

Macrobotanical remains and shell-midden formation processes, are they related? The case of Poças de São Bento (Portugal)

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Abstract The analysis of plant macroremains from Poças de São Bento, a shell-midden in the Sado Valley (Portugal), has provided interesting insights into the shell-midden formation processes and the presence of resources which are often “invisible” in this kind of sites. Preservation and representation issues are discussed in a bidirectional way. Potential complementary explanations for the presence of such plant remains in hunter-gatherer open-air sites are offered. The understanding of plant exploitation patterns by these last hunter-gatherers in Portugal is crucial for the comprehension of the multifaceted phenomena of Neolithisations, in this case, characterised by a long availability phase and ultimate adoption of domesticates.

Keywords Mesolithic · Neolithisation · Archaeobotany · Hunter-gatherers · Taphonomy

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Introduction

In the European Atlantic façade, the introduction of domesticated species is an apparently late, heterogeneous and complex matter, partly due to the persistence of many foraging societies well after the introduction of agricultural technology into neighbouring regions (Arias 2007). In the Atlantic coast of the Iberian Peninsula, in Portugal in South-Western Europe, the phenomenon is further complicated by the absence of coherent multidisciplinary data (Cruz Berrocal 2012). Moreover, because of the limitations imposed by the taphonomy of the contexts and the uncertainties concerning the dated samples, a great part of the available radiocarbon chronology should be regarded with caution (Carvalho 2010). According to the current evidence, the most likely explanation for the introduction of domesticated species is the arrival by sea (e.g. Martins et al. 2015; Zilhão 2011). However, the acceptance of this premise of the model does not necessarily confirm the colonisation of inhabited areas (probably not really uninhabited after all, see Berger and Guilaine 2009) by Neolithic immigrants nor exclude the adoption of domesticated species by the Mesolithic populations, either done readily or gradually (e.g. Dean, Valente and Carvalho 2012; Jackes, Lubell and Meiklejohn 1997; Jorge 2000). Indeed, the latest genetical evidence seems to argue in favour of an integration of a small group of people in the Neolithic with previously existing populations of a Palaeolithic/Mesolithic origin (Santos et al. 2014 against Chandler, Sykes and Zilhão 2005 and Lalueza Fox 1996). Single explanatory and linear models are being criticised, and regional mosaics of distinct processes are being identified (Cruz Berrocal 2012). The earliest littoral Neolithic sites in Portugal with domesticated species occur in the sixth millennium cal BCE (Carvalho 2010; López-Dóriga and Simões 2015), contemporary to the Late Mesolithic occupation of estuarine regions with shell-midden sites. Therefore, it is a

necessary step to characterise these latest hunter-gatherer societies in the area in order to be able to get a further understanding of the events occurring in the sixth millennium cal BCE. The study of shell-middens in Europe to better understand the Mesolithic-Neolithic transition is a well-trodden topic of research (Álvarez et al. 2011). Although shell-midden research has a long tradition and a methodological renovation is being brought forwards (Álvarez et al. 2011; Balbo et al. 2011), plant remains play a minor role or are rarely even mentioned. This is a relatively common weakness in studies about hunter-gatherer sites in general, despite the major role plant resources must have played (Antolín, Beriñuete and López 2016). It was the purpose of this research to bring plant macroremains, often unsearched or/and unfound, to the arena, as they have scarcely been permitted to play any role in this discussion before.

