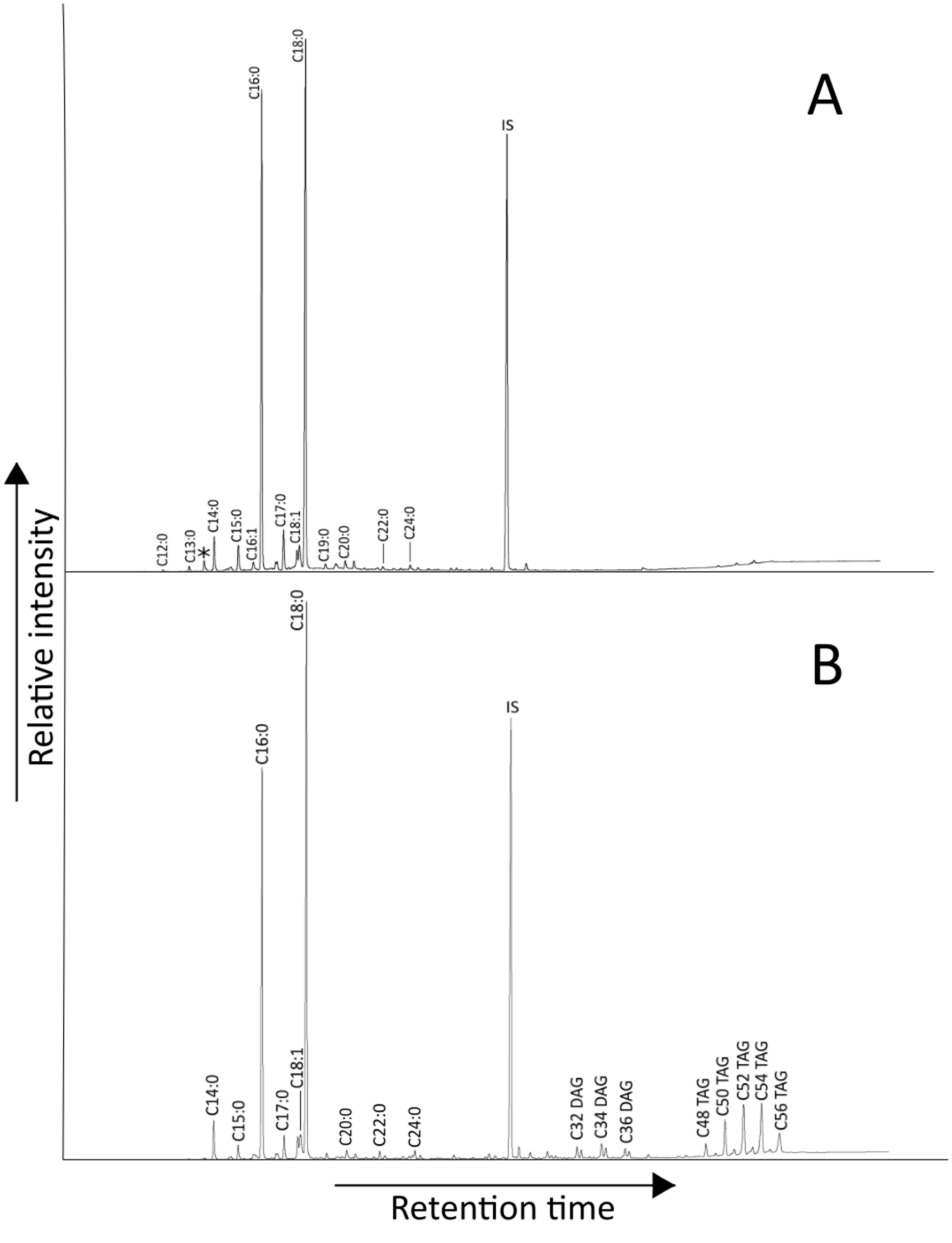


*Figure 88. High temperature gas chromatograms of the extracts GSM11 (A, wheelmade pot) and GSM15 (B, handmade pot), indicating presence of degraded animal fat. IS: internal standard; *: phthalate; DAG: diacylglycerol; TAG: triacylglycerols; with* Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

In one cooking pot extract beeswax was identified mixed with animal fats (fig. 89). The identification is based on the presence of C_{40-50} wax esters, C_{24-34} even numbered alcohols (C_{30} dominant) and C_{27-31} odd numbered alkanes and C_{20-28}

even numbered LCFAs with C_{24} dominating (Roffet-Salque et al. 2015)). In the extract ruminant fat was possibly processed, due to the presence of $C_{15:0}$ and $C_{17:0}$ free fatty acids, but the identification is only tentative to the lack of isotopic evidence (Mottram et al. 1999).

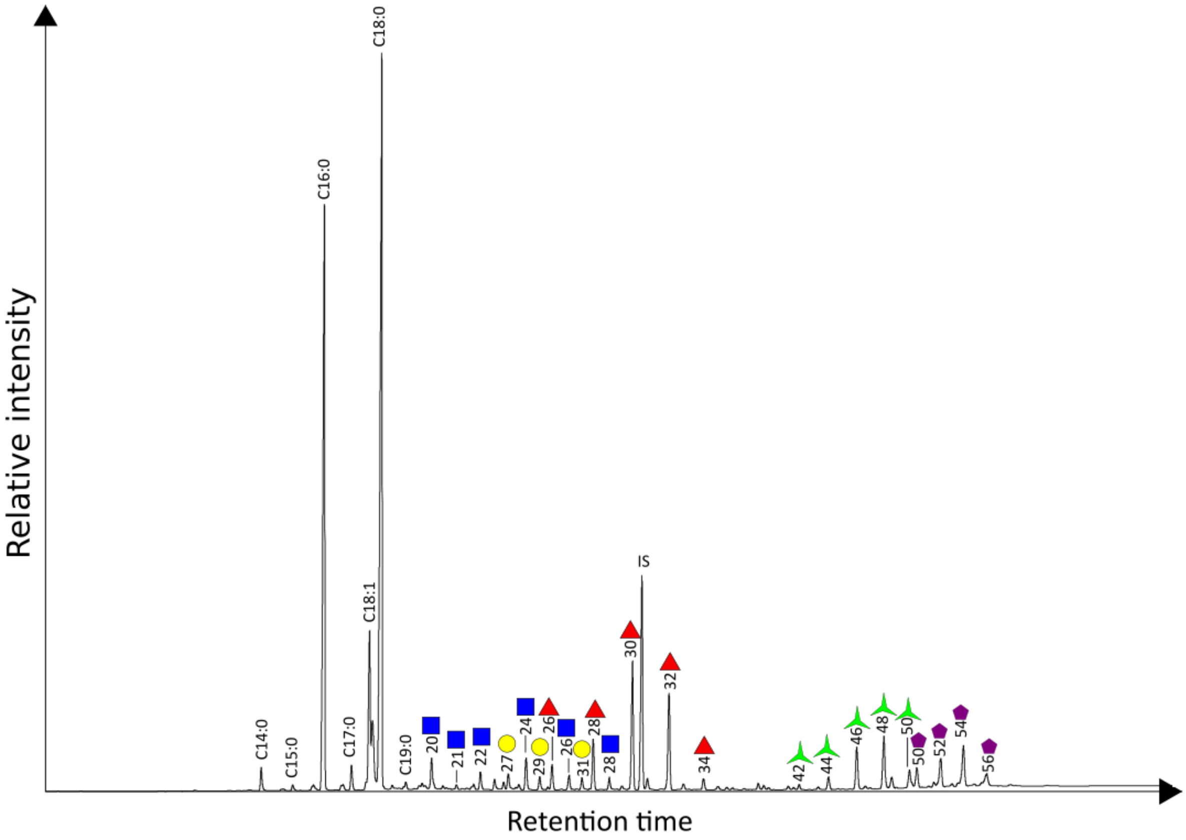


Figure 89. High temperature gas chromatogram of the extract GSM20 (wheelmade pot), indicative of a mixture of animal fat and beeswax. IS: internal standard; blue square: fatty acid; yellow circle: alkane; red triangle: alcohol; green star: wax ester; purple pentagon: triacylglycerol; with N: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.6.3.2 Basins

No extract of basins sampled from Genuri-San Marco analysed (*n* = 8) contains lipids.

6.6.3.3 Casseroles

In the only extract of a casserole analysed a highly concentrated (168 µg/g) degraded animal fat has been identified (fig. 90). Free fatty acids $C_{14:0}$ to $C_{20:0}$ are present, with $C_{16:0}$ and $C_{18:0}$ dominating. Monounsaturated fatty acid $C_{18:1}$ and $C_{50\text{-}52}$ TAGs are also present. The identification of $C_{31,\ 33,\ 35}$ mid-chain ketones testifies that animal fat has been heated over 300°C (Raven et al. 1997), suggesting that the casserole was used for cooking animal products. Compound-specific stable carbon isotope analysis was carried out on the extract: $\Delta^{13}C$ value (-0.2‰) is consistent with non-ruminant fat, but mixture with ruminant is not excluded, as also suggested by the identified compounds. No aquatic biomarkers (≥C_{20} APAAs; IFAs, including TMTD; DHYAs) have been found in the extract.

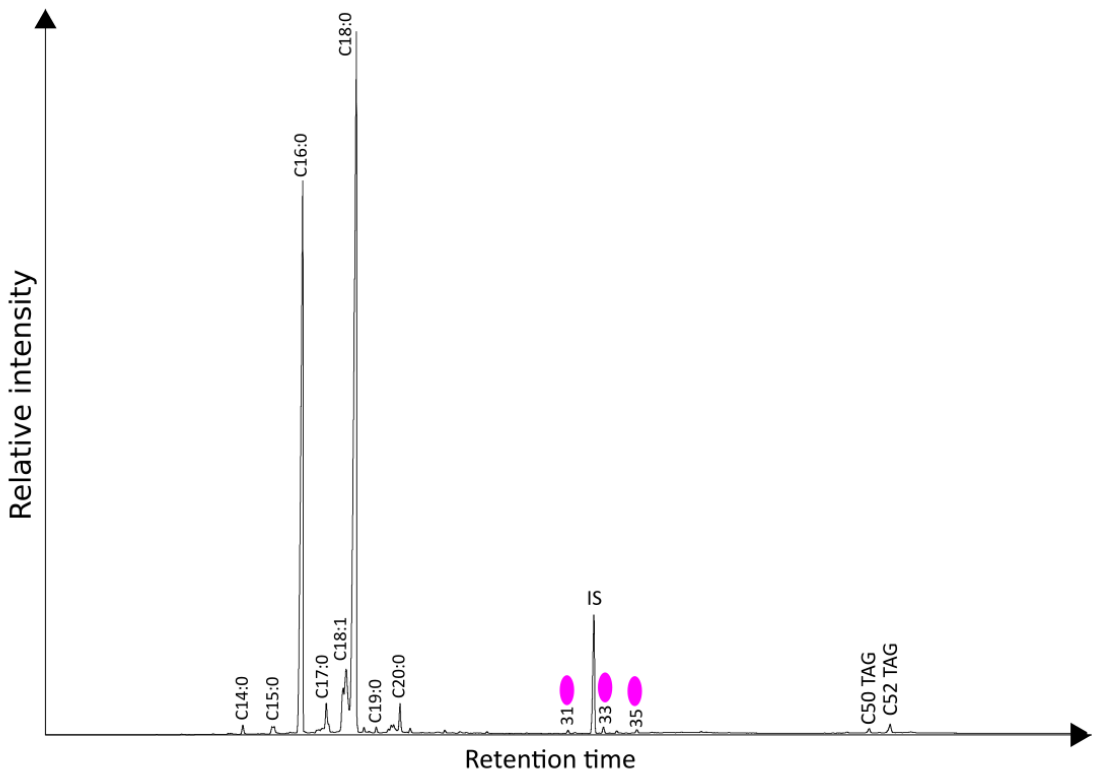


Figure 90. High temperature gas chromatogram of the extract GSM8 (casserole), indicative of degraded animal fat heated over 300°C. IS: internal standard; pink ellipse: ketones; TAG: triacylglycerols; with Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

6.6.3.4 Chronological pattern

In the case of Genuri-San Marco only one chronological phase of the settlement was investigated, so that no chronological patterns among the assemblage investigated from Genuri have been identified.

6.6.4 Summary

Nuraghe San Marco was a site inhabited by indigenous people who adopted Punic pottery, as at S'Urachi, but with different chronology (4^{th}-3^{rd} centuries BCE). Despite the limited amount of sherds analysed and the limited faunal and palaeoenvironmental information available for nuraghe San Marco compared to other sites (6.6.1), lipid results from this site offers good insights and comparison.

The main outcomes can be summarised as follows. Animal products have been detected in cooking pots (n = 9) and in the only casseroles analysed. Animal fats detected are often relatively abundant: in 7 cases lipid concentration exceeds 30 µg/g (100 µg/g in two cases). But the low number of sherds does not clarify if this trend is due to a higher animal products consumption or randomness or depositional reasons. In two cooking pots beeswax was identified mixed with animal fat.

Basins, on the contrary, contained no lipids. Results from Genuri-San Marco assume greater significance when compared with other sites, as it is done in Chapter 7.

6.7 Results of the analyses: a brief summary

The results have been illustrated per site, outlining lipids detected and identified commodities per vessel category and, when possible, sub-category. The main elements characterising the results in each site (e.g. lipid preservation conditions or widespread compounds) have been also described, to better contextualise and interpret results obtained.

Generally speaking, the results obtained through this research allowed to identify commodities never detected (e.g. dairy products) or poorly detected (e.g. honey and beeswax) by archaeologists before (research question 1). Other patterns identified refer to presence or absence of commodities: no aquatic biomarker was identified, while ruminant adipose fat appears generally dominant among animal fat sources.

Results per site revealed limited possibilities for in-depth interpretation and for linking organic residue to cultural and culinary choices, due to the limited number of sherds involved. The most important patterns recognised relates to differences per vessel category, with cooking pots always richer in animal fat than basins and casseroles (research question 2). Chronological patterns (research question 3) have been identified only in S'Urachi, where the highest number of sherds, from two different excavation areas, has been analysed.

But more information is drawn when comparing and discussing results between sites, as it will be done in the next chapter to answer research question 4 (see 7.4). Comparing results per vessel category, from all the targeted sites, can further reveal specialisations and use of the vessels (7.2). All this information and trends observed when comparing together the full results are analysed and discussed in the next chapter, both per specific commodity (7.1), per vessel category (7.2), over time (7.3) and over space and sites (7.4), to answer my four original research questions.

Chapter 7
Discussion of the results

In this chapter results of the analyses are discussed and compared. The main outcomes of this research are highlighted and interpreted based on archaeological and historical information (chapter 2 and 3). The chapter tackles the research questions posed in the introduction (1.2), recapped here:

1) What commodities were processed in the main ceramic categories involved in cooking and food preparation practices?
2) What do the detected commodities suggest about vessel use and specialisation?
3) What do the detected commodities suggest about changes in cuisine and diet over time?
4) Are infra-site and inter-site spatial patterns identified through ORA? What do they imply?

All four questions locate themselves in two broader research aims: 1) to understand how organic residue analysis of cookware can contribute to our knowledge of culinary practices and culture in Phoenician and Punic Sardinia; 2) to create the first major organic residue dataset of pottery in Phoenician and Punic Sardinia (see introduction, 1.2).

The chapter deals with specific variables in each section. Specifically:

Section 7.1 deals with specific commodities deserving further attention (question 1). Subsections are focused on animal fats (7.1.1); honey and beehive products (7.1.2); and plant products (7.1.3). In section 7.2, results are discussed per vessel category, comparing them among sites and outlining trends and implications about vessel use and specialisation (question 2). In section 7.3, changes over time and detected continuity are illustrated and discussed (question 3). In section 7.4, results, compared between sites, are discussed to outline identified trends and cultural implications of these patterns (question 4).

7.1 Discussion of the specific commodities processed in pottery

7.1.1 Animal fats

Animal products are the most commonly identified commodity in this project, which is often the case in ORA due to their high lipid content, frequent processing via cooking, and the relative stability of biomarkers used to identify them (see 4.3.1). They have been identified in 143 cooking pots, 11 casseroles, 1 basin and 1 baking tray, often mixed with other commodities, but they are the dominant commodity in 65 cooking pots and 4 casseroles. Specific vessel category insights, also related to animal fat detection, are discussed in the following section 7.2.

In the present section results relating to animal product processing in the pots are summarised and compared with faunal data, with particular focus on the origin of the fats detected through stable carbon isotopic signature of individual fatty acids (7.1.1.1). Additional paragraphs are focused on thematic issues needing further attention due to their relevance for Phoenician and Punic Sardinia: non-ruminant fats and pigs (7.1.1.2) and milk and dairy products (7.1.1.3); fish and aquatic resources (7.1.1.4).

7.1.1.1 Carbon isotope values of animal fats: synthesis and comparison with faunal data

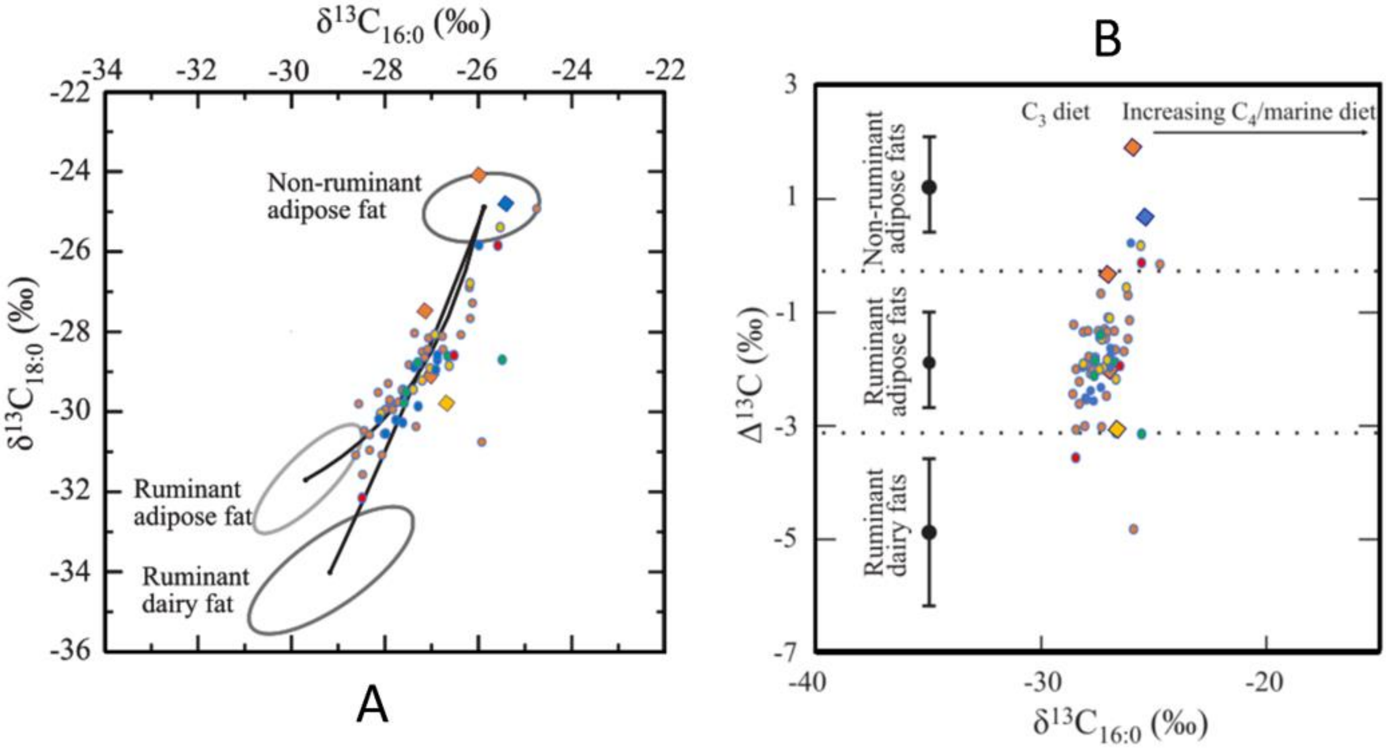


Figure 91. $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids (A) and difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained (B) for all the analysed FAMEs, colour per site. Blue: Pani Loriga; Green: Nora; Orange: S'Urachi; Yellow: Olbia; Red: Genuri S.Marco. Extracts possibly containing plant oil are indicated with a square. The $\delta^{13}C$ values obtained for the modern reference fats were adjusted for post-Industrial Revolution effects of fossil fuel burning by the addition of 1.2‰ (Friedli et al., 1986). The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012) as reported in Dunne et al. 2012. Analytical precision is ± 0.3‰.

The $\delta^{13}C$ values of individual fatty acids from 66 extracts identified as animal fats (61 cooking pots, four casseroles and one basin) were determined using GC-C-IRMS to enable the animal fat source to be characterised. More than 90% of the analysed extracts identified as animal fats came from cooking pots. An isotope plot of the complete dataset (where $\Delta^{13}C$ (‰) is defined as $\delta^{13}C_{18:0}$ - $\delta^{13}C_{16:0}$) is shown in fig. 91. Based on the higher concentration of *n*-hexadecanoic acid ($C_{16:0}$) compared to *n*-octadecanoic acid ($C_{18:0}$), five sherds potentially containing plant fats (oil) mixed with animal fats are marked in the plot with squares. All stable carbon isotope values, shown in fig. 91, are thus consistent with animals raised on a C_3 diet (wheat, legumes) in an arid environment (Faquhar et al. 1989), as was the case in Punic Sardinia based on available evidence. A marine contribution to the diet of the animals, which is a different interpretation of the $\delta^{13}C$ values, is unlikely based on the available botanical, archaeological and historical data (chapter 2).

Faunal data helps in pushing the interpretation further. Whilst the stable carbon isotopes values help illuminate origins based on animal metabolisms, archaeozoology helps link this to the potential species it might have been. In Phoenician and Punic Sardinia, ruminant fats can originate from ovicaprines, cattle or, less likely, red deer, while non-ruminant fats come predominantly from pigs. Chickens, rabbits and other wild animals are not considered in the interpretation of results. They are rare in the faunal assemblage and would generally yield much less meat than pigs (see chapter 2), being statistically irrelevant in the isotope values interpretation. Animal fat with aquatic origin was not detected, as there was an absence of aquatic biomarkers (APAAs, isoprenoid fatty acids and vicinal dihydroxy acids) in every lipid extract identified as animal fat (see 7.1.3).

Some further interpretation of $\delta^{13}C$ values of fatty acids can be offered for sites where solid archaeozoological evidence is available.

In S'Urachi, available faunal data from the contexts under investigation (Ramis et al. *in press*, see 5.1.1) allows a more precisely discussion of the origin of free fatty acids found in vessels. Ruminant remains (cattle, ovicaprines and deer) outnumber pigs throughout the history of the site (see 6.1.1). Ruminant species represent 72% of the fragments in Area D and 86% in area E, thus it is unsurprising to find ruminant fats forming the majority of extracts. The low percentage of non-ruminant fats in lipid extracts (5%), however, is significantly lower than pig remains (15%), and non-ruminant remains in general (18%). The significance of this will be discussed below (section 7.1.1.2).

Faunal data can also help in interpreting the existing difference in isotopic values between the two areas (see fig. 44). Area E (6^{th}-4^{th} centuries BCE) at S'Urachi produced one sherd with a lipid extract interpreted as dairy fat. In the same area, $\delta^{13}C$ values of four other extracts are consistent with a mixture of dairy and adipose ruminant fat (see 6.2.1). In Area D, the more recent context (5^{th}-2^{nd} centuries BCE), $\delta^{13}C$ values of the extracts on the contrary do not suggest dairy fat contribution. Cattle was the most common milk-producing animal to be found in Area E (33% of domestic animals), while in area D the percentage of bovines decreases to 16% of domestic animal remains. This evidence suggests that the difference in $\delta^{13}C$ values between the two areas is possibly due to the processing of dairy products being more common in the pre-Punic and early Punic period. Another explanation for the difference between the two areas also exists, possibly complementary to the first one. In Area E, deer (ruminant animals) constitute nearly the entirety of the wild animal record (17% of the total). In Area D, the contribution of wild birds and chickens to the faunal assemblage is higher, with the number of bird bones being similar to the number of deer bones (approximately 8% of the total each). The percentage of pig bones remains the same (fig. 92). Considering that more meat is obtained from individual deer than from individual birds, this suggests a move towards hunting. This would represent a potential development in culinary uses. This may thus account for the change in $\Delta^{13}C$ values average and ranges.

Faunal data are not as abundant or detailed at other sites. At Pani Loriga, the proportion emerging from isotope analysis on lipids (90% ruminant) is consistent with faunal evidence (see 6.2.1; fig. 92). According to available faunal evidence (D. Ramìs, *pers. comm.*), the processing of ruminant products in the majority of pots is predictable. Ruminants (cattle, ovicaprines, deer) were more numerous than non-ruminants (pigs, chickens) in the faunal assemblage itself, constituting 85% of the animal remains.

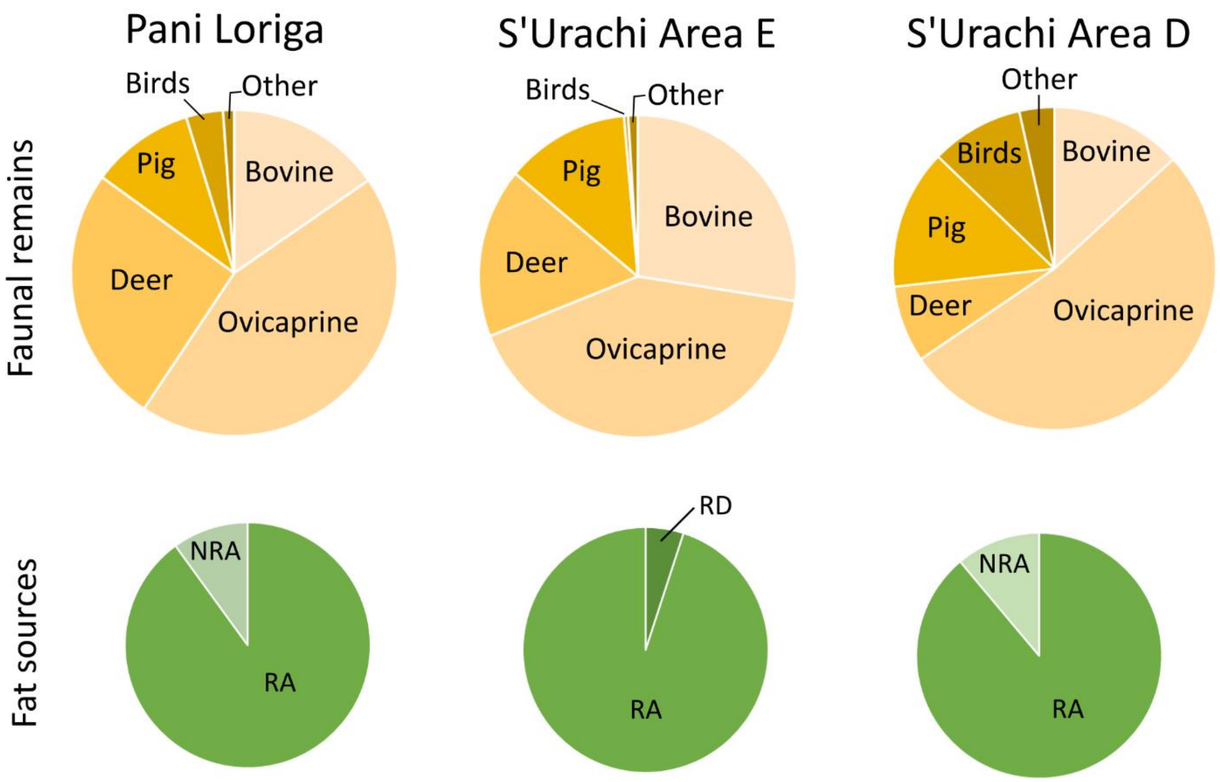


Figure 92. Comparison of faunal remains (number of fragments) per species with fat sources identified using δ¹³C stable carbon isotope values of individual fatty acids in three different analysed contexts. NRA: non ruminant adipose; RA: ruminant adipose; RD: ruminant dairy.

At Genuri San Marco and Olbia, the lack of precise and published archaeozoological data prevents detailed comparisons. Nevertheless, it is known that, in Olbia, ovicaprines and cattle were more numerous than pigs, while deer was the most hunted wild animal (Cavaliere 2010b). Cattle and ovicaprines were also found in greater numbers than pigs at Nora, but faunal evidence enables the exclusion of deer from the possible identification of ruminant fats, since it is irrelevant in the assemblage (Sorrentino 2009).

Other aspects related to animal fat interpretation will be discussed in the following paragraphs, divided by theme and fat origin (non-ruminant, 7.4.1.2; ruminant dairy, 7.4.1.3).

7.1.1.2 Pigs and non-ruminant fat

Only four extracts (two cooking pots and two casseroles, 6% of the 66 extracts identified as animal fat) can be identified as unambiguously containing non-ruminant fats. Non-ruminant fats were probably also processed in other vessels, providing $\Delta^{13}C$ values consistent with a mixture of ruminant and non-ruminant fat (fig. 91). A connection between casseroles with non-ruminant product processing is weakly suggested by these results (see 6.2.3), but the number of sherds involved (*n* = 4) is too limited for any meaningful generalisation to be drawn. Nevertheless, isotope values indicate pig and non-ruminant meat in general as a commodity processed in cooking pots and casseroles. However, such processing appears to be rare and not exclusively linked to a particular vessel type.

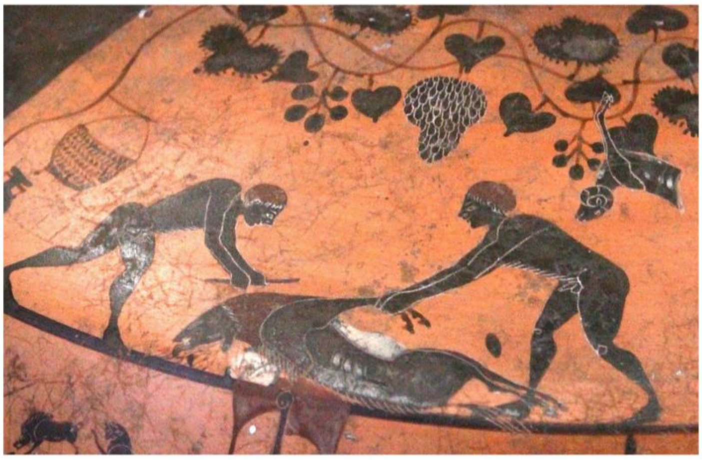
These non-ruminant fats are interpreted as porcine fat. Pigs were common throughout the target period (see 2.2.2.4). Other non-ruminant animals have $\delta^{13}C$ values could occasionally overlap with pigs (Mukherjee et al. 2005), but they were uncommon, according to the faunal evidence. Wild birds and rodents, such as rabbits or dormice, were rarely consumed (see 2.2.2.4), and chickens started to be commonly reared only in the 3rd century BCE (Carenti 2013). Due to this rarity, these should not be considered in the context of Phoenician and Punic Sardinia when interpreting $\delta^{13}C$ values.

The types of animal fats identified using isotope analysis do not correspond to what was expected based on archaeozoology evidence where available. In summary, pigs are the second or the third largest group of domestic animals at all the target sites where faunal data is available, following ovicaprines and cattle. There is no reason to think that the trend could be misrepresented due to unpublished data or non-investigated contexts (see 2.2.2.4). In Phoenician and Punic settlements, pigs were certainly reared for dietary purposes (D'Andrea 2019; Campanella-Zamora 2008; Wilkens 2008). This is confirmed by butchering traces and slaughtering ages (1-3 years) chosen to maximise meat yield. The same happened in Iron Age Sardinia (Masala 2017).

In this context and having considered these elements, it is difficult to directly link the percentage of extracts containing non-ruminant fats to actual pig consumption at the sites and on the island. The percentage of pig bones in Phoenician and Punic Sardinia, despite varying between sites (see 2.2.2.4), is always assessed as between 13% and 40% of the total of domestic animals (Wilkens 2012: 98), and domestic animals always represent more than 70% of collected bones (see 2.2.2.4). Pigs were very likely reared mainly to be eaten, based on available sources and comparisons, both from the ancient Mediterranean and modern rural Sardinia. Given this picture, the low percentage of pig fats in the analysed vessels seems to have two possible explanations.

The first one is related to a predominance of ruminant fats due to processing meats from different animal species in the same vessel. $\Delta^{13}C$ values result from the combination of isotopic values of all animal products processed in that vessel (Dudd-Evershed 1998; Evershed 2008), so they indicate the predominant origin of animal fats. In the analysed extracts, $\Delta^{13}C$ values of fatty acids identified as non-ruminant fats are around 0.2‰. These could indicate a mixture of non-ruminant and ruminant adipose fats in the vessels. In Phoenician and Punic Sardinia, the most relevant animals in the diet were cattle, sheep, goat, pig, and, to a lesser extent, deer, which were also hunted for antlers. Excepting pigs, four of the five species are ruminant. In some of the targeted sites (e.g. S'Urachi and Pani Loriga) it is known that deer bones were more numerous than pig bones (fig. 92). It has to be considered that $\delta^{13}C$ values in most of the targeted extracts analysed are consistent with a mixture of ruminant and non-ruminant fats. This is stated according to existing models available for prehistoric Britain (Mukherjee et al. 2005: 83), used here as an indirect reference since the most detailed models are, up to this point, available for that region and not for Sardinia. However, $\delta^{13}C$ values of ruminant fat in the target area are more enriched than in prehistoric Britain, and no precise comparison in values interpretation is possible.