During the Mesolithic, human population in Central and South Portugal seems to move from the littorals and concentrate semisedentarily around big river estuaries (namely the Tagus-Muge, Sado and Mira, see Fig. 1) and the upper southern coast (littoral Alentejo), creating characteristic shell-middens which were deposited during a time lapse of about a millennium (Araújo 2009). Around 50 Mesolithic shell-middens, most of them in open-air sites, are known and many of them have been already excavated (Gutiérrez-Zugasti et al. 2011). Unfortunately, the panorama is blurred by the fact that a great amount of research was carried out in the earlier twentieth century, when records were not kept in ideal conditions. These sites are characterised by intense shell-food processing (possibly overvalued; Balbo et al. 2011) accompanied of other domestic and funerary activities which suggest certain degree of sedentism (Araújo 2015). The high intersite variability (resources exploited, size of the middens, presence of features, such as postholes or hearths) and the homogeneity of the material culture and funerary rites are usually interpreted in two divergent ways (Diniz and Arias 2012): as a single settlement system per estuary, with residential sites, seasonally but regularly occupied in alternating seasons (Arnaud 1985; Gutiérrez-Zugasti et al. 2011) or with different populations inhabiting different sites (Guiry, Hillier and Richards 2015; Umbelino et al. 2007). Dogs were the only domesticated animals, according to the abundant faunal studies carried out; however, no actual data existed regarding the presence or absence of plant domesticates. It has been a common assumption in Portuguese archaeology that charred plant remains are not preserved and archaeobotany is generally underdeveloped (Tereso et al. 2015). As a consequence, only a twice (one in the Sado and one in the Tagus-Muge area) sampling for plant remains has been carried out in shell-middens and results were negative (Larsson, pers. comm.) or remain unpublished (Wollstonecroft et al. 2006). Thus, the only evidence regarding the consumption of plant resources (other than wood, Monteiro 2013) was indirect and came from isotopic values

in bones (e.g. Guiry, Hillier and Richards 2015; Umbelino et al. 2007) which usually undervalue the importance of plant foods (Fraser et al. 2013). New research with innovative methodologies has been carried out recently in the area to overcome this shortcoming and bring plant resources into the discussion.