Based on available data, a mixture of different animal products in the analysed vessels is possible. It is not possible, however, to quantify exactly how much mixing of animal products took place, and it is difficult to assess the relative amount of different animal products processed in a vessel over its lifetime. Indeed, the fatty acid concentration of animal muscles and tissues vary considerably, as they are affected by factors such as diet, species, age and sex (Mukherjee et al. 2005: 83). The combination of sheep, cattle, goat, deer and pig fats could have produced, in the 94% of the cases (62 on 66 extracts), isotope values consistent with ruminant fat. If it is assumed that it was common to process meat from different species in the same vessel, the current result, showing values consistent with ruminant fat in the 94% of the cases, is explainable. As a result, possibly pigs were commonly processed in cooking pots and casseroles, but the mixing of meats made this presence undetectable, even if pig fats were more abundant than bovines or ovine fats. This would lead to a false perception that pig meat was less commonly processed than the single ruminant species meat found in the targeted vessels.



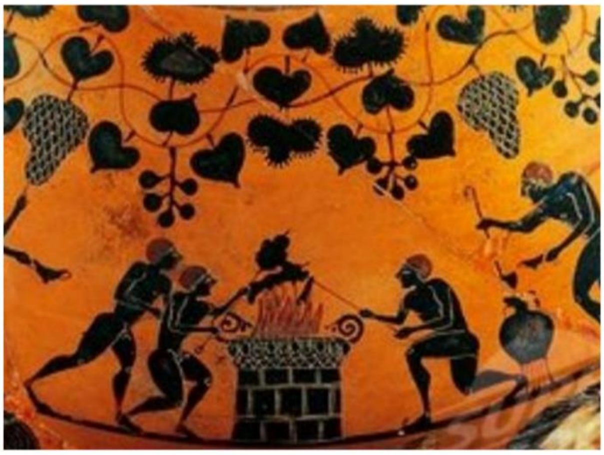


Figure 93. Two subsequent scenes from the "Ricci Hydria" (Necropoli della Banditaccia, Cerveteri, 530 BCE) with killing of a pig and cooking of meat with skewers. Museo Nazionale Etrusco di Villa Giulia.

Given the evidence available, this explanation is plausible and substantiated by the data. It implies the frequent cooking and consumption of different animals in the same vessels. It has, however, one potential weakness to be considered. Since most of the cooking pots and casseroles contained little or no lipids, it appears unlikely that such a large majority of extracts containing animal fats all came from vessels used to process multiple species. This weakness suggests a second explanation.

The second explanation does not preclude the first and is possibly complementary to it. The rare presence of porcine fats in pottery could be simply related to the infrequent processing of porcine products in cooking pots and casseroles, compared to other domestic species. It is possible that pig was cooked without the use of ceramic vessels, for example grilled or skewered. This has been suggested also in other regions where isotope analysis of animal fats have been undertaken, such as prehistoric Britain (Copley et al. 2003; Mukherjee et al. 2005). In Punic Sardinia, the practice of skewering meat is established. Iron and bronze skewers are commonly found in sanctuaries, probably used during the ritual cooking and sharing of meat during sacrifices (Botto 2017b). Outside Sardinia, the practice of skewering meat is widely attested in iconographies in the contemporary Mediterranean (Van Straten 2016: 115-153), and in some cases pigs can be evidently enumerated among the skewered animals (as in the "Ricci Hydria" from Cerveteri (Cerchiai 1995; fig. 93)). For Phoenician and Punic Sardinia, it is not possible to establish if pigs were among the skewered animals, but it is likely: in the Phoenician and Punic West, pigs are found also in ritual contexts where skewers are found (D'Andrea 2019). Despite elements enumerated being insufficient enough to draw a picture of pig skewering or grilling in Phoenician and Punic Sardinia, they do not exclude the existence of such practices.

In summary, it is possible that porcine fats are less common in cooking pots and casseroles compared to ruminant fats because pigs and boars were consumed grilled or skewered. This hypothesis is based upon the lack of pig fat, combined with faunal and iconographic evidence available. Further data is needed to corroborate this argument. In particular, identifying structures, tools or spaces possibly used in pig cooking could provide additional data about whether different cooking techniques were used on pigs in pre-Roman Sardinia.

7.1.1.3 Milk and dairy products

This project provided the first direct evidence of milk and dairy processing in pre-Roman Sardinia. It also offered a relevant insight about species. Based on data from S'Urachi, showing that the dairy origin of fat is attested only in an excavation area (area E, 6th-4th century BCE) where bovines are more common (33% of domestic animals), it seems possible to hypothesise that milk was primarily produced from cows, at least in S'Urachi, in the 6th–4th centuries BCE (7.1.1.1). It is only a hypothesis, because it is not possible to distinguish species through isotope ratio mass spectrometry (see chapter 4). But, although the evidence is from a single site, it is relevant to highlight this possibility. Wilkens, who published the most relevant paper on Sardinian archaeozoology, suggested sheep as the most relevant milk producer in Sardinian antiquity, but no evidence was given to corroborate this argument (Wilkens 2012: 24).

Moving to the general picture, dairy fats have been recognised as the predominant source of fats in only two of the 66 extracts selected for isotope analyses (fig. 91). Dairy fats were certainly processed also in other vessels, despite being not predominant. This is indicated by $\Delta^{13}C$ values from five additional cooking pot extracts are consistent with a mixture of adipose and dairy ruminant fats. Moreover, the presence of short chain fatty acids as $C_{12:0}$ together with $C_{14:0}$, $C_{15:0}$ and $C_{17:0}$ free fatty acids in several extracts (nine from Nora and five in S'Urachi) accounts for the presence of dairy fats up to 20% of all the fatty acyl moiety (Copley et al. 2003). However, three of the extracts containing $C_{12:0}$ free fatty acid, obtained from two cooking pots and one casserole, have been analysed through GC-C-IRMS. They provide values consistent with ruminant adipose fats (-1.9‰; -0.7‰; -2.1‰) and not with dairy fats. This indicates that dairy fats were not dominant as the origin of animal products processed in those vessels. No direct relation between short chain fatty acids detection and dairy origin of the animal fats detected in the extracts has been identified. In the only extract from S'Urachi unambiguously containing dairy fats ($\Delta^{13}C$ = -4.8‰), the shorter free fatty acid is $C_{14:0}$, as in several other extracts from the same site (n = 37). In the extract providing values consistent with dairy fats from Genuri San Marco ($\Delta^{13}C$ = -3.6‰), the shorter FFA is $C_{14:0}$, which occurs in five further extracts from the site. In sum, data obtained through the analysis suggests dairy products as processed potentially in limited amounts. This evidence refers to the vessel categories involved in this study, and it needs to be further discussed and explained. In fact, it partially contradicts what was expected based on available data and literature, since previous research established dairy products as known and processed in Phoenician and Punic Sardinia.

Dairy products have always been considered a relevant part of the diet in both Iron Age Sardinia (Ugas 2015; Perra 2018) and in the wider Phoenician and Punic Mediterranean, from the motherland to the West (e.g. Spanò Giammellaro 2007; Campanella 2008; Vendrell Betì 2016). As explained in Chapter 2 (2.2.2.5), this is due to a number of factors: zooarchaeological evidence; the presence of dairy products in written sources connected with the Canaanite or the Late Punic world (see Campanella 2008: 85-87); and the occurrence on the island of vessels likely linked to milk consumption, such as baby bottle jugs, from the period of Phoenician and Punic settlement (Fariselli 2017: 313). Ovicaprines and cattle outnumber pig remains at all the sites included in this project where faunal evidence is available (see Chapter 5). Sheep, usually connected with milk production in the ancient Mediterranean (Wilkens 2012: 24), was probably the most common ruminant on the island (a distinction between ovicaprines is often impossible, see 2.2.2.4). Sheep appear to have been used for multiple purposes, but milk production has been hypothesised by different scholars (e.g. Perez Jordà et al. 2010; Portas et al. 2015; Masala 2017) since ancient Sardinian sheep were likely unsuitable for wool production (Wilkens 2012: 46). As confirmed by this research, cattle also were likely used for milk. In sum, despite the absence of evidence such as pottery forms known to be used in cheese-making, milk and dairy production was likely a relevant activity in Phoenician and Punic Sardinia.

Due to the evidence shared above, the low presence of dairy fats detected through organic residue analysis does not seem to be explainable by the low presence of dairy fats in the Phoenician and Punic Sardinian diets. Combining lipid results with the historical and archaeological evidence, there are several tentative explanations for this outcome.

The most obvious potential cause is related to vessel use and to the vessel categories analysed in this project. It is possible that milk and dairy products were commonly consumed and processed at the target sites, but in vessels not analysed in this study. Possibly these vessels did not survive because they were made with perishable materials, such as wood, bark or leather, commonly found in iconographic and literary sources. Among the vessel categories analysed, cooking pots were the only ones where it was expected to detect dairy fats due to their shape and use. However, milk seems to have been rarely consumed as a boiled beverage in the Mediterranean area. Based on literary sources, it was more commonly transformed into yogurt or cheese (Campanella 2008: 85-86) and preserved in containers made from the sheep’s stomach (Campanella 2008: 85). It seems highly likely that milk and its derivatives were rarely processed in ceramic vessels in Punic Sardinia, including the cooking and preparation vessels analysed. The entire process of milk production, transformation and consumption as cheese or yogurt could have happened without the use of pottery, as is still common in the Mediterranean area and in Sardinia (e.g. Counihan 1999; London 2016). This may also be supported by the actual lack of archaeological containers and vessels identified related to this production process (see also 2.2.2.5).

But what about culinary practices? It is known from literature (Cato, *De Agri Cultura,* 85) that cheese was used in Punic cuisine. The recipe of *puls punica* requires three pounds of fresh cheese and a half pound of honey to be cooked in one pot. It is likely that this and similar recipes were reserved for special occasions: honey, in fact, was an expensive commodity (Bortolin 2008). These could have been the only cases when dairy products were processed in pots and in cookware in general. It is possible that casseroles, basins or baking trays were not used to process dairy products in the Phoenician and Punic cuisine, or only rarely used for such purposes. Dairy products were possibly processed in substantial amounts only in cooking pots among the ceramic categories included in the project, and only as cheese in specific occasional recipes. If this is accurate, it could potentially explain the lack of extracts with dominant dairy fats.

As explained in chapter 2 (2.2.2.5), it is not known how common cheese was in the Phoenician and Punic diet and specifically in Sardinia. At this stage of research, there is no reason to exclude the possibility that recipes requiring fresh cheese, such as *puls punica*, were prepared only on special occasions or on an infrequent basis. Material sources are lacking, likely because cheese production did not involve pottery or non-perishable materials. Based on available written sources, mostly biblical, some authors suggest cheese as an uncommon commodity (Campanella 2008: 85-86 with references). But the evidence regarding the prevalence of cheese in Phoenician and Punic Sardinia is up to this point sparse and inconsistent.

In summary, finding dairy fats far less frequently than ruminant adipose fats in Phoenician and Punic Sardinia offers new research insights. It seems to be explainable by culinary choices and practices more than by dairy products' contribution to the diet. Unlike meat, cheese could have been consumed uncooked, as commonly happens today. Boiling meat from old ruminants could have been a standard practice to obtain the maximum amount of fats from each individual. On the contrary, it is possible that most of the cheese was not processed in pots. These culinary choices could have made ruminant adipose fats as dominant in 64 on 66 of the analysed extracts.

This explanation suggests cheese as produced without the use of pottery and dairy products only rarely processed in pots. It seems convincing, since it is consistent with previous knowledge. It implies that recipes as *puls punica* were only occasionally prepared, and that dairy products were consumed mainly uncooked in Phoenician and Punic Sardinia. Further research, and especially material evidence about cheese production in the target area, is needed to corroborate this hypothesis.

7.1.1.4 Fish and aquatic resources

An aquatic origin of animal fats has been not considered or hypothesised during this discussion, due to the lack of unambiguous aquatic biomarkers detected. This represents an unexpected outcome of this research. As outlined in Chapter 2 (2.2.2.6), fish and shellfish exploitation increased with the foundation of Phoenician settlements, when fishing techniques seem to have developed involving long-distance fishing (Masala 2017; Carenti 2013). Fishing and the exploitation of aquatic resources appears to be a secondary activity at all of the sites during this phase (Wilkens 2012), as in the previous one (Lai et al. 2013). Both fish and shellfish, however, were certainly consumed, as revealed by the choices of species and by butchering traces (Wilkens 2000; Carenti 2013). In sites located on the sea, such as Nora, Olbia and Sant'Antioco, fishing has always been considered a relevant activity, which is confirmed by faunal evidence (Wilkens 2000; Carenti 2013; Sorrentino 2009). Fish and shellfish are also attested in S'Urachi (Ramìs et al. 2020) and Pani Loriga

(D. Ramìs, *pers. comm.*). As mentioned in Chapter 2 (2.2.2.6), shellfish found in excavations are primarily related to consumption and diet.

Therefore, the lack of aquatic biomarkers deserves consideration. On the one hand, palmitic acid ($C_{16:0}$ FFA) in high concentration can be a feature of aquatic fats, but higher $C_{16:0}$ FFA compared to $C_{18:0}$ FFA (detected in 19 of the lipid extracts identified as animal fat) also could be due to contamination, presence of plant oil, beeswax and a number of other sources (see 4.3). If aquatic fat has been processed in the vessel together with terrestrial animal fat, a stable carbon isotope signature cannot indicate the aquatic origin of the fat, since the two values easily overlap (Cramp et al. 2019). On the other hand, specific aquatic biomarkers have been targeted in this research, but they have not been detected (Cramp and Evershed 2014). Aquatic biomarkers (≥C_{20} *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs); isoprenoid Fatty Acids (IFAs), including TMTD and dihydroxy acids (DHYAs), are absent in all the extracts targeted for mass spectrometry in selected ion monitoring mode (GC-MS-SIM; (*n* = 72, see Appendix, tables I-VI) and in full-scan mode (see 5.2).

To sum up, the evidence obtained through this research does not confirm the processing of aquatic products in any of the analysed sherds. Based on modern comparisons, casseroles in particular appear to be appropriate for fish processing. Their shape makes them suitable for quick cooking with oil, but ORA has not provided relevant data in this instance (see 7.2.3). Therefore, the lack of relevant biomarkers in the vessels analysed in the present study suggests that these vessels were not used for fish processing/cooking. Since in Phoenician and Punic Sardinia it is presumed that fish were eaten, it is instead suggested that fish and other aquatic resources were cooked and processed in other vessels or structures. As with pig, a skewer or a grill is a possibility, but other hypotheses can be considered regarding fish. Baking fish in ovens has been proposed in the past (Campanella 2008: 79). Results do not confirm it. But residues may have burned in the direct heat and therefore destroyed, so it cannot be certain that fish were not baked in ovens (see 7.2.5). Another suggestion is that fish was consumed in salty sauces. Ancient sources discuss this as a particularly Phoenician method of consuming fish (2.2.2.6). Salting facilities have been identified in Iberia, Sicily and possibly Sardinia (Martìn Hernàndez et al. 2017). Such a process of preparation and consumption of fish does not require pottery, either. Therefore, it is possible that most of the fish preparation and cooking processes did not involve vessels targeted by this research.

However, it also must be highlighted that some biomarkers used for the identification of marine resources (Evershed et al. 2008) are formed in specific conditions. For example, APAAs form when unsaturated fatty acids, biomarkers of aquatic resources, are subjected to prolonged heating at 270°C within a pottery matrix. Stable carbon isotopic signatures can indicate aquatic origin only if the vessel was used to process predominantly or purely aquatic products with limited mixing with terrestrial products (Cramp et al. 2019). These biomarkers are characteristic of aquatic resource processing in archaeological vessels, but their absence alone cannot exclude fish and shellfish processing in the analysed vessels.

In summary, there are numerous possibilities to justify the absence of fish and aquatic biomarkers in the entire assemblage of Phoenician and Punic cookware. They primarily relate to the fact that these biomarkers are produced under specific conditions that may not have been met during processing. Comparisons to confirm this hypothesis are few, to my knowledge. But in the references targeting APAAs through GC-MS-SIM in the central and western Mediterranean (e.g. Salque 2012), no evidence of aquatic biomarkers has been detected. Additionally, DHYAs, which can originate from oxidation of unsaturated fatty acids originally present in fresh fat (Hansel and Evershed 2009), have not been found, to my knowledge, in pottery from the central and western Mediterranean. When said to be identified, the position of the double bond was not investigated (e.g. Notarstefano 2012).

Other explanations relate to specific culinary customs and fish processing practices that do not involve cooking pots, casseroles and basins. These interpretations are, however, corroborated at this stage of research only by negative evidence. This evidence is obtained through organic residue analysis applied to a relatively small number of sherds. Caution is needed in formulating a hypothesis regarding fish and shellfish processing and consumption. Any further interpretation should be corroborated by additional research and evidence. In particular, further research is needed to determine if this result is related to environmental conditions, making APAAs unsuitable as a biomarker for the area or the specific vessels tested. Alternatively, aquatic resource consumption and preparation in pre-Roman Sardinia, and possibly in the Phoenician and Punic western Mediterranean, should be substantially reconsidered.

7.1.2 Beeswax and honey

The detection of beeswax in 16 of the analysed extracts (12 cooking pots, three basins, one baking tray) and the probable presence of beeswax in six additional extracts from cooking pots represents one of the most striking outcomes of this project (examples are shown in figs. 58, 70, 83 and 94).

Beeswax and honey were known to be used in Sardinia and in the Phoenician and Punic world (see 2.2.2.5), but, to my knowledge, no vessel related to food processing has otherwise been linked to beeswax and honey during the Iron Age and the Phoenician/Punic periods on the island. Beeswax had been detected previously in amphoras (Bordignon et al. 2005; Botto-Oggiano 2012; also in Corsica, Rageot et al. 2016). It was also detected in one cooking pot from Sant'Antioco, analysed in a previous study (Pecci 2008). This pot came from the same SU (500) selected for this project. This last evidence cannot be underestimated because only eight cooking vessels had been analysed and published for Phoenician and Punic Sardinia prior to the present study.

Results obtained through organic residue analysis undertaken for this project are consistent with previous data and provide evidence for beehive products as commodities in Punic Sardinia. The same statement cannot be easily extended to the Phoenician period. Only one of the samples containing beeswax, NRBS22, was detected in an undoubtedly Phoenician context, i.e. 7th century BCE. Beeswax appears to be a commodity linked particularly with cooking pots and one specific subtype of basin (BA6, see 6.2.2).

Beeswax was detected at every site involved in the project but in different proportions and different kinds of vessels. At Pani Loriga, it was detected in four handmade cooking pots and one basin (from a total of 52 extracts); at Olbia, in two handmade cooking pots, one wheelmade pot, one baking tray and potentially in two additional wheelmade cooking pots (83 extracts, but very poor preservation); at Nora, in two wheelmade cooking pots (possibly three) and two basins

(78 extracts); at Genuri San Marco, one wheelmade and one handmade cooking pot (27 extracts); and one wheelmade pot (27 extracts) at Sant'Antioco. At S'Urachi (101 extracts, very good preservation), no extract unambiguously contained beeswax, but it was potentially present in three wheelmade cooking pots. Numbers are summarised in table 22.

Beeswax was detected in more than 5% of the entire assemblage of samples, an assemblage which also includes vessels not containing lipids at all. Of the analysed handmade cooking pots, 9.3% (six of 64) contain beeswax. It is a relatively high percentage considering that, in other contexts (e.g. Mediterranean Neolithic, Roffet-Salque et al. 2015), beeswax was detected in far lower percentages of vessels.

Table 22. Number of extracts containing beeswax per vessel category and per site. Tentative identification in brackets.

Site	HM Pots	WM Pots	Basins (BA6)	Baking Trays
S'Urachi		(3)		
Pani Loriga	4		1	
Nora		2 (1)	2	
Olbia	2	1 (2)		1
G. San Marco	1	1		
Sant'Antioco		1		

Organic residue analysis cannot suggest how these beehive products were used. These results could represent the use of honey for culinary purposes or as beeswax for waterproofing, or for beeswax or honey in cosmetics or food storage and preparation. In this instance, archaeological and historical evidence do not provide any definitive answers, but they help establish several points.

First of all, beeswax has only been detected in a minority of cooking pots. This seems to exclude the technological use of beeswax in pots for waterproofing or sealing, at least on a systemic base. For these vessels, it is possible to suggest honey processing for culinary uses. The lack of alkanes in nine of the 18 cooking pots where beeswax was detected suggests that beeswax was exposed to high temperatures, consistent with cooking processes (Regert et al. 2001). In Punic cuisine, this use is established by literary sources (see 2.2.2.5), and especially by the recipe of *puls punica* (Carthaginian porridge). As described in Chapter 2, it required the prolonged heating of a half pound of honey, one pound of spelt and three pounds of fresh cheese. *Puls punica* appears as a "special" recipe due to the quantities of commodities requested. It seems likely that beeswax detected in cooking pots refers to honey, with traces of beeswax processed for culinary purposes. This honey could also be used in porridges. Porridges were certainly prepared in globular cooking pots, the shape being perfectly functional for that cooking process, as explained in Chapter 3 (3.3.1). Other recipes requiring honey are likely to have existed.

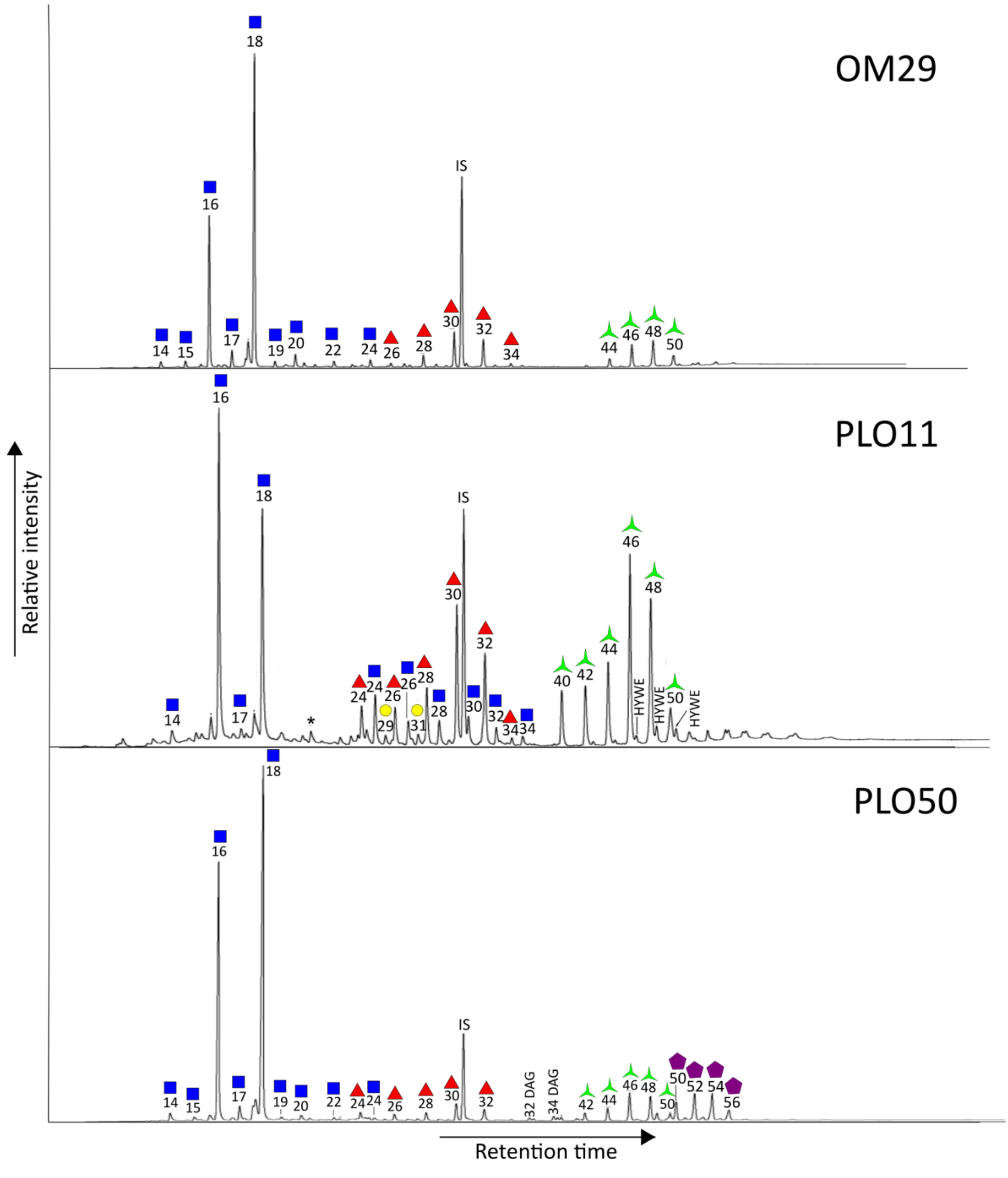


Figure 94. High temperature gas chromatograms of the extracts OM29 (wheelmade pot); PLO11 (handmade pot); PLO50 (handmade pot), indicative of a mixture of animal fat and beeswax. IS: internal standard; blue square: fatty acid; yellow circle: alkane; red triangle: alcohol; HYWE: hydroxy wax ester; green star: palmitate wax ester; DAG: diacylglycerol; purple pentagon: triacylglycerol; with Cn: *acyl carbon atoms number; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

Interestingly, the preparation of *puls punica* in some of these pots is theoretically possible. The available lipid assemblage is in fact compatible with ingredients in meals like *puls punica*. Compounds detected in extracts where beeswax was identified (short chain fatty acids as $C_{12:0}$ together with $C_{14:0}$, $C_{15:0}$ and $C_{17:0}$ free fatty acids) indicate the processing of ruminant products and potentially dairy products (Copley et al. 2003). Compound-specific isotope analyses, however, have not been carried out on extracts containing beeswax. This is due to the fact that the isotopic signature of $C_{16:0}$ fatty acids in mixtures is arising from both $C_{16:0}$ fatty acids in beeswax and animal fats, making isotope values not meaningful. Without the use of isotopic analyses, the presence of dairy fats in these cooking pots is only possible but not proven (Evershed et al. 2002). More importantly, ORA cannot indicate recipes. As explained in Chapter 4, it is not possible to know if these different lipids have been absorbed by the vessel wall during the same or different cooking events. In summary, the cooking of a known recipe such as *puls punica* in these pots is plausible, but its presence cannot be established. However, results of the analysis suggest the existence of porridges made with honey and cheese in the Carthaginian or Sardinian cuisine. These could be potentially similar to the *puls punica* recorded by Mago. Alternatively, results can simply indicate that these ingredients were relatively common in that culture and processed mainly in cooking pots. This represents a significative advancement in understanding Phoenician and Punic culinary practices.

The detection of beeswax in three of the six extracts of the analysed basin subtype BA6 (introflexed bulging rim), mentioned above (6.2.2) deserve further attention. This result does not seem to be random, since no other basin or tripod bowl (n = 85) and no casserole (n = 30) contained beeswax. The outcome suggests a connection of this specific basin subtype with beehive product consumption or use. The BA6 basin is characterised by an introflexed bulged rim and a rounded basin and dated between the 8th and the 6th centuries BCE. The shape in full is not known, as a complete example has never been found. It is also attested in Carthage (Bechtold 2007) and Sicily (Campanella 2009b: 264). In the analysed sherds, charring traces were absent or limited.

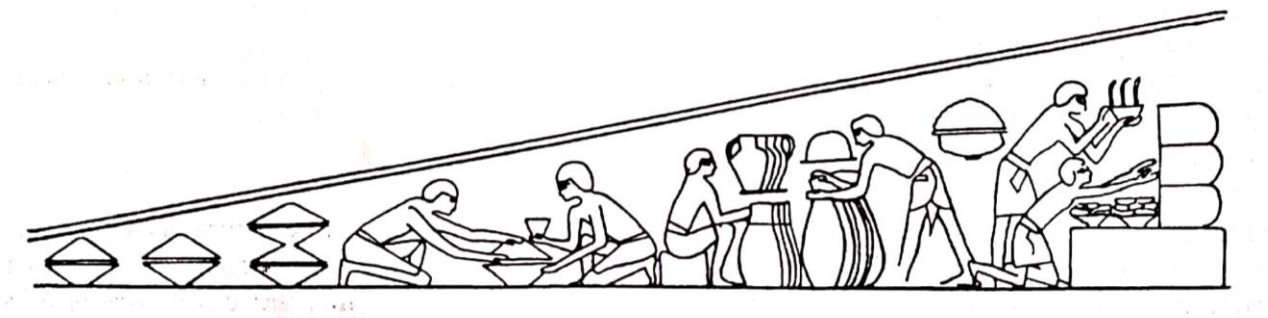


Figure 95. Beehive production scene depicted in Rekhmire tomb (1450 BCE; Thebes), illustrating phases honey collection and storage (Bortolin 2008: 54).

It is difficult to argue about how beeswax was processed in these basins. However, some elements to understand possible uses of beeswax in these vessels are available. The absence of charring traces enables the exclusion of these basins as pans or cookware. Furthermore, the presence of alkanes indicates that honey was not cooked in these basins (Regert et al. 2001). To my knowledge, archaeological literature does not suggest any specific interpretation for this subtype. But some insights coming from beekeeping and honey production processes suggest a possible involvement of these basins in the process. Around the world, honey collection and production have been proven to be similar from prehistory to the modern era, making comparisons of materials and tools between different areas and periods possible

(Bortolin 2008: 37-40). After the collection of honeycombs and before storage, honey needs to be strained on a vessel and decanted for days: this process is necessary to divide combs from honey and then separate pure honey from wax (Bortolin 2008: 52-56). This part of the process is described in Columella's "On Agriculture": "Then, when the honey has been strained and has flowed down into the basin (subiectum alveum) put underneath to catch it, it is transferred to earthenware vessels (vasa fictilia) which are left open for a few days until the fresh produce ceases to ferment ; and it must be frequently skimmed with a ladle. Next the fragments of the honeycombs, which have remained in the bag, are handled again and the juice squeezed out of them. What flows from them is honey of the second quality and is stored apart by itself by the more careful people, lest any of the honey of the best flavour should deteriorate by having this brought into contact with it" (Columella, De Re Rustica, IX, 15, 13; transl. by E.S. Forster and E. H. Heffner, Loeb Classical Library).

Not much is known about this "basin" and the "earthenware vessels" used. They are poorly described in written sources and the moment of straining and decanting is rarely represented in iconographies (Bortolin 2008: 99; Giuman 2008: 72). However, archaeologists with experience in beekeeping (M. Casagrande; R. Bortolin, *pers.comm.*) suggested with caution that the BA6 basins with the introflexed bulged rims could have been used to decant honey. The shape appears suitable for it. A similar vessel is represented on a scene of honey production in the Rakhmire tomb (Thebes, 1450 BCE): the vessel, suspended and covered probably with a wooden lid, is located between collection and storage and probably suggests a transfer and decanting moment (fig. 95). Elements suggesting the involvement of BA6 basins in honey production are limited, but vessels involved in that phase of the process clearly existed and have never been identified: the hypothesis deserves further investigation. Other hypotheses cannot be discarded. These basins could have been used to process honey for food purposes or could have been commonly covered internally with beeswax as waterproofing. Other uses are also possible, but evidence for that is lacking. Further analysis will enable a better understanding of the connection of these basins with beeswax. But, up to this stage, it is possible to state that the vessels were possibly involved in honey production and in the specific phase of decanting: the hypothesis appears plausible and convincing. If further research confirms it, it would constitute a significant advancement in the comprehension of beekeeping practices in the ancient Mediterranean, since the same basins are found in Sicily and North Africa, both regions involved in honey production (Bortolin 2008: 45-47).

On a general level, this data, combined with previous research, indicates that Punic Sardinia was an island where exploitation of beehive products was an established activity. This has been only in part suggested by available evidence, as discussed in Chapter 2 (see 2.2.2.5). One of the most important elements was the worship of Aristaeus, or at least a figure connected with apiculture, which has been established as having occurred in some areas of the island during the pre-Punic period (Spano 1855). The links between the island and Aristaeus, a hero told to have introduced apiculture on the island, are reported by some late sources. But the myth of Aristaeus appeared too weak to argue for widespread bee exploitation on the island in the pre-Roman period. Organic residue results obtained through this project provide new and crucial evidence suggesting apiculture or honey hunting was a relevant activity on the island. These results are consistent with the few organic residue analyses carried out in Sardinia before the current project (see 4.4), and also with environmental data and Roman literary sources indicating Sardinia as an area of honey production (Bortolin 2008: 48). Combining lipid results with the few literary and material sources mentioning and describing apiculture in Sardinia, it is now possible to debate the topic more extensively, trying to highlight details about production and consumption. Honey was probably occasionally cooked in pots, and possibly some of the analysed basins were part of the production process. The lack of extensive organic residue analysis on cookware in contemporary central and western Mediterranean contexts prevents pushing interpretation further. It is not possible to determine if this association of beehive products to specific vessels was a feature unique to Sardinia or something widespread in the region during that period. But this new evidence opens a path for future research. It is also possible that the literary connection of Sardinia with Aristaeus was due to a perceived or genuine connection of the island with beekeeping. But additional research is needed to test this possibility as, at this point, it is only an appealing hypothesis based on limited evidence.

7.1.3 Plants

The processing of plants has been hypothesised as having occurred in several vessels involved in the project, but in most of the cases this hypothesis is based on the previously available written palaeobotanical and iconographic evidence. For example, as it is further discussed in Section 7.2, cereals and legumes, not targeted in this project (Hamman and Cramp 2018), were probably processed in some of the cooking pots where lipid concentration was very low, since they are known to be the most frequently consumed commodities in Phoenician and Punic diet (see 2.2.2). Plant products were also probably processed in basins (7.2.2), presenting lipids in low concentration, and in some casseroles (7.2.3) and baking trays (7.2.4), but all of these hypotheses are based mostly on a combination of evidence about shape and fabric of the vessel, past archaeological hypotheses and only in part organic residues: no unambiguous biomarker of plant products have been detected in these extracts. For this reason, these aspects are discussed in detail in the next section, 7.2, focusing on vessel categories.

Here the commodities identified based on detection of specific biomarkers are discussed: these are leafy plants and resins. In at least 12 other extracts, plant product processing is possible, based on the ratio between $C_{16:0}$ and $C_{18:0}$ saturated fatty acids and the presence of mid-chain C_{16-24} alcohols and monounsaturated fatty acids in high concentrations: but, in all of these extracts, contamination cannot be excluded due to the lack of plant-specific biomarkers.

7.1.3.1 Leafy plants

Biomarkers of leafy plants have been identified in five extracts of cooking pots, one extract of a casserole and two extracts of basins. Biomarkers used to identify these commodities include even numbered long-chain FFAs in the range of C_{20-28}, odd numbered long-chain alkanes (typically C_{25-31}) and even numbered long-chain alcohols C_{24-34} (e.g in fig. 96).

Nine other extracts (six cooking pots, one basin, one baking tray) could have contained leafy plants, but identification is not unambiguous since all necessary biomarkers have not been identified. In the six cooking pot extracts, the presence of beeswax has also been hypothesized, and it seems more likely due to the presence of C_{44-50} palmitate wax esters.

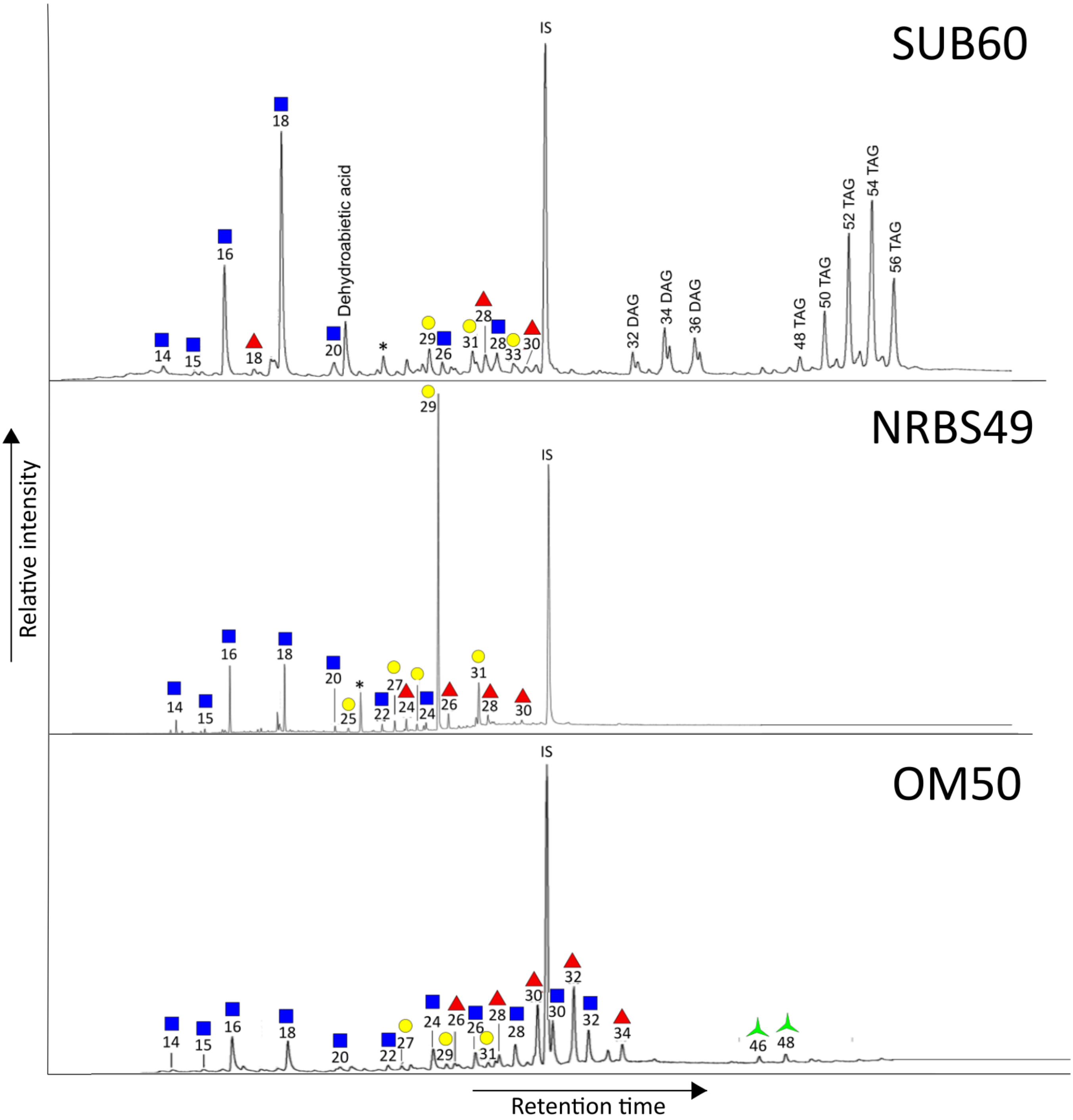


Figure 96. High temperature gas chromatograms of the extracts SUB60 (handmade pot); NRBS49 (handmade pot) and OM50 (wheelmade pot), indicative of presence of leafy plants mixed with animal products. IS: internal standard; blue square: free fatty acid; yellow circle: alkane; red triangle: alcohol; green star: wax ester; DAG: diacylglycerol; TAG: triacylglycerol; with N: acyl carbon atoms number.

This evidence confirms the processing of leafy plants in Phoenician and Punic Sardinia, as has been suggested already by written, iconographic and palaeobotanical evidence (see 2.2.2.3). Moreover, obtained results suggest that leafy plants were commonly processed in cooking pots, since the majority of extracts unambiguously containing biomarkers of leafy plants come from these vessels. It is less clear how commonly were they processed: leafy plants have been identified in only a small minority of cooking pot extracts (2%). However, since animal product processing releases ca. 150 times more lipids than plants (Charters et al. 1997), it is also possible that, in some extracts dominated by animal fat, plant lipids were not detected.

It has not been possible to connect these biomarkers with species. Previously available evidence suggests that these lipids could have originated from vegetables such as artichokes, leeks, lettuce, and cardoon (Spanò Giammellaro 2007). To a lesser extent, due to the lower plant wax contribution (Tulloch 1976), these lipids could also come from onion, garlic or turnip, or from fruits like figs, pomegranates, plums, apples, pears, dates or grapes: plums and grapes were also recently recovered in amphoras together with meat (Portas et al. 2015), suggesting a possible culinary use. This use is also suggested by the organic residues detected in cooking pots. But this is only speculation, since biomarkers detected are not species-specific. Among all possible identifications (see 2.2.2.3), cabbage, known to be consumed in Carthage, should be excluded from the interpretation, since biomarkers of *Brassicae* genus are different (Evershed et al. 1991). To sum up, evidence obtained about leafy plants offers insights about cuisine, the processing of fruits and vegetables, and the use of cooking pots (see also 7.2.1), all of which needs further evidence, especially palaeobotanic data, to be interpreted further.

7.1.3.2 Resins

Dehydroabietic acid and methyl deydroabietate, usually considered markers of resins (Colombini et al. 2005), have been detected only in four extracts: one wheelmade cooking pot and one baking tray from Olbia, one handmade pot from S'Urachi and one wheelmade pot from Nora. No correlation between the vessel shape and the presence of diterpenes has been identified. The presence of only dehydroabietic acid and methyl dehydroabietate constitutes very weak evidence for commodities identification (Rageot et al. 2016: 322), so resins could not be unambiguously identified in the analysed extracts. The same markers also can originate from wood used in burning or firing (post-excavation storage in wooden boxes is excluded, since storage procedures for each sherd are known).

This result diverges in part from the previous organic residue analysis undertaken in Punic Sardinia. Resin was previously detected in amphoras (Bordignon et al. 2005) and, more importantly, in seven of the eight sherds from Sant'Antioco (cooking pots, casseroles and baking trays) analysed by Pecci (2008). This difference is likely due to sampling and analysis procedures. Amphoras indicating the presence of resins were analysed through FTIR (Fourier Transformed Infrared Spectroscopy), and no molecular data was obtained. Sherds from Sant'Antioco were analysed using the same protocol adopted in the present study, although the sampling technique was different: 500mg of sherds were obtained by removing pottery from the internal part of the vessel using a scalpel, and no superficial pottery was removed. The author worked on unwashed and untouched pottery emerging directly from the archaeological excavation (A. Pecci, *pers. comm.*). This is different from the protocol adopted in this project and as a standard in Bristol geochemistry labs. As explained in section 5.3, 1-2 mm of pottery were removed from each sherd used in this research to eliminate contamination. It is possible that this removed layers of material (e.g. resins, waxes, pitches) used for waterproofing. This partial removal is known, but the procedure is standard and necessary when working on washed and handled archaeological materials to avoid superficial contamination.

In summary, results of the analysis do not show plant resins as a usual commodity in Phoenician and Punic pottery for cooking and preparation. Biomarkers are evidenced in only a small number of sherds, and in small amounts, not unambiguously identifying resin. However, the same result could also be due to a small quantity of resin being applied to the sherds and removed during the sample preparation procedures. At this stage of research, it is not possible to provide a detailed interpretation. Based on the described evidence, it seems important to postpone interpretation on resin use in Phoenician and Punic Sardinia. Other organic residue analyses that do not remove the superficial part of the vessels could clarify the issue outlined here.

7.2 Discussion about the results and use of different vessel categories

Comparing results obtained per vessel category, some general patterns can be determined across the island, and these are described in this section.

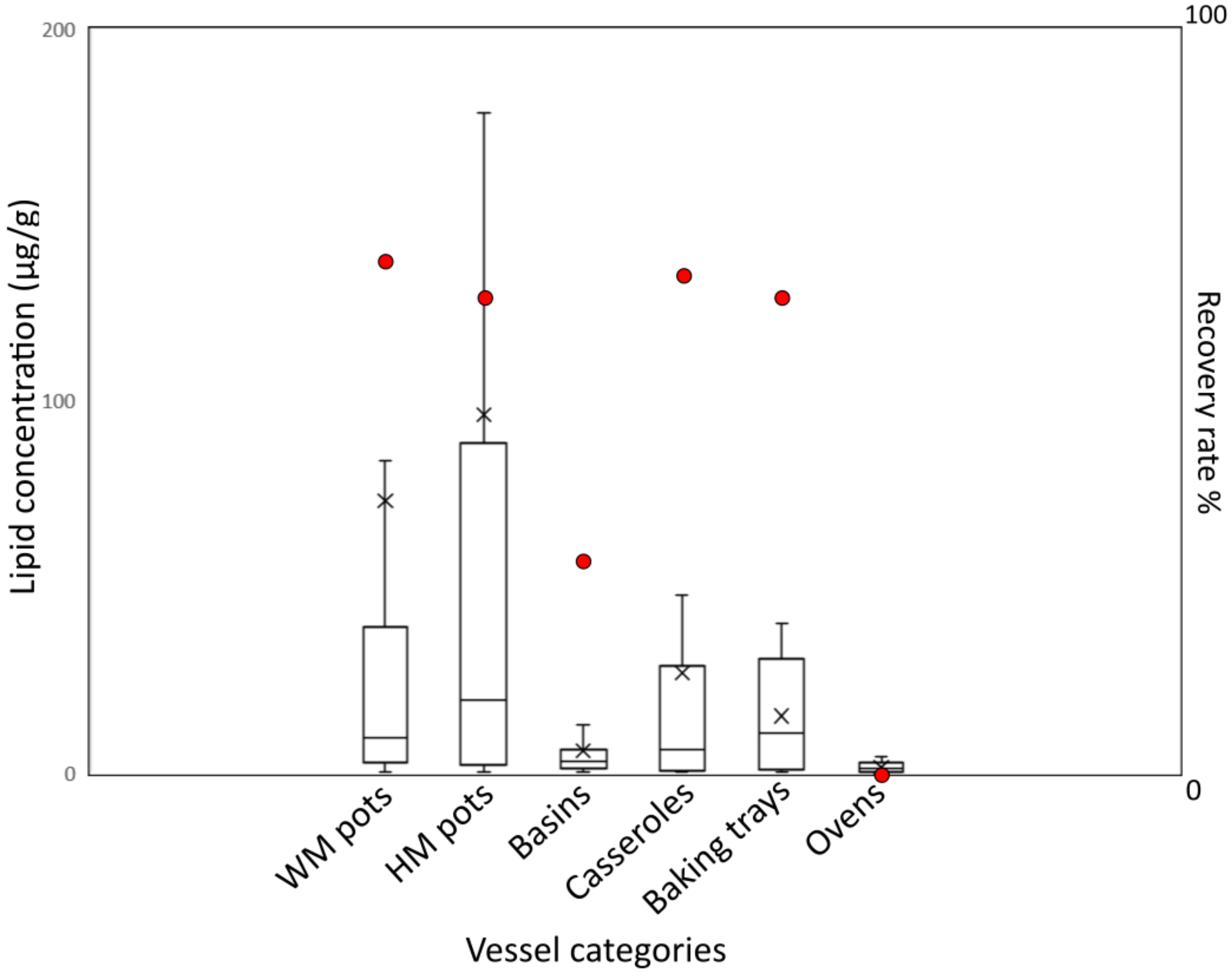


Figure 97. Box plots showing lipid concentrations (X = mean) and recovery rate (red dot) per vessel category in the whole assemblage of analysed sherds. HM (handmade) pots (n = 54); WM (wheelmade) pots (n = 164); casseroles (n = 30); basins (n = 87); baking trays (n = 11); ovens (n = 13).

To introduce this section, the average lipid concentration and the recovery rate for the entire selection of analysed sherds, per vessel category, are summarised in fig. 97. Lipids recovered from different vessel categories are different in composition and concentration, suggesting differences in use. For example, the recovery rate is over 65% for cooking pots and casseroles, which is as expected, since these vessels were used for cooking. Lipid concentrations in cooking pots range between 0 to 1066 µg/g, while for casseroles they range between 0 and 205 µg/g. The overall recovery rate for basins, thought to be involved in food preparation and not cooking, is less than 30%. The mean lipid concentration in basins per site is never above 7 µg/g, and the recovery rate per site is always under 40%. For baking trays, the mean is 15 µg/g, but the value seems to be possibly conditioned by contaminations (see 7.2.5), while for ovens it is 1.5 µg/g, ranging from 0 to 4 µg/g.

The existence of differences in quantity and quality of lipids were not unexpected. Vessel categories thought to provide low recovery rates (basins, baking trays and ovens) have also been included in the analysis (see 5.1), aiming to understand more about the use of the whole cooking assemblage of Phoenician and Punic Sardinia. These differences and patterns are discussed throughout section 7.2, describing implications and interpretations, aiming to identify vessel specialisations and to answer research question 2.

7.2.1 Cooking pots

7.2.1.1 Identified commodities

Based on results obtained, cooking pots appear to be vessels commonly used for meat processing. Nearly all the extracts containing lipids (*n* = 143) can be identified as animal fats. This is consistent with the vessel shape and ethnoarchaeological information, suggesting globular pots as suitable for time-consuming cooking processes such as boiling meat.

The $\Delta^{13}C$ values and $\delta^{13}C_{16:0}$ values from lipid extracts of cooking pots identified as animal fats are shown in the plot in fig. 98, where handmade and wheelmade pots are highlighted in different colours. No relevant difference between the two subcategories is recorded. The $\Delta^{13}C$ values are characteristic of dairy fats in 3.2% of the extracts (*n* = 2) and of non-ruminant adipose fats in 5% of the extracts (*n* = 3). All other extracts (91.8%, *n* = 56) have $\Delta^{13}C$ values consistent with predominantly ruminant adipose fats. Four of the extracts indicated in fig. 98 with squares could have contained plant fats due to the higher concentration of palmitic ($C_{16:0}$) compared to stearic ($C_{18:0}$) acid. In these cases, the interpretation using $\Delta^{13}C$ values is only hypothetical. In summary, ruminant adipose constitutes the predominant source of animal products processed in cooking pots, consistent with faunal evidence (see 7.1).

Analyses undertaken also confirmed that the mixing of meat with other commodities was not uncommon: namely, commodities commonly identified in cooking pots, alternative to animal adipose fats, are beehive products, leafy plants and oils, and milk or dairy fats. Among these commodities, more can be stated about beeswax, which has been detected mixed with animal fats in 18 pots. The absence of alkanes in nine of the 18 pot extracts in which beeswax was identified is consistent with the exposure of beeswax to high temperatures (Regert et al. 2001), probably connected with cooking. This suggests that, in these nine cases, the detected beeswax was used as honey and not as a waterproofing or sealing agent. Beeswax has been detected in cooking pots possibly containing dairy fats, at least according to the presence of short-chain fatty acids. This element is also intriguing and potentially meaningful, because it calls to mind the most famous Carthaginian recipe, *puls punica* (see 2.2.2.1), made by boiling cereals, fresh cheese and honey. Details and beeswax-related insights have already been comprehensively discussed above (7.1.2).

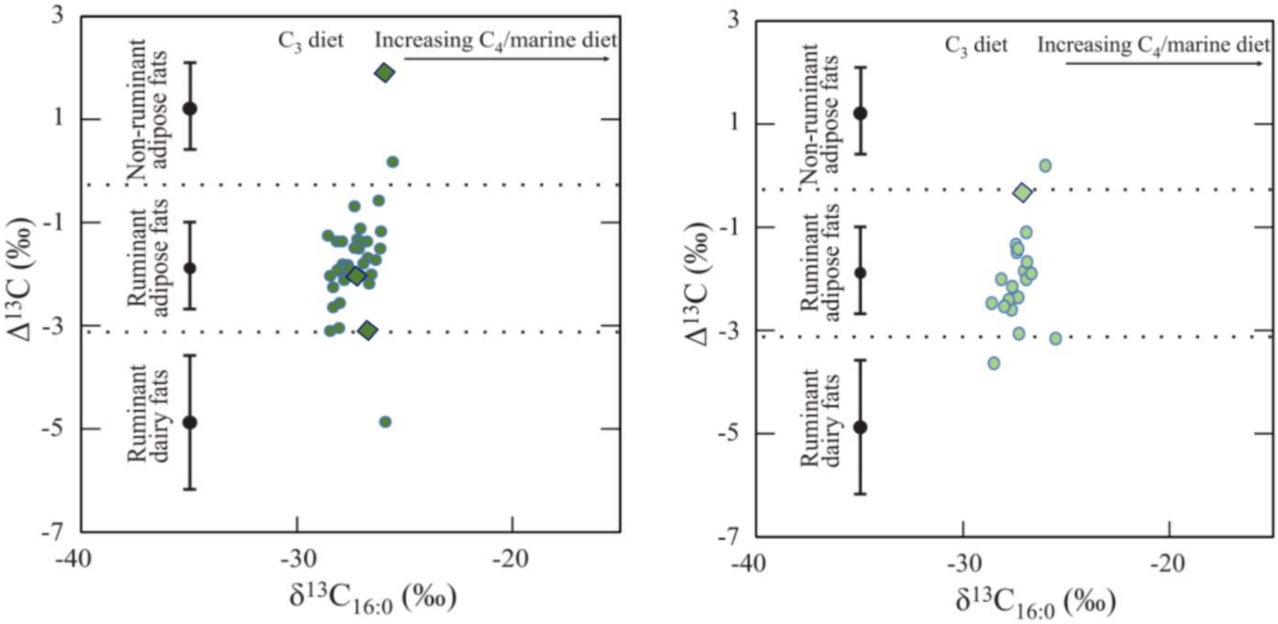


Figure 98. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for extracts of pots. Wheelmade pots on the left (dark green) and handmade pots on the right (light green). Extracts possibly not containing exclusively animal fat are indicated with a square. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

Less can be stated about plant lipids in cooking pots. Leafy plant processing was identified for five pot extracts, despite the fact that six of the extracts possibly containing beeswax could have instead contained plant waxes: biomarkers do not allow an unambiguous identification. In seven pot extracts, the presence of oil is possible due to a higher concentration of $C_{16:0}$ FFA compared to $C_{18:0}$, and the presence of monounsaturated fatty acids in higher concentrations than in the extracts typically showing degraded animal fats. The position of the double bond, diagnostic of oil (Regert el al. 1998; Copley et al. 2005), is not investigated in this project, since other commodities were the target of this research. Other compounds which could confirm the presence of plants, such as sitosterol, are absent, but these are rarely archaeologically preserved (Hammann et al. 2018). The lipid composition in extracts supposed to contain plant lipids is insufficient to push interpretation further, e.g. identifying specific products (Evershed et al. 1991). It is possible to state that the processing of plant products may have been common. No more precise trend has been found regarding plant lipids presence in cooking pots. Regarding milk and dairy products, no pattern of their distribution in cooking pots has been identified. However, this research revealed that dairy products were processed predominantly in cooking pots among the vessel categories investigated for this project. This is interpreted based upon the isotope values of individual free fatty acids, and implications of this result have been further discussed in section 7.1.1.3.

7.2.1.2 Absence of lipids relating to the past uses of pots

Several cooking pot extracts contained little or no lipids. Whilst the mean lipid concentration in cooking pot extracts is 79 µg/g on an island level, the range spans from 0 to 1066 µg/g (see chapter 6). As shown in fig. 99, pot extracts containing more than 50 µg/g represent a minority (34%; 74 of the 218 total analysed sherds), and only 29% of the total contains more than 100 µg/g.

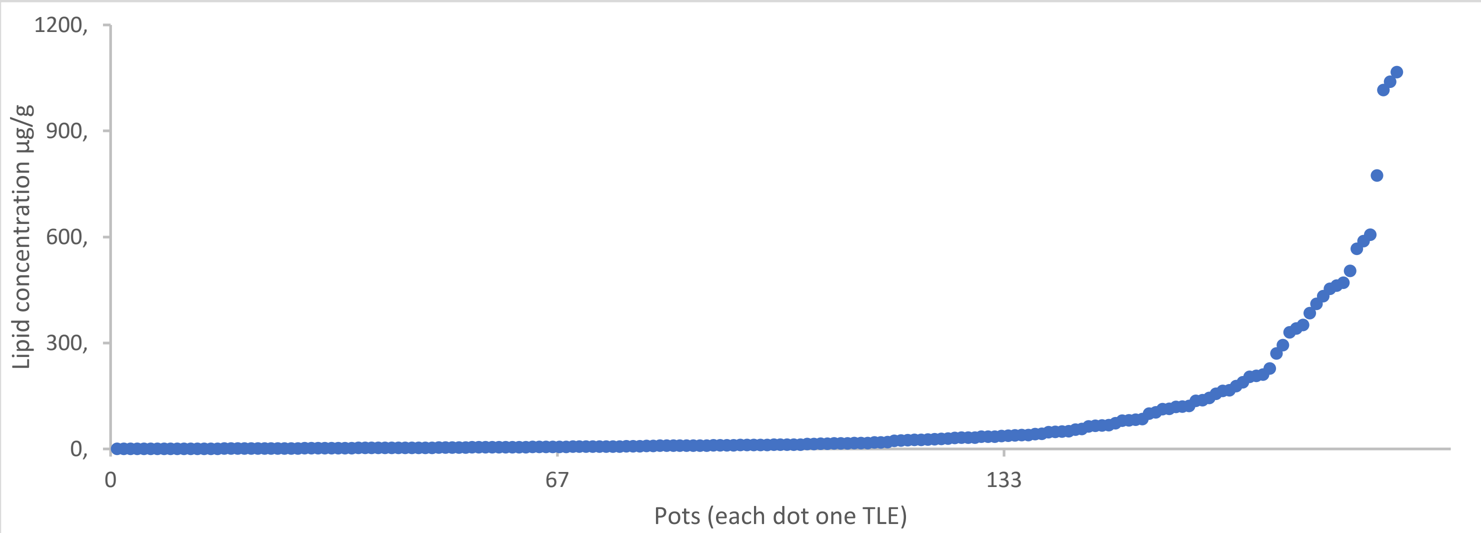


Figure 99. Lipid concentration per pot extract, displayed in increasing order.

When lipid concentrations are very low, poor lipid preservation is always a possibility. But in the case of cooking pots involved in this research, other explanations seem necessary: the lipid concentration varies considerably among pots at the same site or archaeological context. Based on the available evidence, it is possible to hypothesise that the absence of lipids in several cooking pots is linked to their specific use. This absence could be connected to the processing or storage of cereals and legumes, which would not be detected through ORA in absence of specific environmental conditions and without the application of a different analytical protocol (Hammann and Cramp, 2018; Hammann et al. 2019). The processing and storage of cereals and legumes would not have been uncommon, as these are the most important commodities in the Phoenician and Punic diet (see chapter 2). The lack of lipids in cooking pots appears consistent with a community and a culture where staple food was cereal-based and low in lipids, and animal products represented an occasional commodity. This is the case of Phoenician and Punic Sardinia, as discussed in Chapter 2. It is also possible that some of the cooking pots analysed in this study had a different purpose than cooking or food processing. This is due to the ritual use of cooking pots in the Phoenician and Punic cultures, as discussed in section 3.3.1, leading to pots never or rarely being in contact with food. But it is unlikely that a similar ritual treatment involved many of the pots selected for this study, since all of them come from settlements. A broad study of organic residue analysis focused on Phoenician and Punic necropolises is necessary to further investigate this question (see 8.3).

Previously-available evidence (see 3.3.1) suggested cooking pots were vessels primarily used for boiling and making porridges. The analysis undertaken seems to corroborate this interpretation and adds new elements regarding the function of vessels and cooking practices. Three pots from Sant'Antioco had two samples taken, including one from the rim and one from the bottom of each vessel (see fig. 100). The results revealed that lipid concentration at the rim was similar to that at the bottom for each of the three vessels. This suggests that the vessels were used to cook semi-liquids such as porridges or stews rather than water (Charters et al. 1993). Scientific evidence to substantiate this hypothesis is very weak, but the hypothesis is consistent with previous research (see section 3.3.1).

Figure 100. Example of a pot from Sant'Antioco clipped in two different positions, with an indication of lipid concentration per sherd. Sample SAC63AB.

7.2.1.3 Wheelmade and handmade pots: are differences in detected lipids meaningful?

A significant outcome of the present study refers to differences in lipid concentration between subcategories of cooking pots in some of the sites analysed (fig. 101). The average lipid concentration in handmade pots was shown to be more than ten times higher than wheelmade pots at the sites of Pani Loriga, Nora, and, to some degree, Sant'Antioco (only one handmade pot was analysed). In Pani Loriga, this difference is statistically significant (t-test, $p = 0.05$), while in Nora and Sant'Antioco it is not.

The trend detected at these three sites cannot be extrapolated to S'Urachi, the site providing the greatest number of analysed sherds (wheelmade pots $n = 63$; handmade pots $n = 5$). Wheelmade cooking pots in S'Urachi contain higher concentrations of lipids than handmade ones (t-test, $p = 0.02$). In viewing the entire assemblage of analysed cooking pots, the average lipid concentration in handmade pots (96 µg/g, $n = 54$) is not much higher than wheelmade pots (73 µg/g; $n = 164$). The comparison between the two categories proved to be statistically significant only at Pani Loriga and S'Urachi.

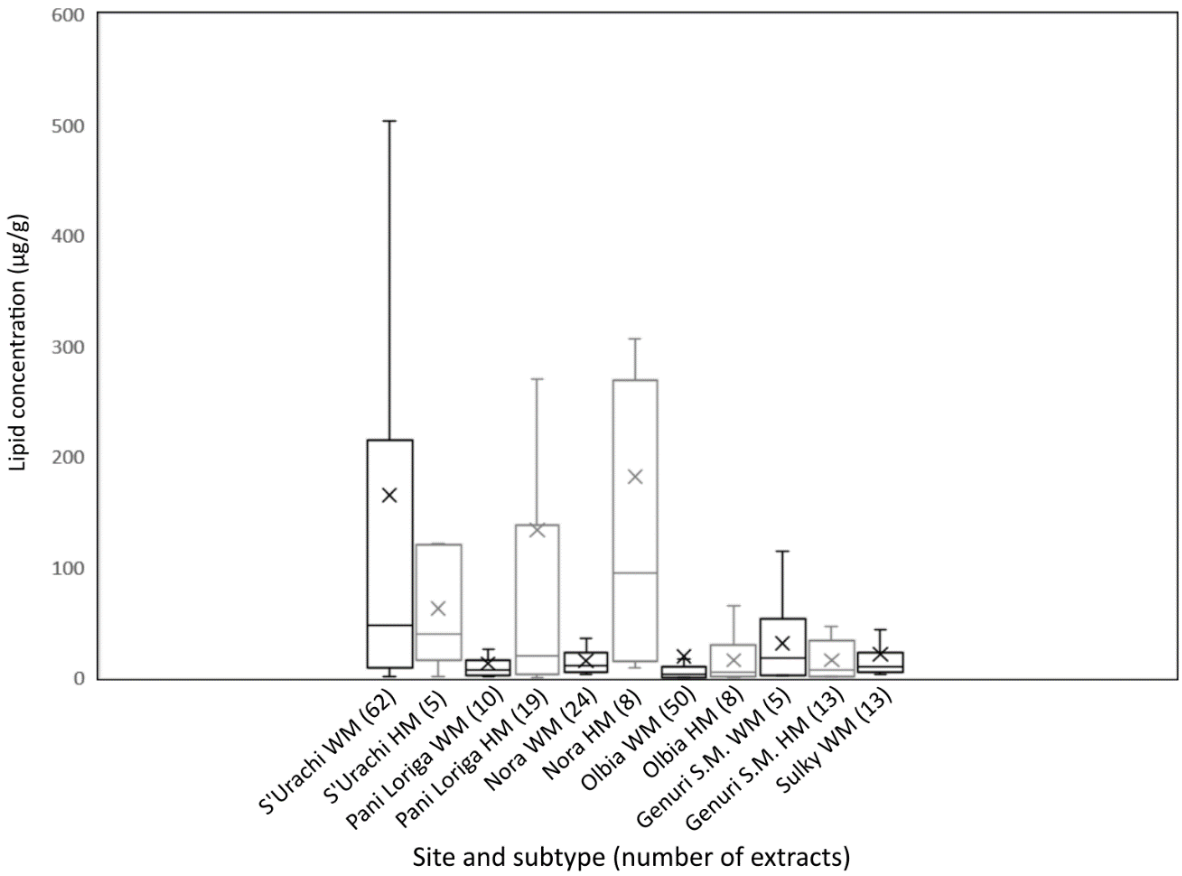


Figure 101. Box plots showing lipid concentrations (X = mean) in pots, per site and subcategory (number of sherds in brackets). WM, black: wheelmade; HM, grey: handmade.

This difference in lipid concentration is connected with animal fat detection (fig. 102): despite animal fats being detected in 143 extracts coming from cooking pots, with similar proportions (65%) in wheelmade and handmade pots, biomarkers of degraded animal fat dominate the chromatographic profile only in 37 wheelmade cooking pot extracts on 164 (17%, but 26 of them in S'Urachi), compared to 22 on 54 extracts of handmade cooking pots (41%). As for lipid concentration, a difference in the animal fat detection rate in handmade and wheelmade cooking pots is higher in Nora and Pani Loriga. In Nora, animal fat is detected in 10 out of 24 wheelmade cooking pot extracts and dominant in two of them; but it is detected in all of the eight handmade pot extracts and dominant in four of them. In Pani Loriga, animal fat is detected in three out of 10 wheelmade pot extracts and dominant in one of them; but it is detected in 14 out of 19 handmade cooking pot extracts, and dominant in nine of them. Despite further archaeological investigations being needed to interpret in detail these results, some insights seem to be already suggested by them.

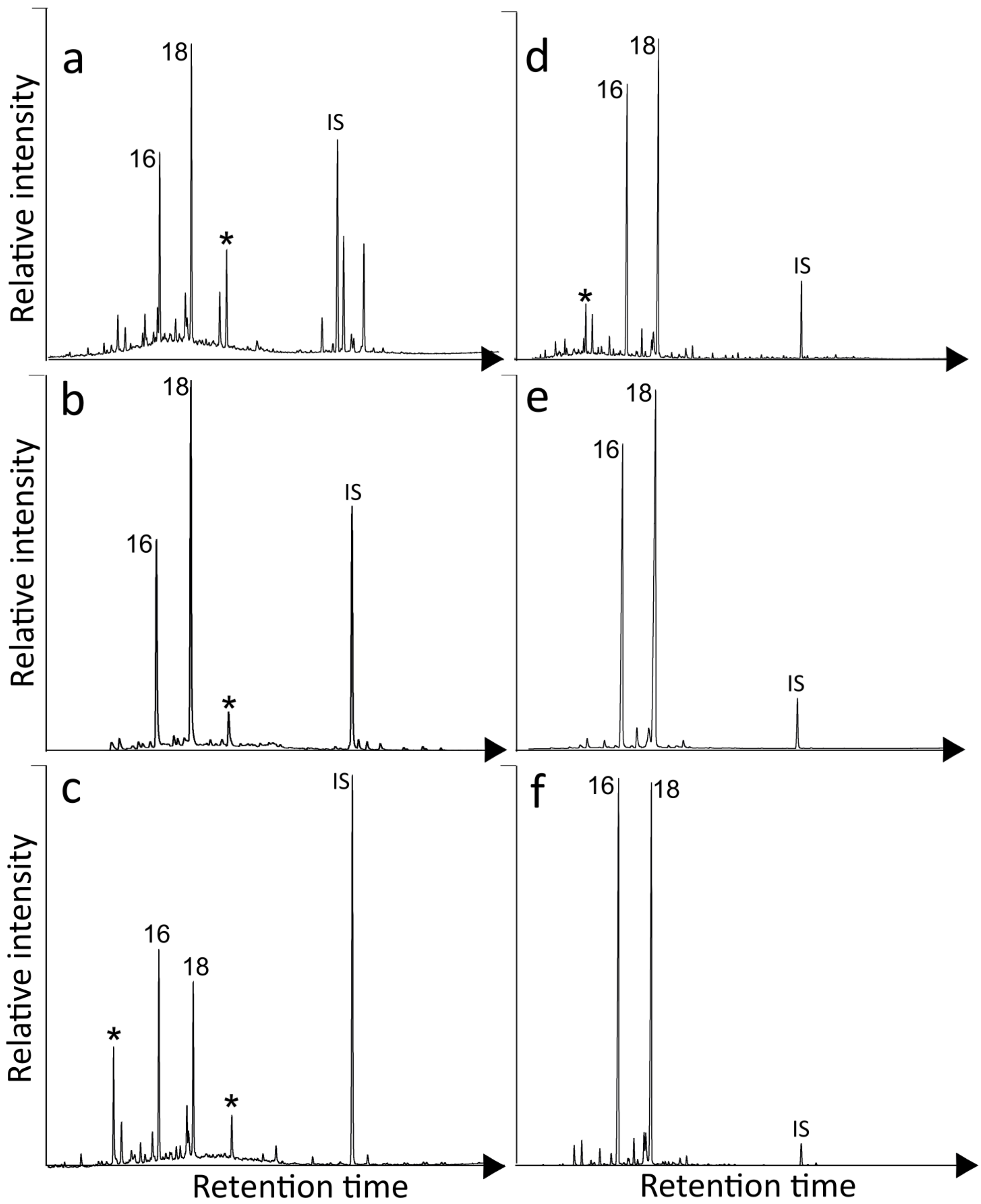


*Figure 102. Examples of extracts of wheelmade and handmade pots containing degrade animal fat from the sites of Nora, Pani Loriga and Sant'Antioco. Wheelmade pots: a, NRBS4; b, PLO43; c, SAC72. Handmade pots: d, NRBS80; e, PLO4; f, SAC17. IS: internal standard; 16: palmitic acid; 18: stearic acid; *: phthalate.*

The first potential reason to explain the differences in lipid concentration and animal fat abundance involves the fabric of the pottery. It can be hypothesised that these differences are due to the different porosity of wheelmade and handmade pot fabrics, such that lipids are more easily absorbed into the walls of handmade pots (Charters et al. 1993; Drieu et al. 2019; Hammann et al. 2020). It has not been possible to undertake a large study of fabrics to test this hypothesis within the framework of this thesis (see further work outlined in section 8.3). However, I used the sources available to estimate how differences in fabrics could have impacted lipid concentration. Since descriptions of fabrics vary too much among published ceramic catalogues (see 3.1), these sources included mainly photos, visual examination of sherds and discussions with pottery specialists who work on Phoenician and Punic Sardinia. The preliminary conclusion is that, up to this stage, explaining differences in lipid concentration through differences in fabric between wheelmade and handmade cooking pots is not possible. Differences in fabrics do not appear so pronounced as to justify such a difference in lipid absorption.

The second hypothesis relies on cultural and functional explanations, which are further mentioned when discussing sites (7.4). Differences in lipid concentration between the two categories are limited to some specific sites: Nora, Pani Loriga and Sant'Antioco. If data about average lipid concentration and animal fat detection in handmade and wheelmade cooking pots are contextualised per site, the picture obtained appears to be potentially consistent. S'Urachi, where no meaningful difference between the two categories is recorded, was an indigenous settlement. The wheelmade pots at this site do not appear to have had a direct link with Phoenician or Punic people living in the settlement. The vessels seem to have been adopted by the local community apparently without any substantial change in the population of the settlement itself (Roppa 2015). In contrast, Nora and Sant'Antioco were new settlements created by Levantine people. Pottery in both of these sites followed Phoenician manufacturing practices, including wheelmade forms. The presence of handmade pots and other vessels connected with indigenous manufacturing at these sites is often linked with living indigenous communities and people who cooperated with the newcomers (see 3.3.1.2). According to the available evidence (e.g. burials, pottery assemblages), it is very likely that an indigenous population existed and contributed to the life of the two settlements.

In Pani Loriga, the situation is different, as the settlement was likely founded jointly by Phoenician and indigenous Sardinian people, as testified by the large presence of indigenous pottery from the earliest layers through to the 5th century BCE (3.2.2). The available archaeological evidence enables the conjecture that the "meaning" and use of the same types of pots could have been different at these different sites. This is not to say that indigenous people in Nora, Pani Loriga and Sant'Antioco used indigenous handmade pots while Phoenician and Punic people used wheelmade Levantine-style pots, as there is no evidence for that. However, it is possible that in the multicultural settlements of Nora, Pani Loriga and Sant'Antioco, the two different types of cooking pots were perceived as being different, potentially each connected with a specific culinary tradition and the processing of specific commodities. Examples of this culinary differentiation in contemporary and past migrations are common (see Chapter 1).

Such a different perception potentially did not exist in S'Urachi, where the entire settlement began to use Phoenician-style pots and pottery without any major change in culture or people inhabiting the territory. The same lack of differentiation in use and perception possibly existed later, as in the 4th–3rd centuries BCE contexts at Genuri San Marco and Olbia. In these sites, differences in lipid concentration between the two categories are not as evident as in Nora, Pani Loriga and Sant'Antioco (fig. 101).
Based on the available evidence, randomness as an explanation for differences in lipid concentration cannot be excluded, although it seems unlikely. Likewise, fabric does not provide a good explanation for these attested differences in cooking pot use. No definitive answer can be provided at this stage, but archaeological and historical information

suggests that differences in lipid concentrations, and, to a lesser extent, animal fat detection, between handmade and wheelmade cooking pots could be connected to the food commodities processed in them, such as a connection of handmade pots with animal products and meat processing. To my knowledge, different uses of handmade and wheelmade cooking pots were not previously suggested before this current research because the shapes (globular profile, dimensions) are similar. However, it would not be surprising if vessels coming from different ceramic traditions were used to process different commodities, despite being similar in external appearance. The use of organic residue analysis seems to have provided an aspect for further investigation, as is further discussed in section 7.4.

7.2.2 Basins and tripod bowls

As explained in Chapter 3 (3.3.2), vessels having different functions, fabrics and thicknesses, and only a relatively similar shape, are grouped in the category of "basins." Based on the results obtained from this research, basins can be interpreted as a vessel category related to processing plant products. Lipid extracts from basins are in fact generally poorly concentrated, with an average lipid concentration of 6 µg/g, five times less than casseroles (comparison between the two categories is significant, $p = 0.03$). This suggests that these vessels were used for processes leading to limited lipid absorption (e.g. food serving or handling), they were only occasionally in contact with food, or they were used to process cereals and other lipid-poor commodities. These hypotheses do not exclude each other. When basins contain significant amount of lipids (more than 5µg of lipids per g of sherd), animal fats are often absent ($n = 21$) or present in very low concentrations ($n = 4$) and, with only one exception (fig. 59B), mixed with vegetal fats or beeswax. This indicates a specific connection of basins with plant commodities, since experimental studies show that boiling lamb accumulates *c.*150 times more lipids in the vessels than boiling *Brassica* leaves (Charters et al. 1997). A difference in use with casseroles seems to have existed since the Phoenician period (see 7.2.3). This is consistent with previously available interpretations, based mainly on shape, fabric and thickness of walls (see 3.3.2). When lipids are recovered, often the identification is limited to generic “plant lipids” (fig. 104). Lipid assemblage allows more in-depth interpretation for some specific subtypes of basins (fig. 103).

The case of subtype BA6, rounded basins with introflexed bulging rim, is the most striking. Based upon the lipid results, this subtype appears connected with beeswax use or honey processing (7.1.2). Beeswax was detected in three of six extracts analysed. BA6 is an early subtype (8th to 6th centuries BCE), uncommon in Sardinia and also attested in Carthage and Sicily (Campanella 2009b: 264). In the analysed vessels, as in the ones published in Nora (Campanella 2009b: 264), walls are not particularly thick (< 2 cm) and no charring traces have been observed. This outcome is strictly connected with the information about beekeeping and honey production possibly obtained through this research project. Since this topic deserves further attention, being one of the most relevant outcomes of the whole research, the use and interpretation of basins BA6 has been further discussed on a specific section on beeswax and honey (7.1.2).

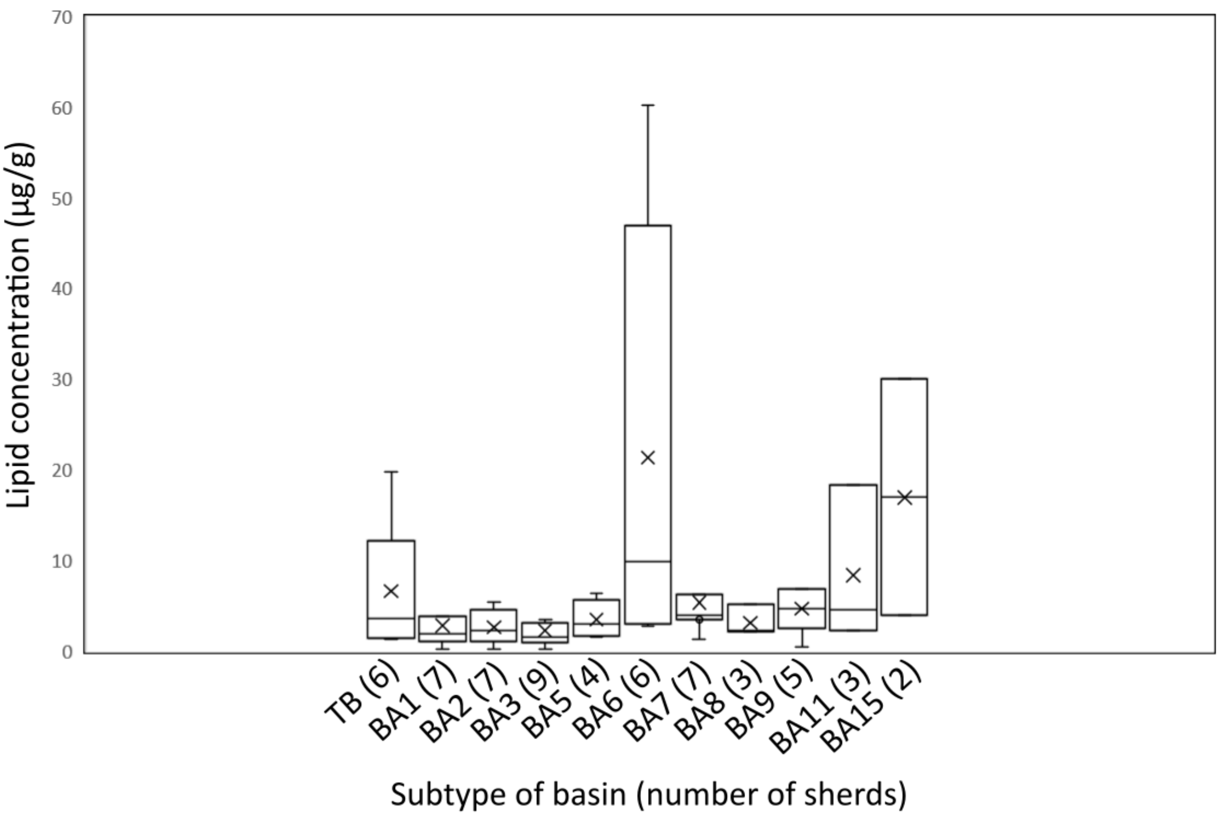


Figure 103. Box plot showing lipid concentration (X = mean) in basins per subtype (following Campanella 2009b), selection from the sites of Nora, S'Urachi, Pani Loriga and Sant'Antioco). Number of extracts in brackets. TB = tripod bowls.

On the contrary, no straightforward interpretation or link with specific commodities is possible in the case of other subtypes of basins. Comparing the lipid concentration of subtypes (fig. 103) differences are not evident. But the sherd number considered for the comparison (59 sherds in total) is also limited. To sum up, values show very low lipid concentration in most of the subtypes of basins (ranging from 2 to 5 µg/g). This suggests that these basins were used to process mainly lipid-poor commodities such as cereals, or they were in contact with food for limited amount of time (e.g. serving or handling). This statement seems true both in the case of more ancient subtypes, as BA1, 2, 3 and 5, common subtypes of basins in the pre-Carthaginian period (8^{th}-6^{th} centuries) and in the case of later subtypes as BA7, 8 and 9 (5^{th}-2^{nd} centuries BCE). In the case of basins BA1, BA3 and BA7, basins characterised by thick walls and hard fabrics, a use as mortars also cannot be excluded. Basins BA2 and BA7, having a shallow shape and in some cases charring traces on the rim, have been in the past associated with a use as burners or cooking bells (Campanella 2009b: 253, 267): results do not deny this possibility. But the general absence of lipids in these subtypes, together with the small number of extracts involved, hinders well-substantiated interpretations pushing past archaeological interpretation further (see 3.3.2).

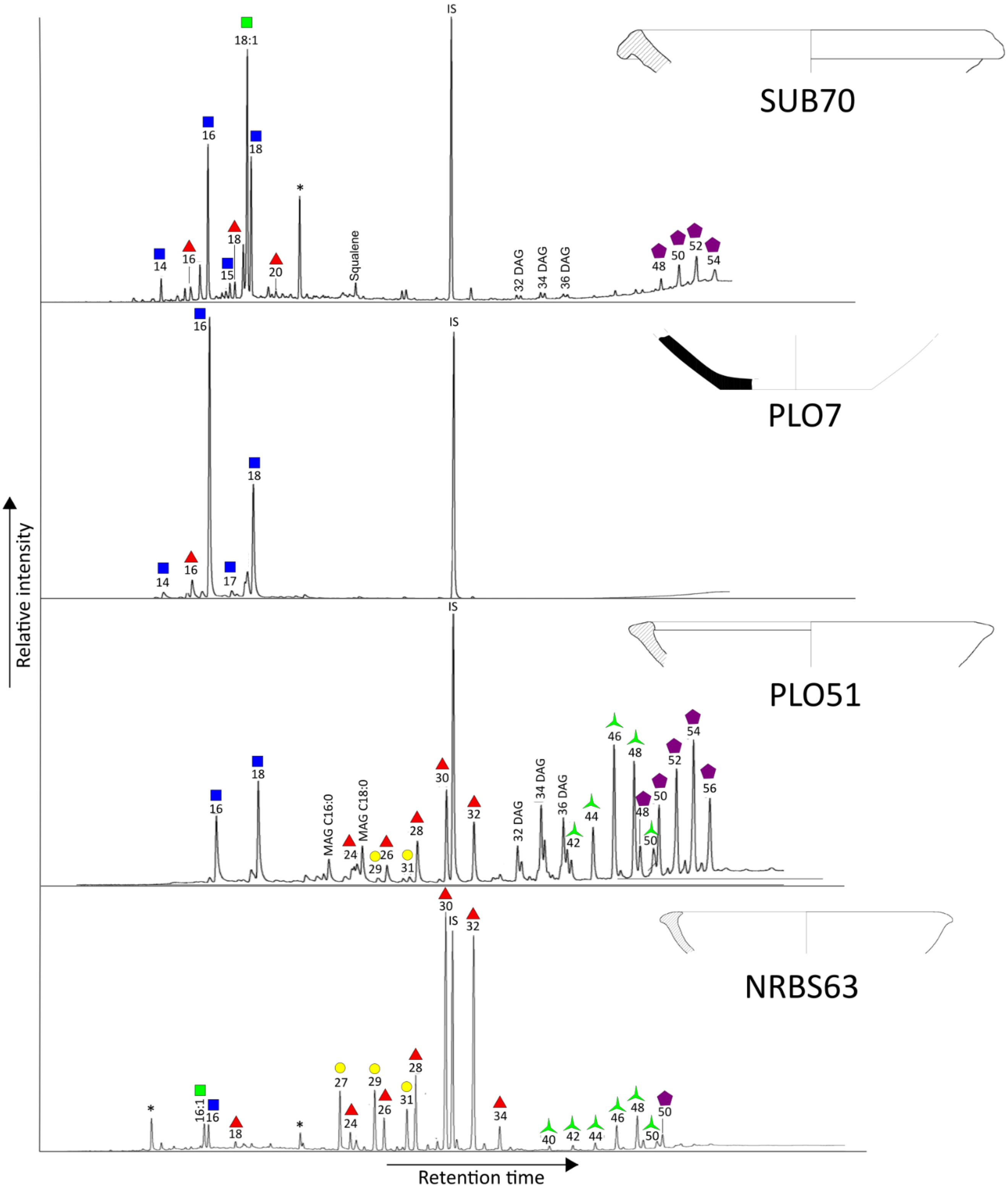


Figure 104. High temperature gas chromatograms of the extracts of basins SUB70 (BA15); PLO7 (undefined bottom); PLO51 (BA6) and NRBS63 (BA6). Shapes from Campanella 2009a and E. Madrigali, unpublished (PLO7). IS: internal standard; blue square: free fatty acid; green square: monounsaturated fatty acid; yellow circle: alkane; red triangle: alcohol; green star: wax ester; MAG: monoacylglycerol; DAG: diacylglycerol; purple pentagon: triacylglycerol; with n: acyl carbon atoms number; x:y= Fatty acids with X-number of carbons and Y-number of double bonds.

Commodities richer in lipids seem to have been more commonly processed in basins especially in some subtypes, where the mean lipid concentration is slightly higher than the mean (fig. 104). The already mentioned BA6, discussed in section

7.1.2 for its connection with beeswax, with mean lipid concentration 21 µg/g. Then BA11, characterised by wide and hanging outstretched lip (4th-2nd centuries BCE; mean lipid concentration 8.4 µg/g), with 3 extracts analysed; and BA15, characterised by bulged rim and a yellow fabric (4th-3rd centuries BCE; lipid concentration 17 µg/g, only two extract analysed). These subtypes may have been involved in processing low-lipid plant commodities (maybe vegetables or spices), since $C_{16:0}$ free fatty acid and C_{16-24} alcohols are often attested in these extracts (fig. 104, see also chapter 6). This relatively low lipid concentration, but higher than general mean for basins (6 µg/g) could be related to food handling or grinding for short periods of time, or, when charring traces are attested, to the heating of liquids for non-culinary purposes.

However, these outcomes could be also due to randomness or contamination: unambiguous plant-specific biomarkers are not found, and difference in lipid concentration and number of extracts involved is limited. Moreover, with such a small number of extracts involved, differences appear to be connected in some cases with inter-site differences in lipid preservation: in subtypes BA11 and BA15 the mean lipid concentration is respectively 8 and 17 µg/g, double than most of the other subtypes. But in both cases the number of extracts involved is low (3 and 2 respectively) and the higher mean is due to the value from single extracts from S'Urachi, where lipid preservation is in general higher also for basins (see 6.1.3). In other subtypes, with higher number of extracts, the impact of values from single extracts is generally lower. Other basin extracts (e.g. the undefined bottom show in figure 103, PLO7) show lipid concentration over 30 µg/g. With the exception of BA6, differences between subtypes of basins detected cannot be easily linked with specific past uses of subtypes. Nevertheless, the product processing suggested by the chromatographic profiles of basins does not seem to be related to cooking: the low-lipid concentration, the fabric and thickness of the vessels, and the fact that casseroles are attested on the island in the same period seem to preclude this possibility. Casseroles are in fact vessels more suitable for frying or quick cooking. Limited insights about culinary practices can be offered so far based on these limited findings. Further analysis is needed to test the reliability of the trends and interpretations outlined here.

Lipid concentrations in tripod bowls, on the other hand, has an average of 6 µg/g. Lipid analysis appears to confirm, or at least not reject, the use of tripod bowls as mortars to grind non-tough commodities, such as spices or vegetables (see 3.2.2), based upon the presence of $C_{16:0}$ FFA and C_{16-20} alcohols. But, once more, contamination cannot be excluded based on this lipid distribution. No further interpretation can be made due to the small number of sherds analysed (n = 6) and the lack of specific biomarkers.

7.2.3 Casseroles

The number of casseroles analysed (n = 30) is lower than the number of cooking pots and basins, but some major aspects of this vessel category can be highlighted. In general, the results suggest that this ceramic shape was predominantly used to cook non-animal commodities. A broad variety of non-animal ingredients (oil, plants) is suggested by recovered lipids (see Chapter 6). In lipid extracts from casseroles, animal fats (detected in 11 extracts) are typically not dominant and are mixed with vegetal lipids.

Results from casseroles appears to be particularly meaningful when compared with the ones from cooking pots, a vessel category also used for cooking and with 223 analysed extracts. The recovery rate in casseroles was usually higher than in cooking pots, except in Olbia: general poor lipid concentration at the site has to be considered when interpreting this value. The mean lipid concentration, on the other hand, in casseroles is 27 µg/g, while in pots it is 79 µg/g (the comparison is significant, $p = 0.00$). The mean lipid concentration for casserole extracts is 5 µg/g in Nora, 10 µg/g in Sant'Antioco, 0.4 µg/g in Olbia (in line with the poor lipid concentration in the site) and 65 µg/g in S'Urachi, higher than at other sites but still far lower than cooking pots. Comparison between average lipid concentration in cooking pots and casseroles is significant in S'Urachi ($p = 0.02$), Olbia ($p = 0.01$) and Nora ($p = 0.05$), while it is not in Sant'Antioco. Quantitative results obtained for casserole extracts per site are summarised in figure 105.

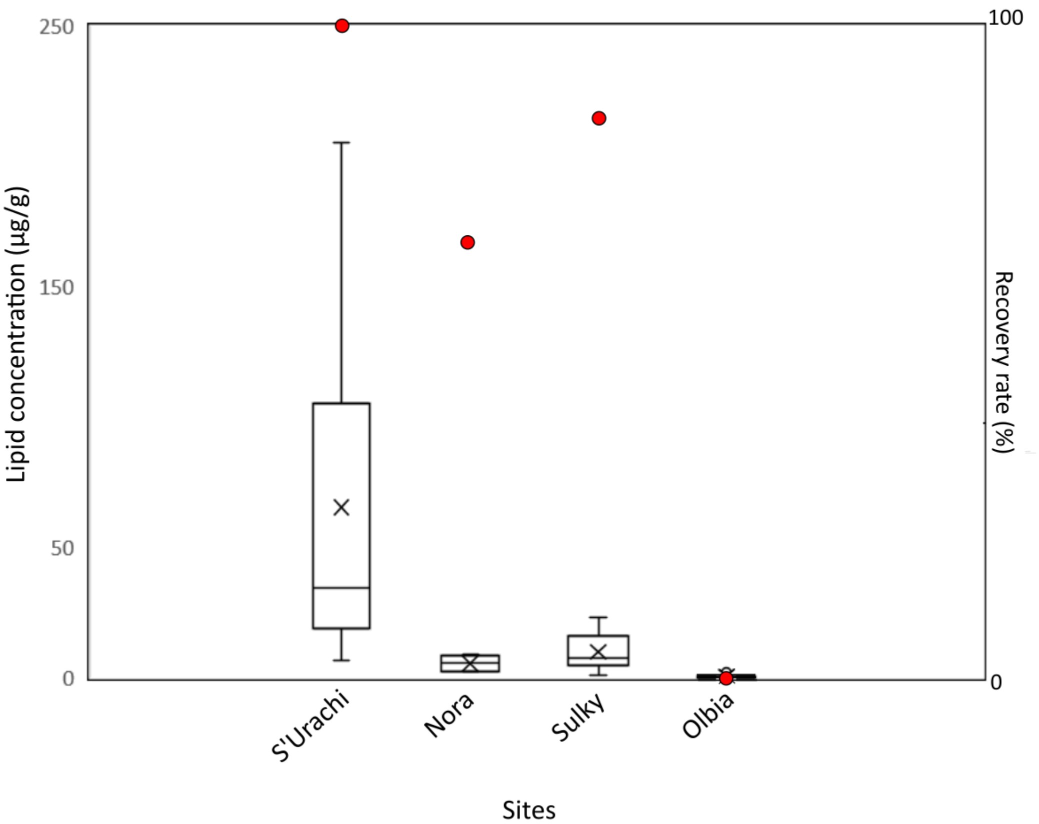


Figure 105. Box plots showing lipid concentration (X = mean) and recovery rate (red dot) in casseroles extracts coming from the sites of S'Urachi (n = 8), Nora (n = 6), Sulky (n = 6) and Olbia (n = 9).

The lower concentration of casserole extracts and the mixture of animal and vegetal fats is, however, not a strict trend. Casseroles with a high concentration of animal lipids, likely to have been used to process animal products, are also observed (figs. 51 and 90). Stable carbon isotope ratio mass spectrometry has been carried out on the four extracts containing degraded animal fats (three from S'Urachi and one from Genuri San Marco), revealing that two of them have ruminant adipose origin (-2.03; -0.7‰) and two of them non-ruminant adipose origin (-0.16; -0.2‰).

Comparing extracts from cooking pots with extracts from casseroles (fig. 106), there appears to be a minor difference in the $\Delta^{13}C$ values, with extracts from casseroles being on average higher in $\Delta^{13}C$ than in pots. In two of the four casseroles, values are consistent with non-ruminant fats, whereas only three out of 61 cooking pots had values consistent with non-ruminant fats. With such a small sample size, it is difficult to conclude whether the $\delta^{13}C$ difference or $\Delta^{13}C$ values from cooking pots is meaningful or not, especially as it is not statistically significant. The three lipid extracts forming a cluster in the plot and containing a mixture of ruminant and non-ruminant fats, all come from sherds found in 4th–2nd BCE century layers. The extract SUB34, identified clearly as ruminant adipose fat, comes from a sherd dated to the first half of the 5th century and it is less concentrated (fig. 52B). Further data is needed to check possible significance of this difference.

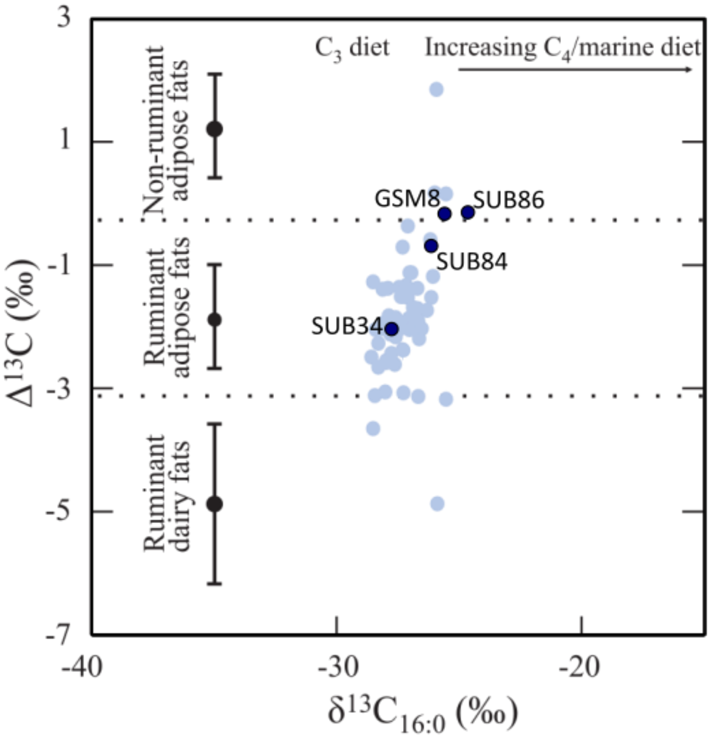


Figure 106. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for casserole extracts in dark blue and labelled. In light blue values of the extracts from pots. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012). Analytical precision is ± 0.3‰.

7.2.3.1 Use of the vessels and site-based exceptions

The existence of such a variety of chromatographic profiles, each containing vegetal and animal fats in very different concentrations, suggests that casseroles were used in different ways, although primarily for non-animal commodities (fig. 107). Based on shape and fabric, it was suggested that casseroles were used for quick-cooking and frying of multiple commodities (see 3.2.3). These analyses, with the general low lipid concentration and detection of animal fats, suggests that meat and animal products were in general not predominantly processed in casseroles.

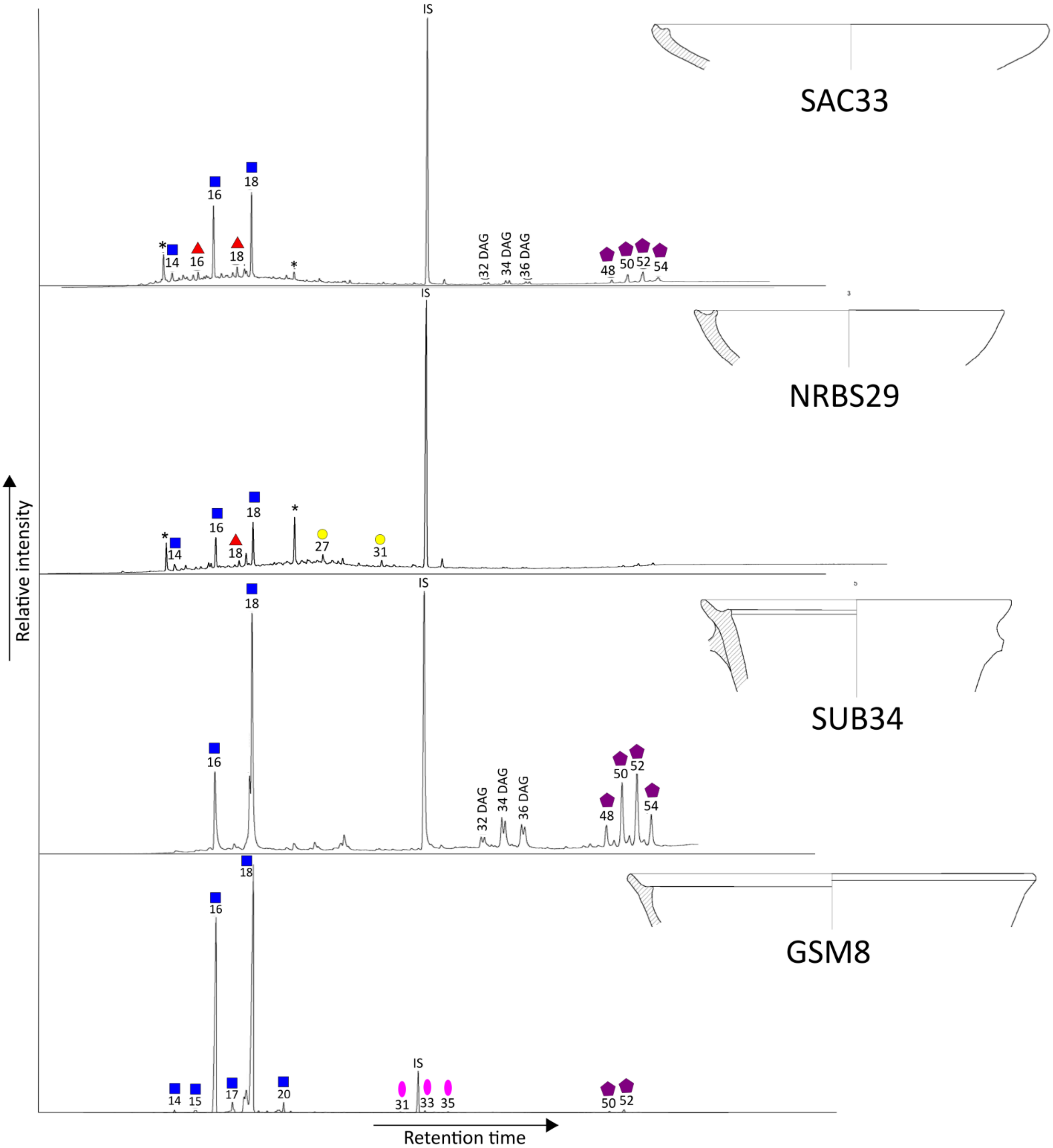


Figure 107. High temperature gas chromatograms of the extracts of casseroles SAC33 (5th century BCE); NRBS29 (5th century BCE); SUB34 (5th century BCE) and GSM8 (3rd century BCE). Shapes from Campanella 2009b. IS: internal standard; blue square: free fatty acid; yellow circle: alkane; red triangle: alcohol; pink ellipse: ketone; DAG: diacylglycerol; purple pentagon: triacylglycerol; with Cn: *acyl carbon atoms number.*

Other possibilities should also be discussed. Low lipid concentrations can also be explained by the manufacture of the vessels. Casseroles are generally burnished or slipped, whereas cooking pots were left more porous. This feature may have reduced the amount of lipids absorbed (Correa-Ascenscio and Evershed 2014). The detection of small amounts of lipids can also be related to waterproofing. The use of resins or waxes to waterproof the vessel is not confirmed by the analysis (7.1.3), but it cannot be excluded up to this point. Past analyses undertaken in Sardinia, analysing only one casserole extract, detected resin in it (Pecci 2008). The mixture of small amounts of animal fats with plant lipids as the result of a mixture of materials used to waterproof the vessel and food commodities processed in it is a possibility. However, as stated above, a small number of casseroles analysed in this study preserved a relatively high amount of animal fats. This indicates that burnishing, slipping or waterproofing did not always hinder lipid absorption. Based on this evidence, differences in lipid absorption cannot be justified only by manufacturing technique. At present, the interpretation that casseroles were used to process different commodities from cooking pots seems the most likely option based on the results obtained.

Existing site-level exceptions in lipid concentration also appear informative. Although comparisons are not statistically significant, the existing differences in lipid concentrations that occur on a site-by-site basis are potentially not random. For example, in Olbia casseroles provided nearly no lipids, while in S'Urachi they provided far more lipids than in any other site. This could be related to environmental and depositional conditions at each site (see 6.1). However, some alternative explanations can be sought. At S'Urachi, casseroles are more than doubly concentrated than the island average (not statistically significant), while cooking pots and basins are more concentrated than the average but with much smaller proportions (statistically significant). Casseroles in S'Urachi were probably used to process more animal products than at other site (see 7.1).

The site of Olbia is the only one where lipid concentrations in casseroles is lower than in basins (not statistically significant). As this outcome is an outlier, it could potentially be meaningful. For the island as a whole, the average lipid concentration in casseroles is 27 µg/g. The lack of lipids in casseroles at Olbia is, for this reason, unsurprising, as lipid preservation at this site is generally low. However, it is unexpected to find lower concentrations of lipids in casseroles than in basins. It could be due to small contaminants that remain undetected, or it could be due to a different use of casseroles, and possibly basins, in Olbia compared to other Punic sites on the island. Available data are not enough to establish if these exceptions are related to past use and are not caused by sampling or depositional reasons.

A final important element needs to be highlighted. In general, the most concentrated casseroles come from Area D in S'Urachi and from the Nuraghe San Marco at Genuri (figs. 51 and 90). Casseroles in these contexts are all dated to the 4th–2nd centuries BCE. Given the temporal span, possibly the results suggest a change in the use of casseroles between the introduction of the vessel in the 5th century BCE and the later centuries (in S'Urachi the difference is quite clear; see 6.1). This constitutes one of the few possible changes over time detected during this research (see 7.3). However, this data is not statistically significant and is limited to only two sites. Olbia Mercato is also a 4th–2nd century BCE context, but casseroles provided very few lipids (6.4). No difference was detected among casseroles over time at Nora. Data seems in general too limited to provide further interpretations. Further analysis is needed to understand if a change in casserole use and the foods processed in them existed, if it was generalised or site based, and if the differences detected are due to depositional or environmental reasons.

7.2.4 Baking trays

The discussion on baking trays results needs to be limited, due to the low number (*n* = 11) of sherds analysed. Nevertheless, some insights can be offered.

Despite the fact that contamination is likely in two of the extracts and possible in three of them (table 23), the data derived from the remaining extracts support that baking trays were used as multifunctional pans. This view was suggested by several scholars (Mansel 2011: 357; Campanella 2008: 197). The results do not support the view that either the "normal" baking trays or the perforated baking trays (see 3.3.5) were used exclusively for bread baking. This is different from what some other scholars have suggested (Botto 2009: 362). Although unexpected, this result is consistent with residue analysis on a baking tray from Sant'Antioco published by Pecci (2008). In that case, however, the tray was sampled in two different places and organic residues (free fatty acids) were detected only in the bottom of the tray, not on the rim. In the present study, all samples are from rims (fig. 108).

These vessels appeared to have been primarily used to process non-animal commodities, but animal fats are occasionally spotted in them (OLB1, fig. 79). This is similar to most of the casseroles (see above), but the small number of baking trays prevents any significant comparison.

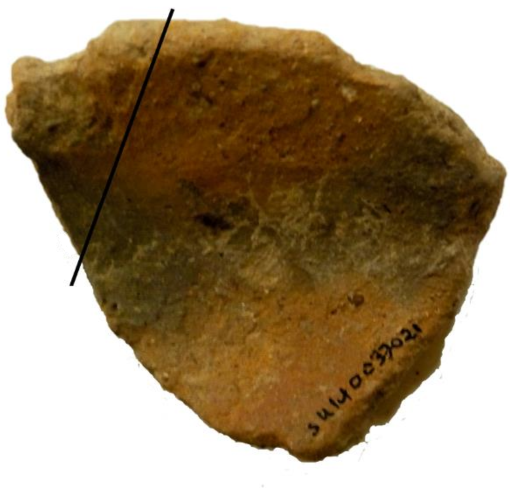


Figure 108. Example of baking tray from S'Urachi with the indication of the sampled area.

No detailed functional interpretation can be offered at this stage of research. More analyses are needed to further investigate within this category. But up to this point, these results offer new evidence to corroborate the interpretation of baking trays as multifunctional cooking vessels.

Table 23 Summary of compounds and commodities identified in baking tray extracts.

Sample name	Site	Lipid concentration (µg/g)	Identified compounds	Identified commodities
SUB7	S'Urachi	22	Saturated Fatty Acids C15-C18; Unsaturated FA C18:1; alcohols; TAGs C50-54; contaminants?	Animal fats, vegetal fats? Contamination?
SUB96	S'Urachi	1	None	
PLO1	Pani Loriga	11	SFA C16, C18; UsFA C18 :1; alcohols C16, C18; TAGs C48-54	Animal fats and plant lipids (oil?)
PLO13	Pani Loriga	1	None	
PLO16	Pani Loriga	0	None	
PLO42	Pani Loriga	0.5	None	
NRBS33	Nora	6	SFA C16, C18; UsFA C18:1; AL C18; phthalate	Plant and animal fats? Contaminants
NRBS35	Nora	20	SFA C12-24; UsFA C16:1, C18:1; AL C16, C18; tricaplyrin	Plant and animal fats? Contaminants?
NRBS81	Nora	22	SFAC12-18; UsFA C16:1, C18:1; AL C14, 16, 18, 20; mid-chain alkanes; phthalates	Plant lipids and animal fats? Contamination?
OLB1	Olbia	35	SFA C14-18, 24; UsFA C18:1; Dehydroabietic acid; AL C24-32 (even-numbered); Wax esters C42-50; TAGs C50-56.	Animal fats, beeswax, resin, oil?
SAC1	Sant'Antioco	31	SFA C14, 16-18; UsFA C16:1, C18:1; AL C14, 16, 18, 20; phthalates, squalene.	Plant lipids? Contamination?

7.2.5 Ovens

The mean lipid concentration in ovens (*tannurs*) is 1.5 µg/g and the recovery rate is 0%. In the 13 extracts analysed, the lipid concentration ranged between 0 and 4.2 µg/g. The lipids found at low concentration are often plasticisers or contaminants (fig. 109). The results obtained enable statistically significant comparisons with other vessel categories. Qualitatively speaking, the only information available is the relative absence of lipids.

Tannurs were included in this thesis to investigate if they were used to cook fish or bread made with cheese or lard, as hypothesised by archaeologists (see 3.3.5). *Tannur* extracts were revealed to contain no lipids. On the basis of available evidence, there are three main potential reasons to explain this absence of lipids.

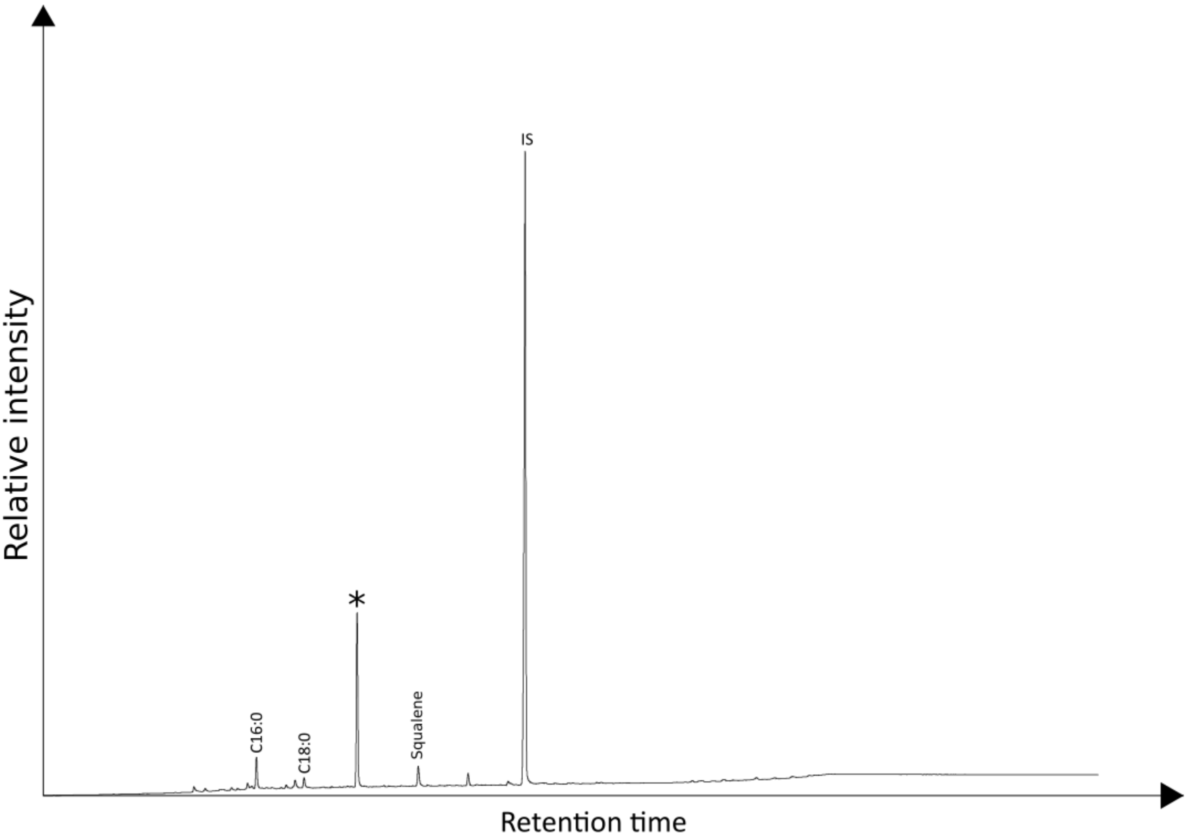


*Figure 109. High temperature gas chromatogram of the extract NRBS40 (tannur). IS: internal standard; *: phthalate; Cx:y= Fatty acids with X-number of carbons and Y-number of double bonds.*

The first possibility relates to random chance: only ovens *not* containing lipids were sampled. This appears, however, very unlikely. Although additional analysis would provide further data points, there is no reason to assume that additional data would contradict the current results. Analyses on *tannur* extracts were stopped since the sequence of extremely similar results offered consistent and statistically significant data from three different sites.

The second possibility is related to the shape of *tannurs* and the cooking processes in which they are used. In contrast with the other analysed ceramic categories, each of which has a container form, *tannurs* are not containers or vessels, but ceramic structures. They can serve as direct food containers, allowing to cook breads on their side, or indirect containers, holding the heat source over which the cooking vessel is placed. In the first case, breads in *tannurs* occupied only a portion of the oven wall. It is possible that lipids did not penetrate the ceramic wall, thus making detection by organic residue analysis impossible, or that the wall areas sampled were not used for cooking lipid-rich breads. In the second case, fish and other commodities may have been grilled directly in the middle of the oven. But in such circumstances, only a small amount of lipids may have reached the bottom and side walls through splattering during cooking. The bottom and side walls were directly exposed to very high heat from the fire, however, and themselves reached high temperatures. Therefore, it is likely that the lipids splashed onto the interior surfaces of the oven would have degraded due to the high temperatures achieved by the oven walls (Reber et al. 2019).

The third possibility is related to the food processed in these ovens. It is possible that *tannurs* were used exclusively or predominantly to bake breads made with water and cereals, commodities containing very few lipids (Hammann and Cramp 2018). This possibility is indeed very likely. It is what was suggested by available evidence, based on ethnographic comparisons and iconographic sources (2.2.2.1).

It needs to be underlined that evidence suggesting animal products processing occurred inside *tannurs* is, up to this point, extremely limited. No evidence for bread with lard or cheese production on Sardinia exist before the modern era, and evidence does not exist to suggest fish or meat was cooked inside *tannurs.* These were and are just research hypotheses (2.2.2.6). Analysis undertaken does not reject the existence of these potential uses in Phoenician and Punic Sardinia. It makes clear that evidence for these foods is lacking at this point; organic residue analysis did not definitively answer this question as wished. Therefore, based on results obtained, Phoenician and Punic ovens should be interpreted still as ovens primarily used to bake breads made with cereals or legumes, i.e. low lipid commodities.

7.2.6 Comparing vessel categories: concluding statement

To sum up, comparing results by vessel category, some general patterns are outlined across the island. These refer especially to some kind of specialisation detected for each vessel category, and it addresses research question 2. Comparing results, it seems evident that the use of cooking pots was different from the use of casseroles, the use of casseroles was different from the use of basins, and vice versa for each vessel category. Despite existing limitations in interpretation due to the number of sherds and the variety of vessel categories and sites (5.1), the connection of vessel category with specific use and types of commodities represents a useful advancement in the comprehension of culinary customs in Phoenician and Punic Sardinia.

7.3 Change and continuity over time

As stated in the introduction (Chapter 1), one of the aims of this project is to investigate changes in vessel use and potentially culinary customs over time. This was intended to be done through the detection of different commodities processed in cookware. Having illustrated all the results, it is possible to state that organic residue analysis did not detect clear changes in pottery use across the centuries on a general level (figs. 110 and 111).

Three possible changes limited to single sites or vessel categories have been, on the contrary, hypothesised and discussed. Two of them regard one vessel category. Some late casseroles (4th-2nd centuries BCE) contain notably higher frequencies and concentrations of animal fat than the vast majority of casseroles (see 7.2.3). Some late basins (5th-2nd centuries BCE) appear to have been used to process commodities richer in lipids compared to earlier ones, e.g. leafy plants instead of cereals (7.2.2). But these changes are based on a limited sample size and not established at every site. Randomness cannot be excluded for them. One last possible change over time refers to S'Urachi, where isotope values of analysed animal fats seem to suggest a more frequent presence of dairy products in area E (6th-4th centuries BCE) than in area D (5th-2nd centuries BCE; see 6.1). However, this pattern is currently specific to S'Urachi and is not confirmed on an island level (fig. 111).

In general, diachronic patterns in the results are few, and can be unambiguously observed only by studying single major vessel categories (e.g. cooking pots, basins, casseroles) within individual sites with multiple phases (e.g. S'Urachi) to eradicate other contributing variables. The diachronic continuity that appears to be generally indicated on a broader level is observed through quantitative similarities, compounds identified (fig. 110) and the stable isotope compositions of the extracts (fig. 111). There are several different explanations that may justify this result.

The first reason may be due to sampling bias. As explained in Chapter 5, it was challenging to obtain a consistent sample of sherds. Although the 7th to the 2nd centuries BCE are included, there is a lack of detail per period, as for the earliest centuries (7th, 6th BCE), around 20 sherds, based on typology, have been analysed, with only a few (less than 5) per site; on the contrary, for the centuries 5th to 3rd BCE more than 60 sherds have been analysed, often dated based on archaeological context (see 5.1). It is also possible that trends have not been detected due to inter-site variation in environmental conditions and different lipid preservation. Although sherds from each phase can be aggregated across the multiple sites included, there is always the possibility that inter-site variation exceeds diachronic patterns and thus masks any possible trends in the latter. Focusing on only one site may have allowed changes to be detected. But it has not been possible as no permit for just one site was forthcoming and the *Soprintendenza* suggested the inclusion of multiple sites in the project (see introduction, 1.2). The fact that the clearest developments over time are detected on a site level (6.1) could corroborate this hypothesis. Focusing on one site in depth is ideal for organic residue analysis and, as will be suggested in Section 8.3, can provide a direction for future research. This study, however, constitutes the essential pilot work to orientate and focus future research, through balancing the inclusion of a range of key vessel forms and sites of different types with a focus on one major vessel form and some diachronic spread within individual sites (see 5.1). These results would justify a detailed chronological study involving hundreds of sherds from within individual sites in the future (see 8.3).

The second possibility relates to the lack of a firm dating of some vessels. As discussed throughout this dissertation, research about Phoenician and Punic cookware has been limited until recently. Although current work is producing further developments, research is still ongoing. The chronology of some subtypes of Phoenician and Punic cooking pots and basins is under discussion by pottery specialists, potentially changing our current understanding. The situation is particularly complex for handmade cooking pots. They were traditionally dated from the Iron Age until the 6th century BCE (e.g. Botto 2009). Recent recoveries from dated and analysed historical contexts (e.g. S'Urachi, Pani Loriga and Olbia) suggested changes in the historical developments and chronology of these vessels. It is now known that they were in use until the Punic age in S'Urachi and Pani Loriga and until the 3rd century BCE in Olbia (see 3.2.1). This major revision in the chronology of a vessel type (sample number = 54) hinders discussion of extracts obtained from these vessels in a diachronic way.

As a result of current debate on the chronology of pottery in Phoenician and Punic Sardinia, diachronic comparisons were undertaken between sherds from different sites and with chronologies spanning two centuries. Vessels of unclear chronology not dated based on archaeological context have been excluded from this comparison. Results, based on typological chronology, are shown in figs. 110 and 111. It is a broad comparison. On the one hand, some vessels have been excluded from the comparison because their place within the overall chronology was unclear. On the other hand, vessels with more precise dating (e.g. only a century, or half a century) have been inserted in broad comparisons spanning several centuries. This caution was needed to avoid overinterpretation based on questionable chronologies. Caution in assigning vessels to more narrow chronological windows could have masked the detection of changes. It also raises the question of whether the same deficiency could prevent the detection of changes and trends on a broader scale. In fact, no broad trend was detected in this study.

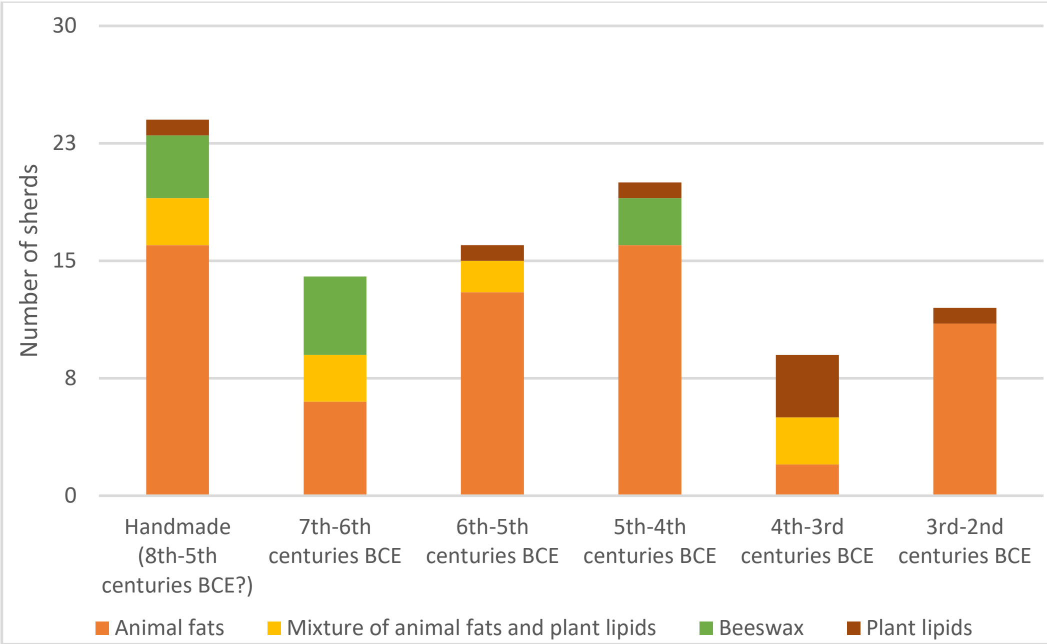


Figure 110. Commodities identified in analysed vessels, per typological chronology (sherds from S'Urachi, Pani Loriga and Nora included in the chart).

The third possibility is related to the nature of diet in Phoenician and Punic Sardinia. Organic residue analysis cannot detect or suggest recipes. Therefore, the lack of substantial differences in lipid composition and distribution does not mean a lack of changes in cuisine and culinary customs. Faunal and botanical records suggest limited changes in the diet with the arrival of Phoenician and then Punic people in Sardinia. New animals, fruits and legumes were introduced, but these novel products would not be detectable through lipid residue analysis. No unambiguous biomarkers exist for commodities introduced in the Phoenician and Punic period as chickpeas, chickens, apples, pears or dates (see Chapter 4). It is also possible that some major changes occurred at the very beginning of the Phoenician period, for example in cereal consumption or deer meat consumption. These would have not been detected in this project, as cookware was not analysed from any timespan earlier than the 8th–7th centuries BCE, so not before the foundation of Phoenician settlements. Up to this point, however, none of these possible changes is suggested by the available evidence. In S'Urachi, an indigenous site, organic residues do not suggest any radical difference with Phoenician culinary customs (see 7.4). Comparison with similar results and analysis focused on Late Bronze and Iron Age Sardinia would provide further useful information, but such a study is not available at present. Finally, both in the Phoenician and pre-

Phoenician period, the core of the diet appears to have always consisted of many products that are not detectable (legumes, cereals) or not specifically distinguishable per species (fruit, vegetables) through ORA: these have been discussed along this chapter as negative evidence, but detection of changes, if referring to these specific foodstuffs, was hindered. The aim of this study was rather to target questions surrounding commodities detectable through ORA, like animal fat, beeswax, resins or leafy plants, obtaining significant results (see 7.1).

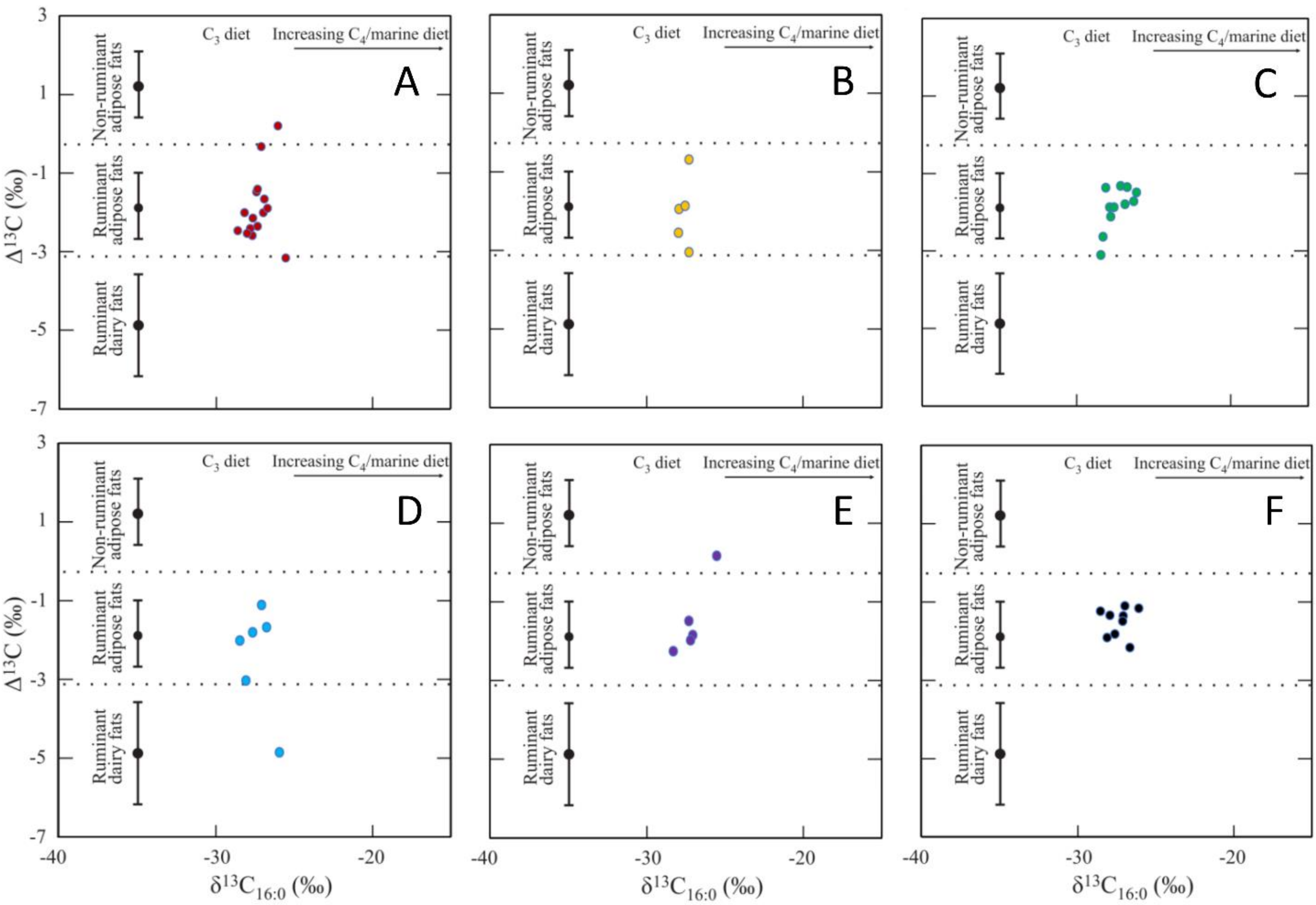


Figure 111. Difference in the $\delta^{13}C$ values of the $C_{18:0}$ and $C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) and $\delta^{13}C_{16:0}$ values obtained for some of the extracts analysed, divided per centuries and chronology. All values shown in the plot come from pots. A: handmade pots (dated approximately between the 8th and the 5th centuries BCE); B: wheelmade pots, 8th–6th centuries BCE; C: 6th–5th centuries BCE; D: 5th–4th centuries BCE; E: 4th–3rd centuries BCE; F: 3rd–2nd centuries BCE. The ranges represent the mean ± 1 standard deviation of the $\Delta^{13}C$ values for the global database comprising modern animal fats from Britain (pure C_3 environment; Copley et al., 2003), Kazakhstan (Outram et al., 2009), Switzerland (Spangenberg et al., 2006), the Levant (Gregg et al., 2009), Turkey (Pitter, unpublished), Kenya and Libya (Dunne et al., 2012) as reported in Dunne et al. 2012. Analytical precision is ± 0.3‰.

Major socio-cultural and political changes occurred in Sardinia during the time targeted in this study (e.g. the creation of cities, migrations, new elites etc.), so it would be reasonable to expect that some changes in culinary customs occurred. But it is possible that, despite changes over centuries, Sardinian cuisine remained based on the same broad ingredients and food categories. On the one hand, it is possible that legumes, cereals, meat and milk were consumed in different ways but in similar amounts, or perhaps the core elements of the diet did not change, in nature and quantity, over the centuries. This seems plausible. On the other hand, major changes are detected by archaeologists in the target context, such as increase in deer hunting, new techniques for rearing livestock, and widespread cereal-based agriculture. But these changes cannot be detected through lipid residues. Organic residue analysis shows continuity in culinary practices despite changes in pottery in other contexts as well (e.g. Craig et al. 2011). An unchanging general diet, at least in its core elements, is a likely explanation, and it is consistent with the whole available evidence shared in Chapter 2.

Only one of the changes hypothesised by archaeologists, based on faunal remains, would have been detectable through ORA. This is the case of the widespread exploitation of shellfish and fish. It has been shown to increase with the arrival of Phoenician people, at least in the opinion of the majority of scholars (2.2.2.6). As opposed to other changes recorded by archaeozoology, it was expected to be detected on a lipid level (see Chapter 4). However, no aquatic biomarkers have been detected in the sherds analysed in this study. Several explanations exist to justify this absence, as it is discussed in section 7.1.1.3.

There is one final element to be considered in interpreting the lack of evident changes. It is also unknown how widespread societal and cultural changes were. Not much is known about social differentiation, both inter and infra-site, in Phoenician and Punic Sardinia (see Chapter 3). It is possible that culinary changes concerned urban elites linked with Carthage, especially during the Punic period, and not a large part of the communities. Analyses are undertaken on common cookware found in both rural and urban fills and dumps. If a change in culinary customs regarded only a small part of the living communities, the scale and target of this study would have prevented the detection of changes limited by class or social group.

7.4 Comparing sites: comprehensive discussion

Results per site have been described in Chapter 6. More details, specifically about comparison between $\delta^{13}C$ values of individual fatty acids of animal fats and faunal remains, have been discussed in section 7.1 (animal fats). In this section, results per site are compared and discussed, trying to answer research question 4.

In contrast to the single vessel categories, which often show consistent patterns between sites and offer insights about vessel use and specialisation, results for each single site, enumerated in Chapter 6, when compared cannot easily be connected with culinary customs and use. This is due to the fact that most of the existing differences cannot be unambiguously attributed to either depositional and environmental conditions or cultural and functional reasons. Most of the differences in lipid results per site, in fact, could be related to environmental and depositional conditions: soil conditions seem to explain, for example, basins having more concentrated lipid extracts in S'Urachi or cooking pots having less concentrated extracts in Olbia than at other sites. Moreover, sherds come from different contexts (urban dumps, fills etc.) dated from different periods, suggesting that one ought to avoid drawing comparisons with poor contexts. However, choices have been applied to obtain a sherd selection as consistent as possible (see 5.1): comparing results between site seems possible and productive.

Contextualising chemical results using the previously available evidence, some insights have been obtained from the available data. When comparing results among sites in light of archaeological and historical evidence, data obtained suggest the existence of a meaningful pattern, possibly connected with culinary practices. This comparison of multiple sites leads to a discussion of one interesting issue suggested by available results, allowing more in-depth interpretation.

7.4.1 Were there two different culinary cultures in Sardinia?

The most meaningful insight raised from data comparisons between sites refer to the possibility of a greater consumption of animal products, including meat, in the indigenous Sardinian world compared to the Phoenician and Punic world.

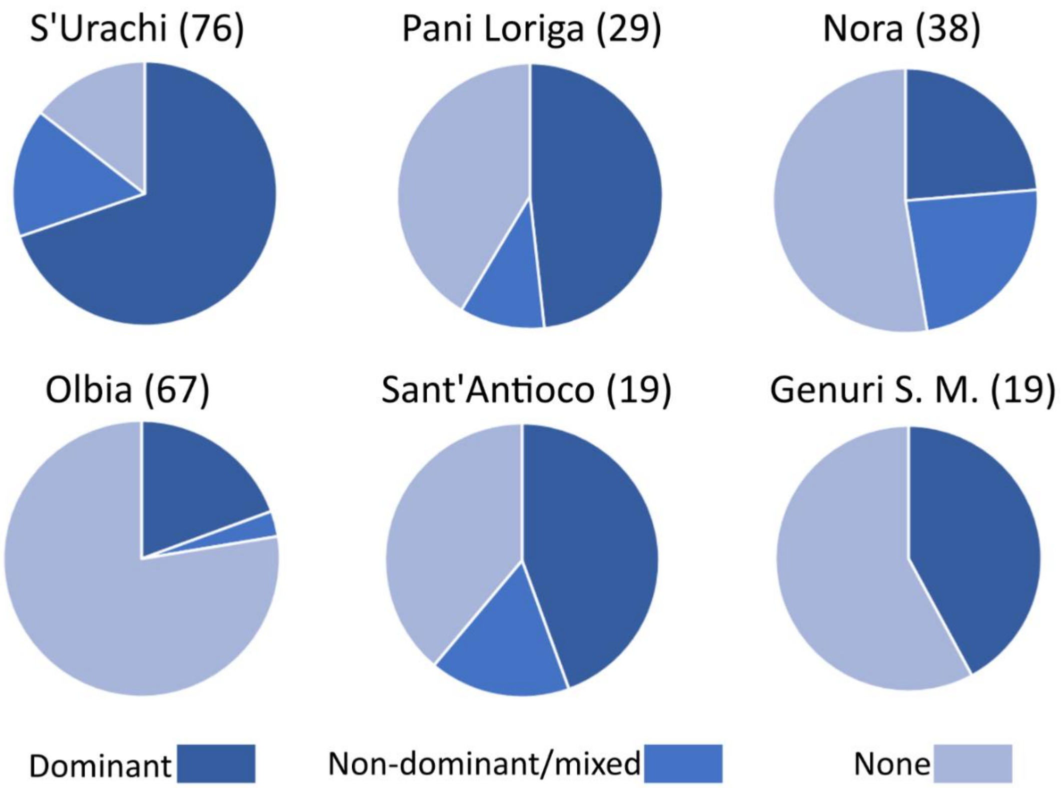


Figure 112. Pie charts showing animal fat detection in cooking pots and casseroles extracts per site (total number of extracts in brackets).

This hypothesis is based on animal fat detection and lipid concentrations across per site: the two values are often related, since animal products release in the vessel walls more lipids than other commodities (Charters et al. 1997). Lipid concentrations were presented in Chapter 6 (figs. 42, 55, 62, 73, 81, 86), while animal fat detection rates per site are synthesised in figure 112. The major outcomes can be synthesised as follows. In S'Urachi, an indigenous settlement, animal products were commonly processed: in 70% of casseroles and cooking pots, animal fat biomarkers ($C_{16:0}$ and $C_{18:0}$ FFAs, TAGs) dominate the chromatographic profile. The lipid concentration in casseroles at S'Urachi, indirectly related to highly concentrated animal fat, is over six times higher than at other sites (see 6.1.3). In Pani Loriga, a settlement likely founded jointly by Phoenician and indigenous Sardinian people, animal products are found in half of the cooking pots (no casseroles analysed), but they are highly concentrated (more than 40 µg/g) only in handmade cooking pots. On the contrary, in Nora and Olbia, animal products were not commonly processed in the vessels analysed. But, notably, in Nora, similarly to Pani Loriga, animal products are more commonly detected in handmade cooking pots than in casseroles or wheelmade cooking pots (see 7.2.1). In Sant'Antioco and Genuri San Marco, the small number of sherds suggest caution in interpreting the pattern. However, also in Sant'Antioco the only handmade pot analysed contains animal fat, and lipid concentration in this extract is five times higher than any other cooking pot extract in the site (fig. 102).

The pattern outlined seems not to be explainable only with depositional or random conditions: in Pani Loriga, for example, lipid preservation seems lower than in Nora (see 6.2 and 6.3). It is known that the higher lipid concentration can be due to multiple reasons, including environmental conditions, differences in fabrics and porosity, cooking methods. However, both detection and concentration of animal fats suggest that animal products were consumed more in S'Urachi, an indigenous Sardinian settlement, than in more "Phoenician and Punic" settlements, such as Nora and Sant'Antioco. They also suggest a difference in handmade and wheelmade cooking pots, use which has been further discussed in section 7.2.1.3: these two subcategories are generally connected respectively with the Phoenician and the indigenous Sardinian world (see 3.3.1).

The picture exposed appears to be consistent. Based on the data derived from the present study, described in Chapter 6 and summarised here, it seems possible to hypothesise the existence of different culinary traditions on the island. This difference can be broadly connected with the different communities inhabiting the island or, more accurately, the different culinary traditions on the island during the Phoenician and Punic period. The first one, definable as "Nuragic" or indigenous, relied more on animal product processing compared to a second one, definable as "Phoenician and Punic", which consumed less meat and animal products. Possibly these culinary cultures coexisted also in the same settlements, if it is assumed that differences in lipid concentration between wheelmade and handmade cooking pots is due to cultural choices (evidence for that in 7.2.1.1). The coexistence of different culinary cultures is suggested by the evidence exposed, but two weaknesses in this argument exist.

The first weakness is related to the 'pots equal people' problem. To corroborate the hypothesis here, it could be too easily implied that handmade pots indicate indigenous Sardinian culture and people, and wheelmade pots indicate Phoenician and Punic culture and people. Although these vessels refer to ceramic traditions originating from these two different cultures, these traditions hybridise, as it has been explained in Chapter 3 (3.3.1). These categories cannot be assumed as being used and consumed by explicit people. Hypothesising the existence of different culinary cultures does not imply division or strict connection between pots and specific culinary choices. Animal products were also processed in wheelmade pots and other vessels all over the island. In S'Urachi, animal fat is more common in wheelmade cooking pots than in handmade ones, and it is widely found in casseroles: this is one of the elements that suggests a difference in the S'Urachi diet compared to other sites. Based on the available evidence, it is possible to establish a broad connection between indigenous Sardinian people as consumers of animal products. This seems to differ from Phoenician and Punic people who mostly consumed cereals, legumes and other non-animal commodities. But these culinary cultures, if effectively existing, interacted and merged for centuries.

The second weakness is related to the fact that not all the data obtained through organic residue analysis coherently substantiate the hypothesis outlined above. Data from Olbia and Genuri San Marco are different. The lipid concentration in cooking pots is low at both sites (18 µg/g at Olbia, 20 µg/g at Genuri), animal fat is not commonly detected (fig. 112) and no substantial difference in lipid concentration between handmade and wheelmade pots has been detected. This difference could be due to random or environmental conditions. Olbia is a site where lipid recovery was shown to be poor due to depositional conditions (see 6.4). In Genuri San Marco the total number of cooking pots (n = 16) and vessels (n = 27) analysed may be too small, leading to misleading results based too much on randomness (see 6.6). Results from Olbia and Genuri could also suggest that data in each site are mostly related to local dynamics. These dynamics could refer, for example, to existing differences in the local community, in the environment and in the Phoenician-indigenous interaction, only partially identified by the archaeologists. This could make the picture presented above not linked with the existence of two main different culinary cultures, but with myriad local differences.

But chronology in Olbia and Genuri San Marco suggests also a different explanation for these results. Pottery at both sites comes from 4th–3rd century BCE contexts. On the contrary, in S'Urachi, Nora, Sant'Antioco and Pani Loriga, handmade cooking pots are dated no later than the end of the 5th century. This chronological difference could also justify the different results. Over the centuries, possibly the culinary cultures originally detectable and relatively distinguished could have merged in a more unified and homogeneous one.

To conclude, the hypothesis presented in this paragraph is based on reduced evidence and it is in need of further investigation. However, evidence suggesting a greater consumption of animal products, including meat, in the indigenous Sardinian world compared to the Phoenician and Punic world appears relevant and consistent. It is also partially corroborated by previously available evidence: the limited consumption of meat by Phoenician and Punic people and the reliance on cereals is suggested by the data addressed in Chapter 2. But a possible preference for animal products in Sardinian indigenous communities has not been considered previously. Studies investigating faunal evidence, organic residue analysis or stable isotopes of bone collagen have been too limited thus far to detect differences on an island or inter-community level (see 2.2). The argument in this paragraph and data obtained through ORA represent a research hypothesis and a solid base for further research (see also 8.3).

Chapter 8
Conclusions and further work

8.1 Research questions and answers

The analyses undertaken answered the research questions presented in the introduction (see 1.2) and also raised new ones. Results of this research confirmed that a relevant amount of archaeological information can be obtained in Sardinia by applying organic residue analysis to cookware. The information obtained includes products processed in the vessels, vessel use and technology, inter and intra-site differences, and more. Some of this data has been already detected during the current research. Further analyses precisely targeting specific vessels can offer other significant advancements to the comprehension of vessels and diet. This project, in fact, started with an extremely limited database. For this reason, it included several different sites and vessel categories (see introduction, 1.2). With this new dataset, more focused data and information can be targeted in the future. Examples of Sardinia-related information obtained through organic residue analysis are discussed in section 8.3.

To introduce the conclusions, answers to the research question outlined in the introduction (Chapter 1) will be briefly summarised and synthesised.

1) *What commodities were processed in the main ceramic categories involved in cooking and food preparation practices?*

Commodities detected through organic residue analysis are mainly animal fats: among them, ruminant carcass fats represent the majority (94% of analysed extracts), while dairy fats and non-ruminant carcass fats jointly represent 7% of the total. Other commodities commonly detected during the analysis are vegetal products, such as plant waxes and beeswax. These are identified in more than the 5% of the extracts. Biomarkers of resins have been detected only in 1.5% of the analysed vessels. Significantly, no aquatic biomarkers have been detected.

The lack of lipids in several vessel types assumed to have been used for boiling indirectly appears to confirm the processing of commodities such as cereals and legumes, which are not rich in lipids and were not targeted in this project (Hammann et al. 2019). Processing of those commodities had been hypothesised based on the evidence available before this project (Chapter 2).

2) *What do the detected commodities suggest about vessel use and specialisation?*

Variations in detected commodities among vessel categories are evident. Such variations can, in many cases, be connected with a specialised use of the vessels. Animal fats, for example, are nearly absent in basins (only one example from a total of 85 sherds (7.2.2)). They are common in casseroles but rarely dominant (7.2.3), while they are often attested as the dominant commodity in cooking pots (7.2.1). Beeswax, as a second example, has been detected only in cooking pots, especially handmade pots, and in one subtype of basin, while dairy products have been identified only in pots and casseroles (7.1.2). As described in chapter 6, the average lipid concentration is five times higher in cooking pots than in casseroles, and five times higher in casseroles than in basins. These differences among vessel categories are clearly connected with vessel use: cooking pots were used to cook meat more than other vessels, while basins were used to process mainly vegetal products, as explained in Chapter 7 (7.2).

Connecting the existing differences within the same category to vessel uses is more complicated, since the number of sherds involved is small, but some hypotheses have been established. For example, one subtype of basin has been connected with beeswax processing and possibly honey production (7.2.2). At some sites, handmade cooking pots have lipid concentrations ten times higher than wheelmade cooking pots (7.2.1), suggesting higher animal products processing in handmade pots. In summary, organic residue analysis, highlighting differences and variations among vessel categories and subcategories, has expanded the understanding of vessel use in Phoenician and Punic Sardinia.

3) *What do the detected commodities suggest about changes in cuisine and diet over time?*

Some possible changes over time have been detected in each vessel category: in basins, lipid concentration is slightly higher in the Punic period, suggesting a possible processing of plants instead of poorer lipid commodities as cereals (7.2.2); in casseroles, some extracts from a later period (4th-2nd centuries BCE) contain high concentrations of animal fats, suggesting a possible change in the use of the vessel shape (7.2.3). But evidence for both changes is not definitive. A more consistent change is attested in S'Urachi on a site basis and is limited to the origin of animal fats, suggesting higher importance of dairy fats in the 6th-4th centuries BCE (6.1). Overall, no mid- or long-term change has been detected on an island level, as explained in Chapter 7 (7.3).

The lack of clear variation in commodities processed over time seems to exist on a general level, and it suggests continuity in food consumption and processing over the centuries. This continuity had already been hypothesised by archaeologists (7.3, see also Chapter 2). Detailed site-based studies, involving more analyses from one single site, are likely needed to detect changes over time (see below, 8.3).

4) *Are intra-site and inter-site spatial patterns identified through ORA? What do they suggest?*

The processing of commodities indeed varies among sites and areas, both in the lipid concentration and molecular assemblages, as summarised in section 7.4. Interpreting the variations between sites and regions was revealed to be more complex than interpreting variations identified between vessel categories. Only some of the detected variations and differences can be unambiguously linked with differences in practices and customs, or, on the contrary, with environmental and depositional reasons. Distinguishing between these two reasons is often not straightforward.

Only in Olbia (poor preservation) and S'Urachi (good preservation) can the comparison of lipid concentrations be clearly connected with environmental and depositional conditions. The interpretation of other inter-site differences is more complex, since the variation is small and at times limited to only some vessel categories (e.g. casseroles, 7.2.3). Linking these differences with culinary practices is often not possible due to the lack of evidence (e.g. basins, 7.2.2). In other cases, however, a connection with culinary customs is possible, despite explanations being tentative and hypothetical at this stage of research. For example, a possible link between high lipid concentration (and animal product processing) and indigenous Sardinian culture was hypothesised. This hypothesis was based on archaeological evidence appearing consistent with chemical results, rather than relying solely on the chemical results, and it poses a new relevant research path to investigate culinary differences in ancient Sardinia (see 7.4).

At this stage of research, the identification of differences and patterns between the sites contributed to answering existing archaeological questions, but it is also beneficial in raising new questions and orientating future research (see below, 8.3).

8.2 Towards a picture of foodways in Phoenician and Punic Sardinia

The information about foodways in Phoenician and Punic Sardinia has been significantly increased through this research, contextualising and comparing the data obtained from ORA with previously available evidence. It is possible to conclude this research by outlining a picture of foodways on the island during the Phoenician and Punic period, especially the latter since the majority of the analysed sherds come from Punic layers (see 5.1). This brief picture, which updates the discussion in Chapter 2, is outlined by thematic issues.

8.2.1 Main commodities processed in vessels analysed

8.2.1.1 Cereal and legumes

Cereals and legumes, according to all previously available evidence, were thought to constitute the base of the diet (2.2.2.1). Cereals are thought to have been five times more common than legumes (2.2.2.2). Based on negative evidence, the results obtained seem to confirm that cereals and legumes were the most common products on the island.

Lipids were not detected in ovens, and more than 75% of the analysed cooking pot extracts contain less than 50 μg/g of lipids. This lack does not seem to be explainable solely through poor lipid preservation, since lipid concentration largely varies within the same archaeological context (7.2.1). Several cooking pots contain little or no lipids, while other pots contain high quantities of animal fats. According to previously available evidence, these results could be related to the processing of commodities that are not rich in lipids, such as cereals and legumes. The sole processing of cereals would lead to low concentrations of lipid being absorbed, and it is known that these commodities constituted the core of the

Phoenician and Punic diet. However, confirming that cereals and legumes were boiled in some of the pots where no lipids were detected would require the use of newly introduced cereal biomarkers (Hammann et al. 2018), so that the whole hypothesis need to be tested through further analyses (see 8.3.1.6).

The use of some basins like mortars to grind cereals or legumes is possible, but due to the thickness and fabric of these basins, it is probable they were used as mortars to grind less tough commodities (e.g. plants and spices). Results obtained from baking trays indicate that they were used for more than baking breads made only with cereals or legumes, but further investigation is needed since the number of analysed sherds is small (n = 11).

8.2.1.2 Vegetables, fruit, oil and other plants

Iconographic and written sources, together with palaeobotanical evidence, indicated fruit and vegetables as relevant commodities in the target area and period (2.2.2.3). The current analysis appears to confirm the widespread use of these products in all the analysed vessel categories, with the exception of ovens (7.2.5). Due to existing limitations in the analytical technique, ORA is often unable to detect single plant species or oil origin (see chapter 4). This research is not an exception. However, specific features and new insights regarding the processing of vegetable matter have been detected.

To sum up, leafy plants appear to have been occasionally processed in cooking pots (unambiguously identified in five extracts, likely in six of them), and in one casserole and two basins (see 7.1.3). The presence of plant lipids and oil also has been putatively hypothesised for 12 more extracts (one casserole, two basins, seven pots and two baking trays). However, biomarkers used in these cases (ratio between $C_{16:0}$ and $C_{18:0}$ saturated fatty acids, $C_{16\text{-}24}$ alcohols) are non-specific and contamination or other sources cannot be excluded. Lipid composition of no extract confirms the presence of plant oil. Connecting the lipid content of extracts with shape and previously available information about the vessel categories, however, basins appear to be linked with plant processing (7.2.2). In casseroles, plant products appear to have been often mixed with animal fat and dominant (7.2.3). In both cases, the common detection of $C_{16:0}$ FFAs in a higher concentration than $C_{18:0}$ could be connected with vessel specialisation in plant processing compared to cooking pots. In extracts of cooking pots containing plant products, animal fat is dominant in the chromatographic profile, as is usual in pots: mixtures with plant lipids have been detected only in a small minority of the cooking pot extracts. Since meat accumulates *c.* 150 times more lipids in the vessel than vegetables (Charters et al. 1997), it is unclear whether the absence of plants in the majority of cooking pots relates to the rare processing of these products or simply a predominance of animal fats in the chromatographic profile, hindering the detection of plant biomarkers (7.1.3). The way these commodities were processed is often not possible to hypothesise, as it varies between single potsherds (see 7.2.2 and 7.2.3).

8.2.1.3 Meat

Animal fats are the most commonly detected lipids in organic residue analysis (see Chapter 4). Meat was undoubtedly processed in cooking pots and, in smaller proportions, casseroles. The absence or low concentration of animal fat in the majority of cooking pots (7.2.1) and casseroles (7.2.3), however, seems to confirm that meat was an uncommon commodity in the Sardinian diet during the Phoenician and Punic period, as suggested by all previously available evidence (2.2.2.4).

Results of stable carbon isotope ratio analysis of individual fatty acids carried out on cooking pot and casserole extracts (7.2.3) suggest that meat consumed in Phoenician and Punic Sardinia largely came from ruminant animals (sheep, cattle, goat and red deer). This evidence offers a significant new element to the study of past foodways in the island. It does not contradict available zooarchaeological evidence (2.2.2.4), but it implies two possible explanations of isotope values. The first is that different types of meat may have been processed in the same vessel. Non-ruminant fats were in the majority, so that that sheep, cow, goat and probably red deer, if cooked frequently, hindered the detection of non-ruminant isotope signatures. The second is that porcine meat was infrequently processed in pots and casseroles, implying the use of other tools such as skewers or grills (7.1.1.2). Both explanations do not contradict each other. Further studies are needed to provide a more in-depth investigation regarding the type of meat and the culinary practices.

Meat was processed mainly in cooking pots. Several casseroles, however, contained a mixture of animal fat and plant lipids, not excluding that meat was processed in them. Four casseroles contained degraded animal fats that are proved to have adipose origin, suggesting that meat was processed in them (7.2.3). Casseroles appear to be more commonly used to process non-ruminant fats compared to cooking pots, but the difference in number of analysed extracts between the two categories (casseroles n = 4; cooking pots n = 61) makes it difficult to compare the categories.

8.2.1.4 Milk and dairy products

As zooarchaeological, iconographic and written sources indicate (2.2.2.5), milk and dairy products had a role in the Sardinian diet, both in the Iron Age and the Phoenician and Punic periods. However, the role of these products in ancient Sardinia has always been poorly investigated, since they cannot be archaeologically recovered. Organic residue analysis on cooking ware dated in the Phoenician and Punic periods confirmed the presence of lipids consistent with milk processing in cooking pots (7.2.1), and probably casseroles (7.2.3) and baking trays (7.2.5).

However, this research offers an unexpected update regarding milk and dairy product consumption in Phoenician and Punic Sardinia. Dairy fat was dominant in only two of the 66 samples submitted to isotope ratio mass spectrometry (7.1.1). Possible explanations to interpret this outcome, discussed above (7.1.1.3), can be summarised as follows. In particular, boiling milk was likely uncommon in this research project's target area and period, as is also suggested by previously available evidence based especially on literary sources (2.2.2.5). Since dairy fat has been detected only on a small minority of analysed extracts (2 of 66), milk was probably often processed in the form of yogurt or, more likely, cheese, through a production process that did not involve pottery. But this last hypothesis need to find some positive evidence (e.g. structures and tools used in cheese making) to be corroborated.

8.2.1.5 Honey and beeswax

Beehive products are a commodity in Sardinian foodways, likely relevant to both diet and vessel technology. Existing evidence provided the initial indication of this (2.2.2.5), and the current research offers meaningful advancements. Organic residue analysis detected beeswax in 16 extracts (5% of the total), especially cooking pots and basins (7.1.2).

It is not possible to determine if this beeswax was processed in the form of honey for culinary purposes, or in the form of beeswax itself for technological uses such as waterproofing. However, the available knowledge, described in Chapter 7 (7.1.2), indicates that honey was processed and cooked in pots where beeswax was detected. The reasons for the detection of beeswax only in basin subtype (BA6) is more complex and unclear. Heating and cooking of beeswax seem to be excluded according to the chromatographic profile of basin extracts. It could be processed both as honey, for culinary or other purposes, or as beeswax for waterproofing, or for other uses. However, a possible use of BA6 basins in honey production and storage is suggested by modern and ancient comparisons (7.1.2).

Although questions regarding the use of beehive products remain, it appears that they had an important role in Phoenician and Punic Sardinia foodways, as suggested by the *puls punica* recipe reported by Cato (2.2.2.5). It is also possible that similar recipes reflected an historical and archaeological reality, since beeswax, indicative of honey, has been commonly found in cooking pots in which dairy products could also have been processed (7.1.2). This outcome is extremely important not only for the history of foodways in Sardinia, but for the entire central Mediterranean, since archaeological evidence for the processing of beehive products has been limited thus far (Bortolin 2008: 37-51).

8.2.1.6 Fish, shellfish and aquatic products

The lack of aquatic products in analysed vessels is an unexpected result of this research. It was commonly assumed that fish and shellfish were relevant in the Phoenician and Punic diet (2.2.2.6), but no aquatic biomarkers have been found in the analysed extracts (7.1.1.4). Therefore, it was not possible to determine if aquatic resources were processed in the vessels analysed through GC-MS-SIM (63 cooking pots, four casseroles, four basins and one baking tray). Other vessels did not contain fish or shellfish, since they did not contain animal fats. This contradicts not only the common assumption that Phoenician people were fish eaters but also the limited zooarchaeological evidence available.

This evidence is not enough to revise the role of fish and shellfish in Phoenician and Punic foodways in Sardinia, since it can be related to cooking or environmental conditions that prevent APAAs or IFAs production or preservation (Evershed et al. 2008b). It is also possible that fish were processed in other vessels or cooking facilities (7.1.1.4). Further investigation is needed to interpret the absence of aquatic biomarkers in the presence of available zooarchaeological evidence, and to determine the role of aquatic products in the everyday diet of Phoenician and Punic Sardinia.

8.2.1.7 Other products and drinks

Other products that were consumed in Phoenician and Punic Sardinia have not been targeted by ORA being beyond the scope of the technique (Chapter 4), so little to no advancement has been made regarding these specific topics during this research. Cereals and legumes, not targeted in the analyses, have been discussed above since they were the most relevant food commodity. Other food products such as eggs (2.2.2.5) were certainly consumed in the Punic era, which is when chickens start to be commonly found in excavations, but, as explained in Chapter 2, their role and relevance remain unclear.

Alcoholic drinks were presumably widely consumed, but organic residue analysis cannot distinguish them at present (Chapter 4, 4.3.5), and vessels involved in wine consumption were not targeted for analysis (5.1). As suggested by previous research, wine was the most common drink and had an important social role (see 2.2.2.7). Other drinks are not currently found in Sardinia, since they are not mentioned in written sources and archaeologically undetectable. The common detection of beeswax in pottery during the current analysis suggests that mead should be considered among the drinks possibly produced on the island. Further research is needed to investigate this possibility.

8.2.2 Other issues arising from the current project

8.2.2.1 Cultural and regional differences

The existence of cultural differences and, specifically, culinary differences inside the island has to be taken as a fact, given the historical and archaeological background described in Chapter 3 (3.1). However, it has never been investigated beyond a regional scale (e.g. Sulcis, Carenti-Wilkens 2006). This is also due to the absence of a Sardinian ceramic *corpus* of everyday vessels for the period (see 3.3).

The results from the current analysis detected some of these differences, which are likely related to vessel use or food consumed (see 7.2). More importantly, they detected the possible coexistence of culinary traditions on the island related to the indigenous and Levantine worlds (7.4.1). Based on previously available evidence and the results of organic residue analysis, it seems that foodways in Nora were different from foodways in Pani Loriga, and those foodways were different from the ones in S'Urachi, and so on. This is a normal development on an island targeted by different waves of migrations and different external powers throughout the centuries. It is also to be expected due to the geography of Sardinia, where cultural differences, following natural boundaries, are still significant today (see, for example, the distribution of local languages, fig. 113). Archaeology already highlighted the existence of such regional differences (e.g. in pottery (Bartoloni-Campanella 2000), or burials (Bison 2015)).

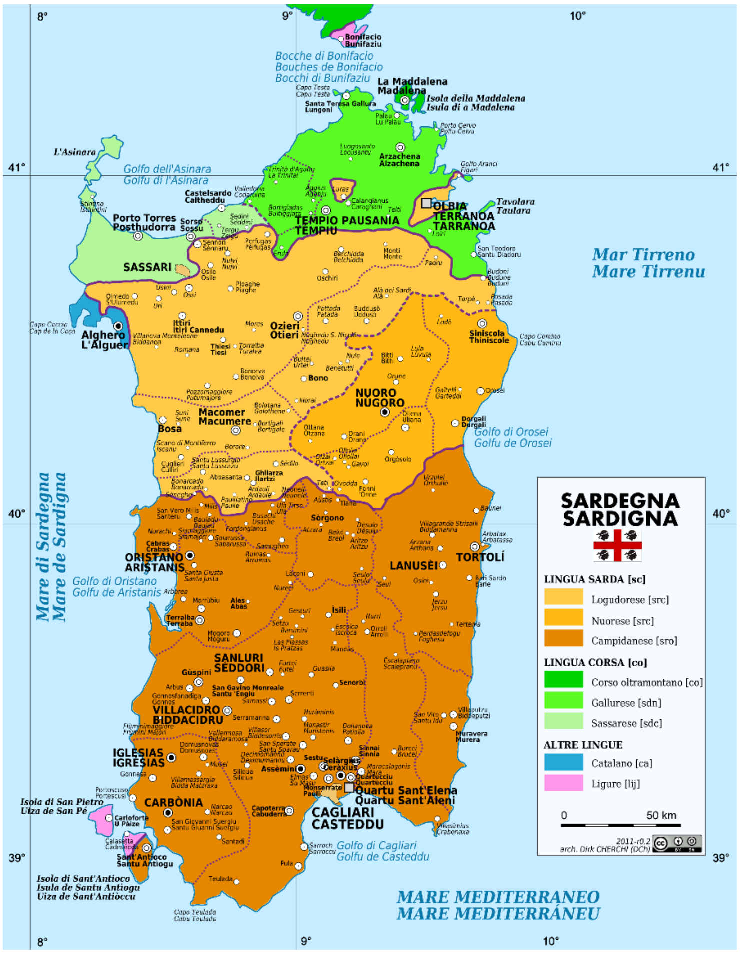


Figure 113. Distribution of local languages and dialects in contemporary Sardinia.

This is a good starting point for further studies, but it needs to be contextualised. As discussed above (7.4), these differences cannot simply be attributed to a dichotomic division between a "Phoenician-Punic" world and an indigenous world. Multiple ways existed to approach the newcomers and their culture (see Hodos 2006), and the newcomers had different cultural traditions themselves (Quinn 2018), so that no uniform blocks should be imagined. This reality likely produced a great variety of local cuisines, only partially detectable through the study of material culture available in the archaeological record.

New local and regional analyses are needed to investigate these differences and comprehensively analyse material culture (see also suggestions below). However, the existence of different cuisines on the island seems established through the current research.

8.2.2.2 Vessel use and specialisation, and absence of vessels

The most relevant results of this project relate to vessel use and to the connection of specific vessels with specific commodities. These outcomes have been described and discussed in Chapter 7 (7.2). The conclusions will be further expanded in this section.

This project confirmed that several of the typological divisions made by archaeologists were linked to different uses. Some of them were already well-established. Cooking pots were confirmed to have been used to cook porridges and stews. Ovens were confirmed to be used mainly to bake breads. Basins were revealed to have a link with plant or low-lipid commodities and confirmed to be not used for cooking, but their use seem to change per subtype. Other insights about uses were less expected. This is the case of casseroles, apparently used only rarely to process meat and animal products and more commonly used to cook mixtures of different commodities. A similar use has been hypothesised for baking trays. Detected differences between vessel categories, despite being based on small numbers of samples, seem evident enough to provide information about culinary practices.

Some differences, or at least apparent differences, within the same category were also detected. The most important is the difference in lipid content between handmade and wheelmade cooking pots in some sites. This difference, suggesting that animal products were more often processed in handmade cooking pots, was widely discussed in section 7.2.1.1. Differences between subcategories of basins have also been hypothesised. One subtype of basin has been connected with beeswax processing while some late subtypes were revealed to contain more lipids than the average amount found in basins (see 7.2.2). But these differences within the same category are based on limited amounts of data. More focused analyses are needed to understand if these differences are meaningful. In summary, it has been confirmed that organic residue analysis, when examined together with other information about the vessel (shape, fabric, assemblage) can provide significant advances to understand vessel use.

One last aspect to be highlighted is the absence of some commodities (e.g. milk or pig fats) in most of the vessels analysed, despite knowledge of their consumption due to previously available evidence, both faunal and literary (7.4). It is possible to postulate that the processing of these products occurred in containers and with tools undetectable to archaeologists, as they were likely made with perishable materials (wood, animal tissues etc.) or metals that were melted throughout the following centuries. This hypothesis, indirectly obtained through the interpretation of organic residues detected, can serve to spark future research on culinary practices.

8.2.2.3 Social differentiations

The analyses undertaken did not answer questions about social organisation and differentiations. Studies associating spaces, vessels and faunal remains are needed (e.g. Bendall 2004). In Sardinia, the comprehension of social organisation represents a gap to be filled by archaeological research. How many people consumed fish or meat in the Phoenician and Punic settlements in Sardinia? How often? What was the role of high-level families, magistrates or the Carthaginian state in the distribution and availability of food (Hastorf 2017)? How were feasts organised, and who controlled them? These specific questions have never been answered for Phoenician, Punic and Iron Age Sardinia. It is established that foodways are often a means of social representation and power (Hastorf 2017: 189). Collating the available data, it is possible to elaborate on some of the insights obtained through this research.

It seems likely that there was a hierarchical change with the establishment of the Carthaginian power on the island. Some of the people and settlements on Sardinia entered into a state system at the end of the 6th century BCE and in the following centuries (Moscati et al. 1997; Bondì 2019; see 3.1.3). In turn, this caused a change in culinary practices (examples in Hastorf 2017). However, the detection of possible changes in foodways, leading to more hierarchical distribution, is made more difficult by the likelihood that only a small portion of the population would have consumed something new or different. This represents a limit in the use of organic residue analysis to answer archaeological questions regarding social differentiation in Sardinia. This is true for the whole of the Phoenician and Punic period in Sardinia, since newcomers appear to have been in small numbers, both in the centuries of the first Phoenician colonisation and after the Carthaginian conquest of the island (see summary in 3.1).

Some of the outcomes of this research could be connected with the existence of small groups of people consuming different foods. This is not contradicted by the available data (e.g. Gurguis et al. 2017, which offers bioarchaeological data on burials). Connection of specific products with small groups of people may explain the absence of aquatic products or the low concentrations of non-ruminant meat. However, evidence to argue for the existence of such groups and such a social division is currently lacking, making it only a research hypothesis at present. For example, a higher role of state and magistrates in the control of feasts and sacrifices is clear only by the 3rd century BCE, when written tariffs start to appear (Amadasi Guzzo 1988), and institutions and social organisation of the island and the settlements is not clear before the 4th century BCE (Bondì 2019).

Up to this point, available data about foodways is unable to offer a precise picture regarding social differentiations that exist on the island. The results of organic residue analysis make clear the need to tackle this problem to obtain a better interpretation of culinary practices. For example, the higher processing and consumption of animal products in S'Urachi, compared to other sites, was hypothesised to be linked with a local culinary tradition (see 7.4.1). But, based on the limited available evidence, it is still not possible to exclude that this higher meat consumption was due to less Carthaginian control, leading to more widespread wealth in the settlement. The elements outlined here serve as a starting point for future research.

8.3 The potential of organic residue analysis for the understanding of past culinary customs: Iron Age and Punic Sardinia as a case study

As discussed in Chapter 4, the utility and potential of organic residue analysis in investigating culinary practices is well established. The application of organic residue analysis to investigate movements, changes or continuity in foodways (Lucquin et al. 2016; Cramp et al. 2014), different uses of the same vessel (Cramp et al. 2011), and the introduction of new commodities and products (Roffet-Salque et al. 2015) has offered results from all over the world, suggesting to investigate more issues and contexts throughout this technique.

To conclude this dissertation, I want to briefly outline how organic residue analysis can be applied to Sardinia in the first millennium BCE. The island, and specifically this time period in the history of the island, can constitute a significant case study for both archaeology and archaeological chemistry.

As set out in the aims of the research (Chapter 1), the results obtained through this project constitute a benchmark for future researchers undertaking organic residue analysis in Sardinia and the surrounding areas. Several of the detected data do not appear to have archaeological explanations at this stage, but they are, however, relevant for research developments. Knowing that S'Urachi is a site where lipids are well-preserved while the context of Olbia Via del Mercato is not, or knowing that wheelmade cooking pots in Nora, Pani Loriga and Sant'Antioco usually contain only low concentrations of lipids, can help to focus and orientate future organic residue analysis through the selection of sites and vessels that may provide more lipids. This information was unavailable when this project started, and it can be helpful for the widespread adoption of organic residue analysis in Sardinia and related archaeological contexts. However, these investigations need to be matched on the island with the increased availability of bulk collagen isotopic data (both on animals and humans), palaeobotanical data, palaeopathological data and archaeozoological data.

Although these aspects of research are still in their infancy, they will further enable the study of past foodways as discussed in Chapter 2.

Examples of potential projects to be undertaken are outlined below. These projects are based on organic residue analysis on pottery. Other techniques can also be applied to study foodways, such as isotopic analysis on human bones or the systematic study of faunal evidence. These lines of research are not discussed, as they are beyond the scope of this research.

8.3.1 Recommendations for future research

8.3.1.1 Application of acidified methanol extraction protocol to potsherds

First of all, acidified methanol extraction protocol could be applied to some of the potsherds involved in this project or to new ones. This protocol in recent years became commonly applied in archaeological chemistry, since it achieves higher recovery of absorbed lipids, significantly shortening time needed for the extraction (Correa Ascencio and Evershed 2014). It has not been used in this project, since it causes loss of lipids such as wax esters and triacylglycerols due to methanolysis. Being the first chromatographic scan of a significant number of sherds from Sardinia and the surrounding area, these compounds were among the targeted ones (see 7.1.2).

However, now the knowledge about lipid recovered in vessels from Phoenician and Punic Sardinia is largely widened. It seems useful to apply acidified methanol protocol to sherds or vessel categories which provided low lipid concentrations and poor preservation. This different extraction method can bring higher recoveries and, with those, more information about lipids processed in the vessels. This possibility could apply to all of the following suggested research paths.

8.3.1.2 The pre-Phoenician and indigenous world

Further investigation is needed regarding foodways in the indigenous Sardinian or Nuragic world. Concerning the theme and outcomes of this research, it would be particularly interesting to investigate the period of stronger interaction with the Levantine and Phoenician world, i.e. the Late Bronze Age and Iron Age. The Iron Age lasts until the 3rd century BCE in areas of the island where relationships with the Phoenician and then Punic people were limited. These areas of the island (i.e. the middle, the northwest) have not been included in this research due to different ceramic and historical developments, as explained in Chapter 5. However, people living there cohabited on the island for centuries with "Phoenician and Punic" people, meaning, in this context, also local Sardinian people who lived in Phoenician and Punic settlements and areas, adopting foreign customs. How different were their foodways from the ones of Sant'Antioco/Sulky, the most ancient Phoenician city in Sardinia, but also from indigenous settlements related to Phoenician towns such as S'Urachi? Was there any kind of cultural and culinary boundary?

Material culture, as outlined in Chapters 2 and 3, suggests a continuity in the diet between the two periods, but any detailed interpretation is hindered by the lack of comparable data. Archaeozoological and bioarchaeological data are sparse in spots. Moreover, for the Sardinian Iron Age, from the 10^{th} to the 6^{th} centuries BCE, bioarchaeological data is lacking.

Organic residue analysis can be beneficial in this context, but it has only recently started to be applied (Gradoli and Garnier 2018), leading to the identification of commodities not widely accepted by the field, such as wine or insect-based meals (see 4.4). A database is now available for Phoenician and Punic Sardinia, allowing other scholars to apply the same analysis on dozens of sherds from the pre-Phoenician and/or indigenous settlements on the island. Similar projects would allow a more comprehensive picture of foodways and cultural developments on the island to be obtained, both diachronically and synchronically. They will also enable a better understanding of the outcomes of this research as related to a "Phoenician" way of relating to food, i.e. related to an external Levantine tradition, or a Sardinian tradition as a whole.

8.3.1.3 Site-based analysis

Organic residue analysis is particularly informative on individual sites: the level of detail is greater, and it is easier to compare results over centuries and between vessel types, since the context is bounded (e.g. Nieuwenhuyse et al. 2015). This was known when creating this project, but the idea of an analysis based on one site was abandoned due to the desire to create an island-based database and the inability to get permission to sample 300–400 sherds from the same site. It is, however, still a relevant research path. Now that initial results have been obtained, analysis can be more focused due to the available data. Moreover, with solid pilot data available, it will also be easier to get permissions from the local authorities for site-based studies.

All the sites targeted in this project are suitable for further analysis, but S'Urachi would be the most relevant for future study due to its high-quality lipid preservation. This enables a smaller number of samples to be obtained for meaningful results, detecting at the same time a greater variety of lipids (6.1.1). Excavations are ongoing, and recently 7^{th} and 8^{th} century BCE layers were reached. Beyond the excavations, palaeobotanical and archaeozoological data will offer more comprehensive, detailed data when fully studied and published. Isotopic analysis of animal bones has also been undertaken and will be published soon. As a result, new organic residue analysis in S'Urachi on cookware or vessels related to food consumption and rituals could offer relevant data to better understand culinary changes, diet, and vessel use and specialisation at the site. The detailed archaeological stratigraphy could help in selecting sherds that will provide more information.

Among the other sites, Sant'Antioco/Sulky deserves a brief mention. Archaeozoological information is available, the site is extremely relevant for the history of Sardinia, and organic residue analysis undertaken there on 38 sherds offered relevant insights, since the recovery rate is 70% for cooking pots and 85% for casseroles. Due to the availability of material, only cookware from one landfill (SU 500) has been analysed so far, but new excavations at the site (University of Sassari and Sant'Antioco City Council) are widening the availability of contextualised pottery, especially cookware from the 8^{th}-7^{th} centuries BCE. The availability of a new precise chronological stratigraphy from the 8^{th} century to the Roman era makes Sant'Antioco extremely suitable for a site-based project.

8.3.1.4 Vessel-focused studies: the case of cooking pots

As in the case of single site studies, a project aiming to apply organic residue analysis to a large number of vessels from the same ceramic category can be particularly productive. It can enable a better understanding of the use of that specific ceramic type or category, for example, exploring if it changes throughout the sites, over the centuries or in different contexts. Lucy Cramp's work on Roman *mortaria* in Britain is an example of this type of investigation in action (Cramp et al. 2011).

In Phoenician and Punic Sardinia, this can be particularly relevant in the case of vessels thought to have an extremely specialised use (e.g. baby bottle jugs and zoomorphous *askoi* associated with milk; see 2.2.2.5), as in every vessel category involved in this project. As discussed in Chapters 7 and 8, several questions about cooking pots, basins, casseroles and baking trays have not been answered by the analysis carried out, and new questions have been raised.

Cooking pots are used as a case study because they constitute the most suitable vessel category from the types analysed for this project for several reasons: 1) a recovery rate of over 70% in cooking pots enables relevant information to be obtained in less time and with less expense; 2) cooking pots are a relevant ceramic shape in the Phoenician and Punic world, used both as an everyday instrument and as an urn in cemeteries and *tophet* sanctuaries, with the same vessels used in different contexts; 3) the large number of available pots allow a statistically significant selection of sherds (e.g. 5% or 10% of pots per site or context); 4) some subtypes of Phoenician and Punic cooking pots are available from several different Mediterranean areas, from the Levant to North Africa and Sicily, constituting a marker of Phoenician migration to the West (see 3.2.1). Due to this specific feature, organic residue analysis targeting a limited number of cooking pots per site (approximately 30) could enable answering questions such as:

1) What was processed in cooking pots used as urns?

2) Were they used as everyday vessels before the deposition, as archaeology suggests, or were ritual foods cooked in them that are identifiably different from standard fare?

3) Was there a difference in the use of handmade and wheelmade cooking pots in Phoenician and Punic Sardinia, at least at some sites as suggested by this dissertation, or were the differences detected random, isolated or due to non-cultural reasons?

4) Were Phoenician cooking pots in the Levant or Punic cooking pots in North Africa used to process the same commodities processed in Sardinia, or was their use different?

Lipid analyses on cooking pots could also enable questions about chronology or fabric properties to be answered. These topics are discussed below (8.3.1.4 and 8.3.1.6).

This is just an example of what could be obtained targeting only one vessel category, and answers to these questions would be significant for the understanding of the Phoenician, Punic and Sardinian past.

8.3.1.5 Fabric properties

The possibility that fabric properties and features of the vessels impact lipid absorption and preservation is discussed in Chapter 7 (7.2.1; 7.2.3). It is well established that different fabrics have different capacities to absorb and preserve lipids over archaeological timescales (Correa-Ascensio and Evershed 2014; see 4.2). On a general level, the porosity of the vessel wall was recently linked more directly with lipid absorption and preservation (Drieu et al. 2019), but research is ongoing and the precise impact of fabrics on lipid absorption and preservation is unclear.

It has been explained that differences in fabrics have not been analysed during this project. They were recognised as possibly meaningful only after the first part of residue analysis, and the aim and structure of the research did not allow for further focus on that feature. It could, however, be worthwhile comparing lipid concentrations in different fabrics, especially in the case of wheelmade and handmade cooking pots or similar pots found in different settlements, since fabrics are often local. A new study analysing organic residues based on vessel fabric could allow the development of further analyses, such as the recent researches by Drieu and colleagues (2019) applying gas chromatography and mercury intrusion porosimetry to selected sherds, or by Hammann and colleagues (2020) which, through the use of secondary ion mass spectrometry (SIMS) imaging on sections of potsherds, also established that macroscopic structures in ceramics are involved in lipid preservation, and not only individual pores.

8.3.1.6 Detection of cereals

The inability to detect cereals has been one of the core issues in the interpretation of the results, since it is known they were widely consumed on the island but cannot be detected through ORA (see Chapter 4).

Recent research developed a new, more sensitive method for cereal detection on archaeological pottery based on GC-Q-ToF-MS (Hammann and Cramp 2018). Only a small amount of lipids is liberated, but anoxic degradation conditions allow for better preservation of biomarkers, with twentyfold higher levels of alkylresorcinols and twofold higher levels of plant sterols after 20 weeks compared to oxic conditions.

Anoxic conditions are available in the waterlogged contexts of S'Urachi (6.1.1), allowing for good lipid preservation. Based on available evidence, it is thought that cereals could have been processed in some of the vessels where only small amounts of lipids have been detected (7.2.1). Targeting vessels preserved in anoxic conditions with high sensitivity methods could enable the detection of cereal-specific biomarkers (Hammann et al. 2019), allowing a more precise interpretation of culinary practices and vessel use on the island. In addition, it would allow new data to interpret the absences of lipids in previous studies.

8.3.1.7 Radiocarbon dating: the case of handmade pottery in Punic Sardinia

It has been highlighted that chronology of some handmade cooking pots and handmade vessels is unclear, since their manufacture is consistent across the centuries (3.3.1; 3.3.4).

Animal fats are often found at a high concentration in these pots (7.2.1) and in one baking tray (7.2.4), and thus some of these vessels are suitable for radiocarbon dating of individual fatty acids. A concentration of more than 500 μg/g is required for accurate dating (Casanova et al. 2020), and this should be obtainable in handmade cooking pots. Only eight of the extracts analysed have a concentration > 500 μg/g, but different extraction methodologies (Correa-Ascencio and Evershed 2014) can enable the extraction of higher concentrations of lipids.

If enough lipids are provided, carrying out radiocarbon dating on handmade vessels could allow for relevant issues in Sardinian archaeology to be further analysed. It would be possible to understand if this type of vessel remains unchanging throughout the centuries, or if most of the handmade cooking pots found in historic Sardinian settlements are actually residual prehistoric vessels.

8.3.1.8 Extra-Sardinian comparisons

Sardinia has always been in the middle of trade links and routes, as implied by its position in the centre of the western Mediterranean. To allow for a specific research focus, this aspect has been at least partially overlooked throughout this dissertation. It is nevertheless relevant for the understanding of Sardinian foodways and to contextualise and compare the results of this project.

Since the database for Phoenician and Punic Sardinia is now well substantiated, it would be beneficial to use organic residue analysis and other techniques to investigate foodways in areas of the Mediterranean most connected with Sardinia, where ceramic categories are similar to what is found on the island. How different was the content of cookware in Cyprus, Phoenicia or Carthage when people coming from these areas originally started to establish settlements in Sardinia? Were similar vessels used in similar ways across the Phoenician and then Punic settlements of the western Mediterranean, or did their use vary significantly? Did a common culinary culture exist in the Punic central Mediterranean (Sardinia, Sicily, North Africa) after the rise of Carthage as a central hegemony, or were local cuisines more connected with local customs and cultures than overseas trends?

As discussed in Chapters 1 and 2, the interest in foodways has increased in recent years, and excavations are ongoing in locations such as Tunisia, Sicily, and the Balearic Islands where Phoenician and Punic culture is found. Sites with a precise and comprehensive stratigraphy (e.g. Motya (Nigro 2010), Uthica (Lòpez Castro et al. 2016)) could work as a starting point for these extra-Sardinian comparisons. The use of organic residue analysis, especially at sites where stratigraphy and faunal data are available, could introduce relevant new elements to the study of the Phoenician, Punic and Mediterranean past. In this respect, the results presented in this dissertation will probably make the inclusion of organic residue analysis more systemic in further archaeological projects in the central and western Mediterranean. One of the aims of this whole research project was, in fact, the creation of a solid benchmark to stimulate and orientate future research.

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Appendix

Sample and results list per site

List of tables:

List of abbreviations:

SFA = Saturated fatty acid

UsFA = Unsaturated fatty acid

AL = alcohol

MAG = monoacylglycerol

DAG = diacylglycerol

TAG = triacylglycerol

WE = wax ester

RA = ruminant adipose

NRA = non-ruminant adipose

RD = ruminant dairy

Discarded extracts, very likely contaminated, are highlighted in red in the tables.

Table I. Sherds investigated from S'Urachi, analyses undertaken and main results.

Sample name	SUB1	SUB2	SUB3	SUB4	SUB5	SUB6	SUB7	SUB8	SUB9	SUB10
Vessel category-type (chronology)	Casserole (4th century BCE)	P2 pot (5th century BCE)	P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (6th century BCE)	P3 pot (5th-4th centuries BCE)	Baking tray (8th-5th centuries BCE?)	Wheelmade pot (5th-4th centuries BCE)	P2 pot (6th-5th centuries BCE)	P2 pot (6th centuries BCE)
Context (chronology)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
Analyses undertaken	HTGC GC-MS	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC	HTGC	HTGC GC-MS	HTGC HTGC-MS	HTGC GC-MS (SIM) GC-C-IRMS
Lipid concentration (µg/g)	29	227.5	453	164	31	22.5	22	72	118	204
Identified compounds	SFA C12-18; UsFA C16:1, C18:1; AL C12-24	SFA C14-C18, C20; UsFA C16:1, C18:1; Ketones C31, 33, 35	SFA C14, C16-20; UsFA C18:1; AL C24; DAGs C32-36; TAGs C48-54	SFA C14, C16-18; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C14-20; UsFA C16:1, C18:1; AL C16, 18, 20, 21, 24	SFA C15-C18; UsFA C18:1; AL C18, 20; TAGs C48-54	SFA C15-C18; UsFA C18:1; AL C18, 20; phtalateTAGs C48-54; Contaminants?	SFA C14, 15, 16, 18; UsFA C16:1, C18:1; AL C14, 16, 18, 20; plastifiers; DAGs C32-36; TAGs C50-54	SFA C12, 14-18; UsFA C16:1, 18:1; AL C16, 18, 20-22; DAGs C32-34; TAGs? Contaminant s?	SFA C14, 15, 16, 17, 18; UsFA C16:1, C18:1; DAGs C32-36; TAGs C48-54
$\delta^{13}C_{16:0}$ (‰)			-27.6	-28.5						-27.2
$\delta^{13}C_{18:0}$ (‰)			-29.4	-30.5						-28.5
$\Delta^{13}C$ (‰)			-1.8	-2						-1.3
Lipid characterisation	Plant lipids and animal fat	Animal fats (heated over 300°C)	Animal fats (RA)	Animal fats (RA)	Plant lipids (oil?)	Animal fats	Animal fats? Contamination Vegetal fats? Contamination ?	Animal fats (and plant lipids?); contaminants	Oil? Plant lipidsfats? Contaminatio n?	Animal fats (RA)

SUB11	SUB12	SUB13	SUB14	SUB15	SUB16	SUB17	SUB18	SUB19	SUB20	SUB21	SUB22
P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (End 6th-5th centuries BCE)	Casserole (First half 5th century BCE)	P1 pot (7th-half 6th centuries BCE)	P2 pot (6th-5th centuries BCE)	Tannur (5th century BCE?)	P2 pot (End 6th-5th centuries BCE)	P2 pot (Second half 6th century BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
HTGC	HTGC GC-MS	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC
12	210	10.5	3	39	773	16	31	188	4	103	6
SFA C16-18; UsFA C18:1; phtalates, WE?	SFA C16-18; Ketones C29-35; phtalates; WE?	SFA C16, 18, 20; UsFA C18:1; WEs 44-50; TAGs 50-54; phthalate; squalene		SFA C14-18; UsFA C18:1; TAGs C50-54	SFA C12, 14-18; UsFA C18:1; AL C18, 20alcohols; DAGs C32-36; TAGs C48-54.	SFA C16, C18; UsFA C16:1, C18:1; AL C14, 16, 18, 20; phthalates; squalene	SFA C14-18; UsFA C16:1, C18:1, AL C14, 16, 18, 20, 21; plastifiers; TAGs C48-54	SFA C14-18; UsFA C18:1; TAGs C48-54		SFA C15-18; UsFA C18:1; TAGs C48-54	
				-25.9	-27.9			-28.5		-27.8	
				-30.8	-29.7			-31.6		-29.9	
				-4.9	-1.8			-3.1		-2.1	
Animal fat? Contamination?	Animal fats (heated over 300°C); contaminants	Animal fats; beeswax? Leafy plants?		Animal fats (RD)	Animal fats (RD?)	Animal fats?; contaminants	Animal fats? Plant lipids? Contamination?	Animal fats (RA? RD?)		Animal fats (RA)	Contaminants

SUB23	SUB24	SUB25	SUB26	SUB27	SUB28	SUB29	SUB30	SUB31	SUB32	SUB33	SUB34
P2 pot (End 6th-5th century BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (Second half 6th century BCE)	Handmade pot (7th-5th centuries BCE?)	P3 pot (5th-4th centuries BCE)	P6 pot (4th-2nd centuries BCE)	P2 pot (End 6th-5th centuries BCE)	P2 pot (Second half 7th-6th centuries BCE)	P3 pot (5th-4th centuries BCE)	Tannur (5th-4th centuries BCE?)	Casserole (First half 5th century BCE)	Casserole (First half 5th century BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
4	100	340	121	66	0	5	411	4.6	0	6.6	29
	SFA C15-18; UsFA C18:1; Ketones C31, 33, 35; TAGs	SFA C12, 14-20, 22, 34; UsFA C18:1; AL C24, 26, 28; Ketones C31,33, 35; DAGs C32-36; TAGs C48-54	SFA C15-18, 20, 22; UsFA C18:1; DAGs C32-36; TAGs C48-54.	SFA C15-18; UsFA C18:1; Ketones C31, 33, 35; DAGs C32-36; TAGs C48-54			SFA C14-18, 20; UsFA C18:1; AL C24, 26, 28, 30, 32; Alkanes C25, 27, 29, 31; WEs C44-50	SFA C16, C18		SFA; phtalates	SFA C16, C18; UsFA C18:1; DAGs C32-36; TAGs C50-54
	-27.1	-26.2	-27.5	-26.7			-28.2				-27.7
	-28.1	-27.6	-28.8	-28.4			-29.5				-29.7
	-1.0	-1.4	-1.3	-1.7			-1.3				-2.0
	Animal fats (heated over 300°C, RA)	Animal fats (heated over 300°C, RA)	Animal fats (RA)	Animal fats (RA)			Animal fats; degraded beeswax? Leafy plants?				Animal fats (RA)

SUB35	SUB36	SUB37	SUB38	SUB39	SUB40	SUB41	SUB42	SUB43	SUB44	SUB45	SUB46
P2 pot (End 7th-first half 6th centuries BCE)	P2 pot (Second half 7th century BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (Second half 6th century BCE)	P10 pot (4th century BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (Half 7th-first 6th centuries BCE)	Coppa a calotta, (5th century BCE)	Tannur (5th-4th centuries BCE?)	P2 pot (Second half 7th centuries BCE)	P2 pot (End 7th century BCE)	P2 pot (Second half 7th century BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
135	84	8	432	11	16	5.5	1.4	1	11.6	4	18
SFA C15-18	SFA C15-18; UsFA C18:1; TAGs C48-54	SFA C14, 15, 16, 18; prednisone?; TAGs C48-54	SFA C15-18, 20, 22, 24; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C16, 18; UsFA C18:1; phtalates	SFA C16, C18	SFA C16, C18			SFA C 14, 15, 16, 18; UsFA C16:1, C18:1; AL C16, 18; phtalates.		SFA C15, 16, 18; UsFA C18:1; AL C18, 20; DAGs C32-36; TAGs C48-54
	-28.0		-27.9								-28.0
	-30.6		-29.7								-29.9
	-2.6		-1.8								-1.9
Animal fats (ruminant?)	Animal fats (RA)	Animal fats; contaminants ?	Animal fats (RA)	Animal fats; contaminants	Animal fats	Animal fats, beeswax?			Animal fats? Oil?		Animal fat (RA)s; plant lipids?

SUB47	SUB48	SUB49	SUB50	SUB51	SUB52	SUB54	SUB55	SUB56	SUB57	SUB58	SUB59
P2 pot (6th-5th centuries BCE)	P3 pot (5th-4th centuries BCE)	P2 pot (Second half 6th century BCE)	P2 pot (Second half 7th-first 6th centuries BCE)	P2 pot (6th century BCE)	P3 pot (5th-4th centuries BCE)	Domestic jug (6th-5th centuries BCE)	P2 pot (7th-first 6th centuries BCE)	P2 pot (Second half 6th centuries BCE)	P2 pot (Second half 6th centuries BCE)	P2 pot (End 7th-first 6th centuries BCE)	P2 pot (Second half 6th century BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
HTGC HTGC-MS	HTGC GC-MS (SIM)	HTGC GC-C-IRMS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
80	1066	462	2.4	32	82	3.7	294	2	384	3.7	470
SFA C14, 15, 16, 18; AL C18, 20, 22; alkenes; phthalates; DAGs C32-36; WEs C44-58; other unidentified compounds	SFA C15-18, 20, 22, 24; UsFA C18:1; AL C24, 26; DAGs C32-36; TAGs C48-54	SFA C15-18; UsFA C18:1; TAGs C48-54		SFA C16-18	SFA C16, 18; UsFA C18:1; Ketones C31, 33, 35; TAGs C48-54	Plastifier	SFA C15-18; UsFA C18:1; Ketones C31, 33, 35.		SFA C15-18; UsFA C18:1; Ketones C31, 33, 35; TAGs C48-54		SFA C15-18, 20, 22, 24; UsFA C18:1; Ketones C31, 33, 35; TAGs C48-54
				-26.8	-28.1		-27.4		-27.6		-26.4
				-28.1	-31.1		-28.0		-29.5		-28.1
				-1.3	-3.0		-0.6		-1.9		-1.7
Animal fats? Plant lipids (oil)? Contaminants?	Animal fats (ruminant?)	Animal fats (RA)		Animal fats (RA)	Animal fats (heated over 300°C, mixed RA and RD?)	Contaminants	Animal fats? Oil?		Animal fats (heated over 300°C, RA)		Animal fats (RA)

SUB60	SUB61	SUB63	SUB64	SUB65	SUB66	SUB67	SUB68	SUB69	SUB70	SUB71	SUB72
" S profile" pot (7th-5th centuries BCE?)	Handmade pot (7th-5th centuries BCE?)	P2 pot (Second half 6th centuries BCE)	Miniaturistic pot (6th-5th centuries BCE)	P3 pot (5th-4th centuries BCE)	Tannur (5th-4th centuries BCE?)	Handmade pot (8th century BCE?)	BA7 basin (4th century BCE)	BA3 basin (7th-6th centuries BCE)	BA15 basin (4th century BCE)	BA5 basin (7th-6th centuries BCE)	BA9 basin (4th-3rd centuries BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)
HTGC GC-MS HTGC-MS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS
39	0.5	329	1039	6.4	1.5	30.5	4	1.5	30	6	25
SFA C14-18, 22, 23, 24, 26, 28; alkanes C29, 31; AL C18, 26, 28; dehydroabiet ic acid; DAGs C32-36; TAGs C46-54; WEs C48-52		SFA C15-18; UsFA C18:1; Ketones C31, 33, 35; TAGs C48-54	SFA C15-18; abundant UsFA C18:1; AL C18, 20; DAGs C32-36; TAGs C48-54			SFA C14, 16, 18; AL C15, 16, 18; TAGs C48-52; phthalate			SFA C14, 16, 18; UsFA C18:1 (abundant); AL C16, 18, 22, 27; DAGs C32-36; TAGs C48-54	SFA C16, 18; contaminants ?	SFA C14, 16, 18; AL C18, 20; plastifiers
-28.6		-28.3				-27.1					
-31.1		-31.0				-27.4					
-2.5		-2.7				-0.3					
Animal fats; leafy plantsplant lipids?		Animal fats (RA)	Animal fats?			Animal fat s(NRA) or oil?and plant lipids			Plant lipids (oil?)		Animal fatPlant lipids?; contaminants

SUB73	SUB74	SUB75	SUB76	SUB77	SUB78	SUB79	SUB80	SUB81	SUB83	SUB84	SUB85
BA5 basin (5th-4th centuries BCE)	BA2 basin (7th-6th centuries BCE)	BA3 basin (7th-6th centuries BCE)	BA1 basin (7th-half 6th centuries BCE)	Handmade pot (7th-5th centuries BCE?)	Basin (Half 6th century BCE)	BA2 basin (7th-6th centuries BCE)	BA1 basin (7th-6th centuries BCE)	BA2 basin (7th century BCE)	P6 (3rd-2nd centuries BCE)	Casserole (3rd-2nd centuries BCE)	Pot (3rd-2nd centuries BCE)
Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area E (6th-4th centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)
HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS
1.5	4.6	1.6	3.7	119	3	5.4	8	1.3	18	112	50
				SFA C14-20, 22, 24; UsFA C18:1; AL C22, 24, 26; DAGs C32-36; TAGs C48-54			SFA C16, 18; phthalate; TAGs C48-54		SFA C16, 18; UsFA C18:1; TAGs C48-52	SFA C12, 14-18, 22, 24, 26; UsFA C18:1; TAGs C48-54	SFA C14-18; UsFA C18:1; TAGs C48-54
				-27.3					-26.1	-26.2	-26.0
				-30.4					-27.3	-26.9	-24.0
				-3.1					-1.2	-0.7	2.0
				Animal fats (mixed RA and RD?)			Animal fats?; plastifiers		Animal fats (RA)	Animal fats (RA, mixed NRA?)	Animal fats (RA)

SUB86	SUB87	SUB88	SUB89	SUB90	SUB91	SUB92	SUB93	SUB94	SUB95	SUB96	SUB97
Casserole (3rd-2nd centuries BCE)	Casserole (4th century BCE)	P10 pot (3rd-2nd centuries BCE)	P8 pot (4th century BCE)	Tannur (5th-2nd centuries BCE?)	P10 pot (3rd-2nd centuries BCE)	Pot (3rd-2nd centuries BCE)	P3 pot (5th-4th centuries BCE)	P10 pot (3rd-2nd centuries BCE)	P2 pot (End 7th-first 6th centuries BCE)	Baking tray (?)	P6 pot (3rd-first 2nd centuries BCE)
Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)
HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC GC-MS	HTGC GC-MS	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
39.7	86	503	6	1.4	4	55	29	50	6	1	48
SFA C14-18; UsFA C18:1	SFA C12, 14-18, 24; UsFA C18:1; AL C16, 18, 20, 22, 24; DAGs C32-36; TAGs C48-54	SFA C14-18; UsFA C18:1; AL C16, 18, 20; DAGs C32-36; TAGs C48-54.				SFA; UsFA; plastifiers	SFA C14-18; UsFA C16:1, 18:1; AL C16, 18, 21; phtalate	bis(2-ethylhexyl) cyclohexane-1,2-dicarboxylate or N-Ethyl-O-toluenesulfon amide; phtalatesUnid entified, contaminated			SFA C16, 18; UsFA C18:1; DAGs C32-36; TAGs C48-54
-24.7		-27.9									-28.3
-24.9		-29.3									-30.6
-0.2		-1.4									-2.3
Animal fats (NRA)	Animal fats and plant lipids	Animal fats (RA)				Animal fats?; contaminants	Plant lipids? Contaminatio n?	Contaminatio n			Animal fats (RA)

SUB98	SUB99	SUB100	SUB101	SUB102	SUB103	SUB104	SUB105	SUB106	SUB107	SUB108
P6 pot (3rd century BCE)	P6 pot (3rd-2nd centuries BCE)	P6 pot (3rd-2nd centuries BCE)	P6 pot (3rd-2nd centuries BCE)	Casserole (3rd-2nd centuries BCE)	Basin (4th century BCE)	BA1 basin (7th-6th centuries BCE)	BA11 basin (4th-3rd centuries BCE)	BA9 basin (3rd-2nd centuries BCE)	BA16 basin (3rd-2nd centuries BCE)	P6 pot (3rd-2nd centuries BCE)
Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)	Area D (5th-2nd centuries BCE)
HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS HTGC-MS	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS	HTGC GC-MS
206	606	37	143.6	205	3	1.5	18	7	16	9
SFA C14-18; UsFA C16:1, C18:1; TAGs C48-52	SFA C14-18, 20, 22, 24; UsFA C16:1, C18:1; AL C22, 24, 26, 28; DAGs C32-36; TAGs C48-54	SFA C14-18; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C14-18; UsFA C16:1, C18:1; DAGs C32-36; TAGs C48-54	SFA C14-20, 22, 23, 24; UsFA C16:1, 18:1; AL C18; Ketones C31, 33, 35; DAGs C32-36			SFA C14-18; UsFA C18:1; AL C16, 18, 20, 21, 24.		SFA C14, 15, 16, 18; UsFA C16:1, 18:1; AL C18, 20, 24; Alkanes C25, 27, 29	SFA C14, 15, 16, 18; UsFA C16: 1, C18:1; AL C16, 20; phatalates; TAGs C48-54
-27.1	-28.6	-27.6	-27.1	-27.1						
-29.1	-29.8	-29.4	-28.6	-29.7						
-2.0	-1.2	-1.8	-1.5	-2.6						
Animal fats (RA)	Animal fats (RA)	Animal fats (RA)	Animal fats (RA)	Animal fats (heated over 300°C; RA and RD?)			Plant lipids (oil?)		Plant lipids	Animal fats; contaminants

Table II. Sherds investigated from Pani Loriga, analyses undertaken and main results.

Sample name	Context (chronology)	Vessel category-type (chronology)	Analyses undertaken	Lipid concentration (µg/g)	Identified compounds	$\delta^{13}C_{16:0}$ (‰)	$\delta^{13}C_{18:0}$ (‰)	$\Delta^{13}C$ (‰)	Lipid characterisation
PLO1	Area B (Late 6th-5th centuries BCE)	Baking tray (8th-6th centuries BCE?)	HTGC	11	SFA C16, 18; UsFA C16:1, 18:1; AL C16, 18; TAGs C48-54				Animal fats and plant lipids?
PLO2	Area B (Late 6th-5th centuries BCE)	Handmade pot (8th-5th centuries BCE?)	HTGC GC-MS (SIM) GC-C-IRMS HTGC-MS	1015	SFA C14-18, 20, 22, 24, 26; UsFA C18:1; AL C28, 30, 32; Ketones C31-35; WEs C42-50; TAGs C50-54	-27.3	-29.0	-1.7	Animal fats (ruminant?) heated over 300°C; beeswax
PLO3	Area B (Late 6th-5th centuries BCE)	P2 pot (7th-6th centuries BCE)	HTGC	12					
PLO4	Area B (Late 6th-5th centuries BCE)	Handmade pot (8th-5th centuries BCE?)	HTGC GC-MS (SIM) GC-C-IRMS	178	SFA C14-18; UsFA C18:1	-26.0	-25.8	0.2	Animal fats (NRA)
PLO5	Area B (Late 6th-5th centuries BCE)	Archaic basin (8th-6th centuries BCE)	HTGC	0.2					
PLO6	Area B (Late 6th-5th centuries BCE)	Handmade pot (8th-5th centuries BCE?)	HTGC GC-MS (SIM) GC-C-IRMS	67	SFA C14-18; UsFA C18:1; DAGs; TAGs	-28.2	-30.2	-2	Animal fats (RA)
PLO7	Area B (Late 6th-5th centuries BCE)	Bottom of a basin	HTGC GC-MS (SIM) GC-C-IRMS	17	SFA C16, 18; UsFA C18:1	-25.5	- 24.8	0.7	Animal fats? Oil?
PLO8	Area B (Late 6th-5th centuries BCE)	P2 pot (7th-6th centuries BCE)	HTGC	3					
PLO9	Area B (Late 6th-5th centuries BCE)	BA3 basin (7th-6th centuries BCE)	HTGC	0					
PLO10	Area B (Late 6th-5th centuries BCE)	P5 pot (5th century)	HTGC	1.4					

PLO11	PLO12	PLO13	PLO14	PLO15	PLO16	PLO17	PLO18	PLO19	PLO20	PLO21	PLO22
Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)
Handmade pot (8th-5th centuries BCE?)	Bottom of a basin	Baking tray (8th-6th centuries BCE?)	Basin with carinated rim	Bottom of a basin	Baking tray (8th-6th centuries BCE?)	Handmade pot (8th-5th centuries BCE?)	P2 pot (7th-6th centuries BCE)	Wheelmade pot, bottom	Handmade pot (8th-5th centuries BCE?)	Handmade pot (8th-5th centuries BCE?)	Handmade pot (8th-5th centuries BCE?)
HTGC GC-MS (SIM) HTGC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
81	3	1	8.4	0	0	0	6	64	2	0.6	11.
SFA C14-19, 24. 26, 28, 32, 34; UsFA C16:1, 18:1; AL 24, 26, 28, 30, 32, 34; alkanes; WE 40-50; TAGs C50-54								SFA C16-18; UsFA C18:1			SFA C16, C18
-25.1								-26.9			-27.3
-28.7								-28.7			-29.9
-3.6								-1.8			-2.6
Beeswax; animal fats			Contaminatio n?					Animal fats (RA)			Animal fats (RA)

PLO23	PLO24	PLO25	PLO26	PLO27	PLO28	PLO29	PLO30	PLO31	PLO32	PLO33	PLO34
Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)
Tannur (5^{th} century BCE?)	" S profile" pot (8^{th}-6^{th} centuries BCE)	Handmade pot (8^{th}-5^{th} centuries BCE?)	BA3 basin (7^{th}-6^{th} centuries BCE)	BA2 basin (7^{th}-6^{th} century BCE)	BA3 basin (7^{th}-6^{th} centuries BCE)	Basin with carinated rim	" S profile" pot (8^{th}-6^{th} centuries BCE)	BA3 basin (7^{th}-6^{th} centuries BCE)	BA3 basin (7^{th}-6^{th} centuries BCE)	BA2 basin (7^{th}-6^{th} centuries BCE)	Handmade pot (8^{th}-5^{th} centuries BCE?)
HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
0.3	0	1.5	0.8	0.2	1	6.5	3	3.5	3	2	137
						SFA C16, C18					SFA C15-18; UsFA C18:1
											-26.9
											-28.6
											-1.7
						Animal fats					Animal fats (RA)

PLO35	PLO36	PLO37	PLO38	PLO39	PLO40	PLO41	PLO42	PLO43	PLO44	PLO45	PLO46
Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)	Area B (Late 6th-5th centuries BCE)
BA9 basin (6th-5th centuries BCE)	Handmade pot (8th-5th centuries BCE?)	Handmade pot (8th-5th centuries BCE?)	Wheelmade pot	P2 pot (7th-6th centuries BCE)	P2 pot (6th century BCE)	BA2 basin (7th-6th centuries BCE)	Baking tray (8th-6th centuries BCE?)	P5 pot (5th century BCE)	Handmade pot (8th-5th centuries BCE?)	Handmade pot (8th-5th centuries BCE?)	BA3 basin (7th-6th centuries BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC
0.4	49	19	0.4	0.7	7	2	0.5	25.5	269.5	5	2
	SFA C15-18; UsFA C18:1	SFA C15-18; UsFA C18:1			SFA C16, 18; UsFA C18:1; DAGs C32-36; TAGs C48-54; phtalate			SFA C15-18; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C15-18; UsFA C18:1; Long-chain SFA; DAGs C32-36; TAGs C48-54	SFA C16, C18	
	-27.7	-27.8							-28.0		
	-30.3	-30.2							-30.5		
	-2.6	-2.4							-2.5		
	Animal fats (RA)	Animal fats (RA)			Animal fats? Contaminatio n?			Animal fats	Animal fats (RA)	Animal fats	

PLO47	PLO48	PLO49	PLO50	PLO51	PLO52	PLO53
Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)	Area B (Late 6^{th}-5^{th} centuries BCE)
P2 pot (7^{th}-6^{th} centuries BCE)	Handmade pot (8^{th}-5^{th} centuries BCE?)	" S profile" pot (8^{th}-6^{th} centuries BCE)	Handmade pot (8^{th}-5^{th} centuries BCE?)	BA6 basin (8^{th}-7^{th} centuries BCE)	Tannur (5^{th} century BCE?)	P5 pot (5^{th} century BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) HTGC-MS	HTGC	HTGC	HTGC
0.5	566	13	112	60	0	6
	SFA C14-20; UsFA C 18:1; AL C20 to 32 (even-numbered); WEs C42-50	SFA C16, 18	SFA C14-20, 22, 24; UsFA C16:1, 18:1; AL C24-32 (even-numbered); DAGs; WEs C40-50; TAGs C48-56	SFA C16, 18; AL C24-32; Alkanes C29, 31; MAGs C16:0; C18:0; DAGs C32-36; WEs C42-50; TAGs C48-56		SFA C16, C18
	-27.0	-27.4				
	-29.0	-28.9				
	-2	-1.5				
	Animal fats; beeswax?	Animal fats (RA)	Animal fats (ruminant?); beeswax	Beeswax; animal fats?		

Table III. Sherds investigated from Nora, analyses undertaken and main results.

Sample name	NRBS1	NRBS2	NRBS3	NRBS4	NRBS5	NRBS6	NRBS7	NRBS8	NRBS9	NRBS10
Vessel category-type (chronology)	P1 pot (7th-first half 6th centuries BCE)	P2 pot (Second half 7th century BCE)	P2 pot (Second half 7th century BCE)	P2 pot (Second half 7th century BCE)	P2 pot (end 7th -6th centuries BCE)	P2 pot (end 7th -6th centuries BCE)	P2 pot (Second half 6th century BCE)	P2 pot (End 6th-5th centuries BCE)	P2 pot (End 6th-5th centuries BCE)	P3 pot (5th-4th centuries BCE)
Context (chronology)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)
Analyses undertaken	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC HTGC-MS
Lipid concentration (µg/g)	56	2	10	27	7	4	15	35	15	35
Identified compounds	SFA C12:0, 14:0, 16-18:0; UsFA C16:1, C18:1; AL C16:0; Ketones C31, 33, 35; phthalates		Phthalates, squalene, alcohols	SFA C12:0 to C18:0; UsFA C18:1; AL C18:0; Alkanes C25-29?; Ketones C31, 33, 35; phthalates			SFA C12, 14-18; UsFA C16:1, 18:1; AL C16-24 (even numbered); phthalates; squalene; TAGs C50-54	SFA C16, 18; UsFA C18:1	SFA C16:0, C18:0; Unidentified	SFA C14,16,18; UsFA C16:1, C18:1; AL C28, 30; Dehydroabietic acid; alkanes; WEs C44-50; DAGs C 32-36; TAGs C48-54
$\delta^{13}C_{16:0}$ (‰)	-27.6									
$\delta^{13}C_{18:0}$ (‰)	-29.5									
$\Delta^{13}C$ (‰)	-1.9									
Lipid characterisation	Animal fats (heated over 300°C)		Contaminants	Animal fats (heated over 300°C). Dairy fats or contamination?				Animal fats	Animal fats? Contamination?	Animal fats; beeswax

NRBS11	NRBS12	NRBS13	NRBS14	NRBS15	NRBS16	NRBS17	NRBS18	NRBS19	NRBS20	NRBS21	NRBS22
P5 pot (5th-4th centuries BCE)	Tripod bowl (7th century BCE)	Tripod bowl (7th-6th centuries BCE)	Tripod bowl (7th-6th centuries BCE)	BA1 basin (First half 6th century BCE)	BA1 basin (7th-first half 6th centuries BCE)	BA2 basin (7th century BCE)	BA2 basin (7th century BCE)	BA3 basin (4th-3rd centuries BCE)	BA5 basin (7th-6th centuries BCE)	BA6 basin (7th-6th centuries BCE)	BA6 basin (8th-7th centuries BCE)
Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (Late Roman/Early medieval)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (Late Roman/Early medieval)
HTGC	HTGC GC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC HTGC-MS
24.5	10	1.3	3	1	3	3	1	7	2	5	14.6
SFA C12, 14-18; UsFA C16:1, 18:1; AL C16-24 (even numbered); phthalates; squalene	SFA C12, 14-18; UsFA C16:1, 18:1; AL C16-24 (even numbered); phthalates; squalene									SFA C16:0, C18:0; UsFA C18:1; phtalate	SFA C16:0, C18:0; UsFA C16:1, 18:1; squalene; AL C28-34 (even numbered); WEs C46-50
										Animal fats; contaminants	Beeswax (contamination?)

NRBS23	NRBS24	NRBS25	NRBS26	NRBS27	NRBS28	NRBS29	NRBS30	NRBS31	NRBS32	NRBS33	NRBS34
BA3 basin (Second half 7th-6th centuries BCE)	BA3 basin (Second half 7th-6th centuries BCE)	BA8 basin (4th-2nd centuries BCE)	BA8 basin (4th-2nd centuries BCE)	BA13 basin (7th-5th centuries BCE)	Casserole (4th- 3rd centuries BCE)	Casserole (First half 5th century BCE)	Casserole (End 5th-first half 4th centuries BCE)	" S profile" pot (8th-6th centuries BCE?)	" S profile" pot (8th th-6thth centuries BCE?)	Baking tray (8th-5th centuries BCE?)	Handmade pot (7th -6th centuries BCE?)
Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (7th century BCE)
HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS	HTGC GC-MS (SIM) HTGC-MS GC-C-IRMS	HTGC	HTGC
1.4	0.2	5	2	1	5.5	8	5	30	752	6	29
						SFA C12-C18; UsFA C18:1; AL C18, phtalates		SFA C14, 15, 16, 18; AL C16, C18; phtalates	SFA C15-18; DAGs C32-36; TAGs C48-54		SFA C16, 18; UsFA C18:1; AL 16, 18; other unidentified compounds
									-26.7		
									-28.6		
									-1.9		
						Animal fats; plastifiers		Animal fats; plastifiers	Animal fats (RA)		

NRBS35	NRBS37	NRBS38	NRBS39	NRBS40	NRBS41	NRBS42	NRBS43	NRBS44	NRBS45	NRBS46	NRBS47
Baking tray (8th-5th centuries BCE?)	Tannur (5th - 2nd centuries BCE?)	Tannur (5th - 2nd centuries BCE?)	Tannur (5th - 2nd centuries BCE?)	Tannur (5thth- 2ndnd centuries BCE?)	Tannur (5th - 2nd centuries BCE?)	Tannur (5th - 2nd centuries BCE)	P2 (End 7th- first half 6th centuries BCE)	P3 pot (5th-4th centuries BCE)	P3 pot (5th-4th centuries BCE)	P6 pot (3rd- 2nd centuries BCE)	P6 pot (3rd - 2nd centuries BCE)
Roman Forum – Area P (7th century BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (Modern age)	Roman Forum – Area P (Modern age)	Roman Forum – Area P (Modern age)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)
HTGC GC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC HTGC-MS	HTGC	HTGC
20	0.7	1.8	4	3	1.3	0.2	6	15	12	2	4.5
SFA C12-24; UsFA C16:1, C18:1; AL C16, C18; TAGs C27, 29, 31			Phtalates				SFA C16, 18; phtalates	SFA C15, 16, 18; UsFA C18:1; alcohols; WE C44-50, TAGs C50-56	SFA C15, 16, 18; UsFA C18:1; AL C28, 30, 32; WE C44-50; DAGs C32-36; TAGs C50-56		
Animal fats? Contaminatio n?								Beeswax (or plant waxes?) and animal fats.?	Beeswax and animal fat.s		

NRBS48	NRBS49	NRBS50	NRBS51	NRBS52	NRBS53	NRBS54	NRBS55	NRBS56	NRBS57	NRBS58	NRBS60
P6 pot (3rd-2nd centuries BCE)	P6 pot (3rd centuries BCE)	P6 pot (3rd centuries BCE)	P8 pot (4th-2nd centuries BCE)	P8 pot (4th-2nd centuries BCE)	P8 pot (4th-2nd centuries BCE)	P9 pot (3rdrd-2ndnd centuries BCE)	P9 pot (3rdrd-2ndnd centuries BCE)	P9 pot (3rdrd-2ndnd centuries BCE)	Casserole (4th century BCE)	Casserole (First half 5th centuries BCE)	Casserole (3rd-2nd centuries BCE)
Roman Forum – Area P (3rd-5th centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (5th century BCE)	Roman Forum – Area P (3rd-5th centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (2nd-1st centuries BCE)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (Late Roman/Early medieval)
HTGC	HTGC GC-MS	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
13	28	2	11	8	9	9	3	9	2	2	9
SFA C15, 16, 18; abundant squalene and cholesterol; TAGs C50-54	SFA C14-18, C20, 22, 24; UsFA C18:1; Alkanes C25, 27, 29, 31; AL C24-32		SFA C16, 18; phthalates, alcohols	SFA C16, 18; phthalates; AL C18, 20, 24	SFA C16, 18	SFA C16, 18, other unidentified compounds		SFA C16, 18; phthalates, alcohols			SFA C15, 16, 18; UsFA C18:1; TAGs C48-54
Contamination?	Animal fats; plant lipids (leafy plants?)		Contamination?	Contamination?	Animal fatts; Contamination?			Contamination?			Animal fats? Oil?

NRBS61	NRBS62	NRBS63	NRBS65	NRBS66	NRB67	NRBS68	NRBS69	NRBS70	NRBS71	NRBS72	NRBS73
BA1 basin (7th-first half 6th centuries BCE)	BA2 basin (7th-6th centuries BCE)	BA 6 (8th -7th centuries BCE)	BA7 basin (4th century BCE)	BA7 basin (4th century BCE)	BA8 basin (4th -3rd centuries BCE)	BA9 basin (4th -3rd centuries BCE)	BA9 basin (4th -3rd centuries BCE)	BA11 basin (3rd-2nd centuries BCE)	BA11 basin (3rd-2nd centuries BCE)	BA15 basin (4th century BCE)	Tripod bowl (7th-first 6th centuries BCE)
Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (3rd-5th centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)	Roman Forum – Area P (1st-2nd centuries AD)
HTGC	HTGC	HTGC HTGC-MS	HTGC	HTGC GC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
2	3.6	42.5	6	14	2	7	4.8	4.6	2	4	20
		SFA C16, 18; UsFA C16:1, 18:1; AL C18, 24, 26, 28, 30, 32, 34; Alkanes C27, 29, 31; WEs C42-50; TAG C48		SFA C14, 15, 16, 18; UsFA C16:1, C18:1; AL C18; phtalates							SFA C14, 16, 18; phtalates; squalene
		Beeswax; plants?		Oil? Contaminatio n?							Animal fats? Contaminatio n?

NRBS74	NRBS75	NRBS76	NRBS77	NRBS78	NRBS79	NRBS80	NRBS81
Tripod bowl (7^{th}-first 6^{th} centuries BCE)	Tripod bowl (7^{th}-first 6^{th} centuries BCE)	" S profile" pot (8^{th}-6^{th} centuries BCE?)	" S profile" pot (8^{th}-6^{th} centuries BCE?)	Handmade pot (8^{th}-5^{th} centuries BCE?)	" S profile" pot (8^{th} -6^{th} centuries BCE?)	" S profile" pot (8^{th}-6^{th} centuries BCE?)	Baking tray (8^{th}-6^{th} centuries BCE)
Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (4th-2nd centuries BCE)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)	Roman Forum – Area P (1^{st}-2^{nd} centuries AD)
HTGC	HTGC	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS
4	1.5	10	306	8	158	158	22
		SFA C12-18; UsFA C16:1, C18:1; AL C14,18, 20; phtalate	SFA; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C14-18; UsFA C16:1, C18;1; AL C16, 18, 20	SFA C14-18; UsFA C18:1	SFA C12-20, 22; UsFA C18:1; Alkanes C17, 18.	SFA C12-18; UsFA C16:1, C18:1; AL C14, 16, 18, 20; Alkane C20; phtalates; squalene
			-27.3		-25.6	-27.6	
			-28.7		-28.7	-29.8	
			-1.4		-3.1	-2.2	
		Oil? Contaminatio n?	Animal fat s (RA)	Animal fats; other commodities plant lipids?	Animal fats (RA)	Animal fats (RA)	Plant lipids?s; contaminatio n?

Table IV. Sherds investigated from Olbia, analyses undertaken and main results.

Sample name	OLB1	OLB2	OLB3	OLB4	OLB5	OLB6	OLB7	OLB10	OM1	OM2
Vessel category-type	Baking tray	Handmade pot	Wheelmade pot, bottom	Wheelmade pot	Corynthian basin (7th century BCE)	Corynthian basin (7th century BCE)	Clay matrix	Corynthian amphora	Basin	Wheelmade pot
Context (chronology)	Via de Filippi (3rd-2nd centuries BCE)	Via de Filippi (3rd-2nd centuries BCE)	Via de Filippi (3rd-2nd centuries BCE)	Via Cavour (7th-6th centuries BCE)	Via Cavour (7th-6th centuries BCE)	Via Cavour (7th-6th centuries BCE)	Via de Filippi (4th century BCE)	Via Cavour (7th-6th centuries BCE)	Ex Mercato (3rd century BCE)	Ex Mercato (2ndnd century BCE)
Analyses undertaken	HTGC HTGC-MS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
Lipid concentration (µg/g)	35	14	111	1	0.6	6.5	7.7	16	4.8	26
Identified compounds	SFA C14-18, 20; UsFA C18:1; Dehydroabietic acid; AL C24-32 (even-numbered); WEs C42-48; TAGs C50-54.	Unidentified	SFA C14-18, 20, 22, 24; UsFA C18:1; DAGs C32-36; TAGs C48-54; other unidentifies compounds			SFA C14, 15, 16, 18, 20; UsFA C16:1, C18:1; AL C24; alkanes C27, 29	SFA C16-C18; squalene	SFA C16, 18, 20, 24; UsFA C16:1, C18:1; Alkanes C17-19; AL C12, C24-32 (even numbered); WEs C42-50		SFA C14-18, 20, 24; UsFA C18:1; DAGs C32-36; TAGs C48-54
$\delta^{13}C_{16:0}$ (‰)			-26.7							-28.1
$\delta^{13}C_{18:0}$ (‰)			-29.8							-30.0
$\Delta^{13}C$ (‰)			-3.1							-1.9
Lipid characterisation	Animal fats (ruminant?); beeswax		Animal fats? Oil?			Animal fats and plant lipids (oil)?	Contamination?	Beeswax; plant lipids (oil?)		Animal fats (RA)

OM3	OM4	OM5	OM6	OM7	OM8	OM9	OM10	OM11	OM12	OM13	OM14
P6 pot	" Ear" pot (handmade)	P6 pot	P6 pot	Pot	Casserole	Wheelmade pot	Wheelmade pot, bottom	Wheelmade pot	Wheelmade pot	Casserole	Basin
Ex Mercato (2nd century BCE)	Ex Mercato (4^{th}-3^{rd} centuries BCE)	Ex Mercato (4^{th}-3^{rd} centuries BCE)	Ex Mercato (4^{th}-3^{rd} centuries BCE)	Ex Mercato (4^{th}-3^{rd} centuries BCE)	Ex Mercato (2^{nd} century BCE)	Ex Mercato (2^{nd} century BCE)	Ex Mercato (2^{nd} century BCE)	Ex Mercato (2^{nd} century BCE)	Ex Mercato (2^{nd} century BCE)	(ex Mercato) 2^{nd} century BCE	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)
HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC
1.3	0.3	0.8	5	0.4	0.5	0.5	351	4.7	16	0.5	2
							SFA C14-18; UsFA C18:1; DAGs C32-36; TAGs C48-54.		SFA C14-18; DAGs C32-36; TAGs C46-54		
									-26.7		
									-28.8		
									-2.1		
							Animal fats (ruminant?)		Animal fats (RA)		

OM15	OM16	OM17	OM18	OM19	OM20	OM21	OM22	OM23	OM24	OM25	OM27
Wheelmade pot	Wheelmade pot	Basin	P6 pot	Casserole	P6 pot	Basin	Basin	Wheelmade pot	Wheelmade pot	Wheelmade pot	Basin
ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)	ex Mercato (3^{rd}rd century BCE)	ex Mercato (3^{rd}rd century BCE)	ex Mercato (3^{rd}rd century BCE)	ex Mercato (End 3^{rd}-turn of 2^{nd} centuries BCE)	ex Mercato (End 3^{rd}-turn of 2^{nd} centuries BCE)	ex Mercato (End 4^{th} – turn of 3^{rd} centuries BCE)
HTGC GC-MS (SIM) GC-C-IRMS	HTGC GC-MS	HTGC	HTGC HTGC-MS	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS	HTGC	HTGC	HTGC
165	9.79	1.8	9	2	2	1.5	1.3	38	0.7	7	0.4
SFA C14, 16, 18; UsFA C18:1; DAGs C32-36; TAGs C48-54	SFA C14, 15, 14, 18, 20, 22, 26; UsFA C18:1; MAG C18:0		SFA C16, 18; WEs C42-50; DAGs C34-36; TAGs C48-54					SFA C14-18, 20, 22, 24; squalene; other unidentified compounds			
-25.6											
-25.4											
0.2											
Animal fats (NRA, mixed RA?)	Animal fats		Animal fats and degraded beeswax? Or plant waxes?					Contaminant s?			

OM28	OM29	OM30	OM31	OM32	OM33	OM34	OM35	OM36	OM37	OM38	OM39
Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	" Ear" pot, handmade	" Ear" pot, handmade	" Ear" pot, handmade	" Ear" pot, handmade	Greek style pot (chytra)	Basin	" S profile" pot?	Casserole
ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	(ex Mercato) First half 3rdrd century BCE	(ex Mercato) 2ndnd century BCE	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (2ndnd century BCE)
HTGC	HTGC GC-MS (SIM) HTGC-MS	HTGC	HTGC GC-MS	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
2.4	34	2	6	0.6	10	3	6.5	2	0.3	0	0
	SFA C14-19, 20, 22, 24; UsFA C16:1, C18:1; AL C26-32 (even-numbered); dehydroabietic acid; WEs C44-50		SFA C15, 16, 18; UsFA C16:1, 18:1; phthalate; squalene; TAGs C48-52		SFA C16, C18; UsFA C18:1; TAGs C48-54						
	-26.8				-27.1						
	-28.6				-28.9						
	-1.8				-1.8						
	Animal fats (ruminant?); beeswax; resins?		Animal fats? Contamination?		Animal fats (RA)						

OM40	OM41	OM42	OM43	OM44	OM45	OM46	OM47	OM48	OM49	OM50	OM51
“ Ear” pot, handmade	Jug	“ Ear” pot, handmade	Casserole	Wheelmade pot	Wheelmade pot	Wheelmade pot	“ Ear” pot, handmade	Wheelmade pot	Casserole	Wheelmade pot	Wheelmade pot
ex Mercato (2^{nd} century BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)	ex Mercato (End 4^{th}-3^{rd} centuries BCE)
HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC GC-MS (SIM) HTGC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS	HTGC
36	2.8	65	4	4.5	6	0.5	0	2	0	15	0
SFA C14-18, 22, 24; UsFA C18:1; AL C24-32 (even-numbered); alkanes C27, 29, 31; WEs C44-50; TAGs C48-54		SFA C14, 16-18, 20, 24; UsFA C18:1; Alkanes C27, 29, 31; AL 26-32 (even-numbered); WEs C42-50; TAGs C48-54			SFA C16, C 18; UsFA C18:1					SFA C14-20, 22-24, 26, 28, 30, 32; UsFA C16:1, C18:1; Alkanes C27, 29, 31; AL C26-34 (even numbered); WEs C44-50	
-27.0											
-28.1											
-1.1											
Animal fats (ruminant?); beeswax		Animal fats; beeswax								Leafy plants Beeswax?	

OM52	OM53	OM54	OM55	OM56	OM57	OM58	OM59	OM60	OM61	OM62	OM63
Casserole	Wheelmade pot	Casserole	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Basin	Wheelmade pot
ex Mercato (End 4th-3rd centuries BCE)	ex Mercato (End 4th-3rd centuries BCE)	ex Mercato (End 4th-3rd centuries BCE)	ex Mercato (End 4th-3rd centuries BCE)	ex Mercato (End 4th-3rd centuries BCE)	ex Mercato (End 4th-2nd centuries BCE)	ex Mercato (End 4th-2nd centuries BCE)	ex Mercato (End 4th-2nd centuries BCE)	ex Mercato (3rd-2nd centuries BCE)	ex Mercato (3rd-2nd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
0	9	0	0	0	1.8	0	0	0	1.8	0	0
	SFA C16, C18; DAGs C32-36; TAGs C48-54										
	-27.2										
	-29.2										
	-2										
	Animal fats (RA)										

OM64	OM65	OM66	OM67	OM68	OM69	OM70	OM71	OM72	OM73	OM74	OM75
Basin	Wheelmade pot	Dish	Wheelmade pot	Casserole	Casserole	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot
ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)
HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC
0	156	0	0	0	0	2	4.2	0	24	0	0
	SFA C16, C18; UsFA C18:1								SFA C16, C18; UsFA C18:1		
	-26.2								-27.3		
	-26.8								-28.8		
	-0.6								-1.5		
	Animal fats (RA, mixed NRA?)								Animal fats (RA)		

OM76	OM77	OM78	OM79	OM80	OM81
Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot	Wheelmade pot
ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)	ex Mercato (End 4th – turn of 3rd centuries BCE)
HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC
0	0	0	0.6	10	0
				SFA C16, C18; DAGs C32-36; TAGs C48-54	
				-27.4	
				-29.4	
				-2	
				Animal fats (RA)	

Table V. Sherds investigated from Sant'Antioco, analyses undertaken and main results.

Sample name	SAC1	SAC17	SAC29	SAC30	SAC31	SAC32	SAC33	SAC34	SAC35	SAC46
Vessel category-type	Baking tray	" S profile" pot	Casserole	Casserole	Casserole	Casserole	Casserole	Casserole	Casserole	P2 pot
Typological chronology	7^{th}-5^{th} centuries BCE?	7^{th}-5^{th} centuries BCE?	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	6^{th} century BCE
Context (chronology)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)
Analyses undertaken	HTGC HTGC-MS	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC HTGC-MS
Lipid concentration (µg/g)	31	587.5	23	48	6	1	13	9	6	43
Identified compounds	SFA C14-18; UsFA C16:1, C18:1; even numbered AL C14-24; phthalates; squalene	SFA C14-18; UsFA C16:1, C18:1; phthalates			SFA C16, 18; phthalate		SFA C14-18; UsFA C18:1; phthalates; DAGs C32-36; TAGs C48-54.	SFA C16, 18; phtalate	SFA C14, 16, 18; UsFA C18:1	SFA C14-16, 18, 24; UsFA C18:1; AL C18, 24, 26, 30, 32, 34; phthalates; alkanes C27, 29, 31; WEs C40-50; TAGs C48-52
Lipid characterisation	Animal fats and plant lipids? Contamination?	Animal fats (ruminant?)	Contaminants?	Contaminants?			Animal fats (ruminant?)		Animal fats	Animal fats, beeswax.

SAC50	SAC51	SAC54	SAC55	SAC57	SAC58	SAC63A	SAC63B	SAC66A	SAC66B	SAC72	SAC73
Basin BA6	Basin BA7	Basin BA7	Basin BA6	Basin BA7	Basin BA7	P5 pot, rim	P5 pot, bottom	P5 pot, rim	P5 pot, bottom	P6 pot	P5 pot
7^{th}-6^{th} centuries BCE	6^{th}-5^{th} century BCE	5^{th} century BCE	7^{th}-6^{th} centuries BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	5^{th} century BCE	Late 5^{th} century BCE?	5^{th} century BCE
SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)	SU 500 (5^{th} century BCE)
HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
3	4	3.5	2.7	4.8	1.3	9	10	14.5	16	25.5	2.5
						SFA C14, 16, 18; UsFA C18:1; phtalate	SFA C14, 16, 18; UsFA C18:1; phtalate	SFA C14-18; UsFA C16:1, C18:1, AL C16, 18; phthalate; DAGs C32-36; TAGs C48-54.	SFA C12, 14-18; UsFA C16:1, C18:1, AL C16, 18; phthalate; cholesterol; DAGs C32-36; TAGs C48-54.	SFA C14-18: UsFA C16:1, C18:1; phthalates	
						Animal fats	Animal fats	Animal fats (ruminant?); plant lipids?	Animal fats (ruminant?); plant lipids?	Animal fats (ruminant?)	

SAC75	SAC76	SAC77	SAC78	SAC79	SAC85A	SAC85B	SAC89
P5 pot	P5 pot	P5 pot	P5 pot	P5 pot	P5 pot, rim	P5 pot, bottom	P5 pot
5th century BCE	5th century BCE	5th century BCE	5th century BCE	5th century BCE	5th century BCE	5th century BCE	5th century BCE
SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)	SU 500 (5th century BCE)
HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC
4	113.3	9	4.5	11	6	8	4.8
	SFA C14-18; UsFA C18:1; phthalates	SFA C14-16, 18; UsFA C18:1; phthalate		SFA C14-16, 18; UsFA C16:1, 18:1; DAGs C32-36; TAGs C48-54.	SFA C14-16, 18; UsFA C16:1, C18:1; AL C14, 16, 18; phthalates, squalene, cholesterol.	SFA C14-16, 18; UsFA C16:1, C18:1; AL C14, 16, 18; phthalates, squalene, cholesterol.	
	Animal fats (ruminant?)	Animal fats		Animal fats	Animal fats; contaminatio n? and plant lipids	Animal fats; contaminatio n? and plant lipids	

Table VI. Sherds investigated from Genuri – San Marco, analyses undertaken and main results.

Sample name	GSM1	GSM2	GSM3	GSM4	GSM5	GSM7	GSM8	GSM9	GSM10	GSM11
Vessel category-type	Basin	Basin	Basin	Basin	Basin	Handmade pot	Casserole	Wheelmade pot	Basin	Wheelmade pot
Context (chronology)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)
Analyses undertaken	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS
Lipid concentration (µg/g)	6	1	2	1	1	33	168.5	1.4	0.5	33
Identified compounds						SFA C14-20; UsFA C18:1	SFA C14-20; UsFA C18:1			SFA C12-22; AL C18, 20, 24, 26
$\delta^{13}C_{16:0}$ (‰)							-25.6			-26.6
$\delta^{13}C_{18:0}$ (‰)							-25.8			-28.6
$\Delta^{13}C$ (‰)							-0.2			-2.0
Lipid characterisation	Contaminants?					Animal fat (ruminant?)	Animal fat (NRA)			Animal fat (RA)

GSM12	GSM13	GSM14	GSM15	GSM16	GSM18	GSM19	GSM20	GSM21	GSM22	GSM23	GSM25
Handmade pot	Handmade pot	Handmade pot	Handmade pot	Basin	Handmade pot	Handmade pot	Wheelmade pot	Wheelmade pot	Handmade pot	Basin	Handmade pot
Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)	Nuraghe San Marco (4^{th}-3^{rd} centuries BCE)
HTGC	HTGC	HTGC	HTGC GC-MS (SIM) GC-C-IRMS	HTGC	HTGC	HTGC	HTGC HTGC-MS GC-MS (SIM)	HTGC	HTGC	HTGC	HTGC
1	17	0.3	39.5	0.4	7	46	114	3	1.7	1	0.7
			SFA C14-18; UsFA C18:1; DAGs C32-36; TAGs C48-54.			SFA C14-18; UsFA C18:1; TAGs C48-54	SFA C14-22, 24, 26, 28; UsFA C16:1, C18:1; AL C26-34 (even numbered); Alkanes C27, 29, 31; WEs C42-50; TAGs C48-56				
			-28.5								
			-32.1								
			-3.6								
			Animal fat (RD)			Animal fats (ruminant?)	Animal fats (ruminant?); beeswax				

GSM26	GSM27	GSM28	GSM29	GSM30
Wheelmade pot	Handmade pot	Handmade pot	Handmade pot	Handmade pot
Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)	Nuraghe San Marco (4th-3rd centuries BCE)
HTGC	HTGC	HTGC GC-MS (SIM) HTGC-MS	HTGC	HTGC
1	0.3	32	20	3.6
		SFA C14, 16-18, 20, 22, 24; UsFA C18:1; AL C14, 26, 28; Alkanes C27, 29; DAGs C32-36; WEs C42-48.	SFA C14, 16-18; UsFA C18:1; DAGs C32-36; TAGs C48-54	
		Animal fats; beeswax?	Animal fat (ruminant?)	