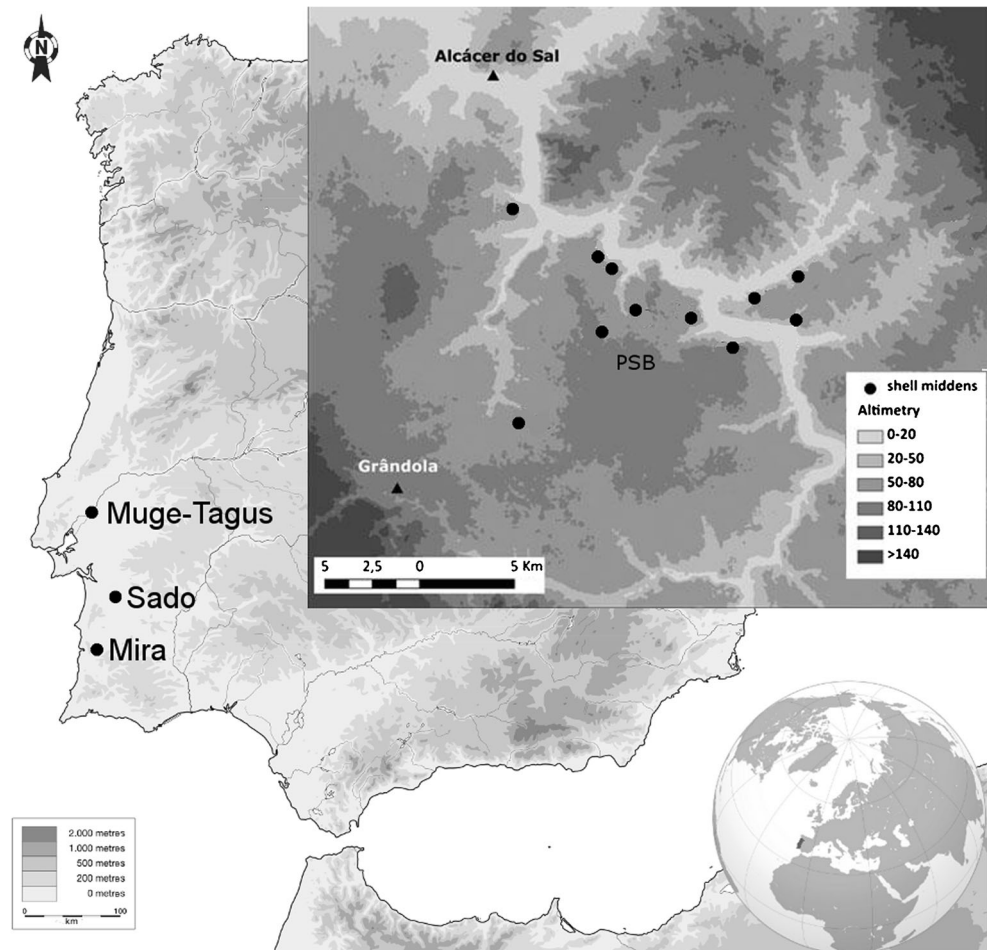
Materials and methods

The site

The site of Poças de São Bento (Fig. 1) was first excavated in the Late 1950s by Manuel Heleno (Machado 1964), the director of the National Museum of Archaeology at Lisbon. Later research included a test pit in 1986 and a partial excavation between 1987 and 1988, by a team lead by José Morais Arnaud, from the Portuguese Institute of Archaeology, and Lars Larsson, from Lund University in Sweden (Arnaud 1985; Arnaud 1989; Arnaud 1990; Arnaud and Larsson 1994; Arnaud 1993; Arnaud 2000; Larsson 1996; Larsson 2010). More recently, research digs have been carried out since 2010 within the framework of the Spanish-Portuguese project Sado-Meso, under the direction of Pablo Arias and Mariana Diniz from the universities of Cantabria (Spain) and Lisbon (Diniz and Arias 2012; Arias et al. 2016; Arias et al. 2015).

Poças de São Bento, with around 4000–3500 m², is the second largest shell-midden in the Sado valley shell-midden system (Arnaud 1989). It belongs to a cluster of 12 shell-middens, and, like the others, its height is not conspicuous, being at most 1.5 m. The juxtaposition of small depositional mounds, instead of the massive accumulation of detritus in the same mound (as occurs in the Muge-Tagus shell-middens) or the predominance of a type of shell, peppery furrow shell (*Scrobicularia plana*), over more bulky ones, such as common cockle (*Cerastoderma edule*), might be the reason(s) for this relatively small height (Arias, pers. comm.). Animal remains, mostly shell (Álvarez-Fernández et al. 2012), crustacean and marine fish remains (Gabriel, Diniz and Arias 2013), and also mammal bones were recovered. A small proportion of the bones were found to have been transformed into tools, and several perforated shells and fish vertebra were also identified. Lithic raw material was primarily local (Pimentel et al. 2015) and was transformed in situ into tools, including microliths (Araújo, Arias and Diniz 2015). Fire-cracked rocks, small concentrations of fire-altered shells and wood charcoal fragments served to identify several small hearths, and several possible postholes were tentatively identified at the base of the shell-midden (González Morales and Arnaud 1990; Arias et al. 2015). Under the and in the shell-midden layer, several burials were identified, which were concentrated in small groups (Stjerna 2015). A further occupation of Neolithic chronology, separated by a chronological hiatus,

Fig. 1 Location of the Tagus-Muge, Sado and Mira shell-middens in Portugal (*left*) and shell-middens in the Sado valley (*right*)



was identified in the upper layers above the shell-midden, with pottery sherds (Diniz and Cubas 2015) and pounding and milling stones.

Radiocarbon dates ascribe the formation of anthropical layers to the sixth and fifth millennia cal BCE (Table 1). Bones from different mammals and non-woody plant macroremains from the Mesolithic layers have been submitted for radiocarbon dating but, due to insufficient carbon or collagen, dating has failed.

Methods

Although flotation was carried out before our project, only a portion of the layers in the site were sampled and no plant macroremains were recovered (Larsson, pers. comm.). The studied flotation samples were obtained in the most recent excavations between 2010 and 2013 in trench 1 (Fig. 2), which have been excavated extensively (2 m² in 2010; 6 m² in 2011 of which 4.5 m² were shell-midden; 12 m² in 2012 and 2013) and have provided a lengthy and complex stratigraphy. Micromorphological analyses (Simões et al. 2015) complement the stratigraphical description of trench 1 (Araújo, Arias and Diniz 2015; Arias et al. 2016, Fig. 3).

An extensive sampling and retrieval strategy for plant macroremains have been carried out; 100 % of the non-superficial soil, excavated from 2010, has been collected in 10l samples and has been floated in a Siraf-type machine (Williams 1973), with a mesh of 250 µm for the recovery of the light fraction and a 1 mm mesh for the heavy fraction. A random subsample (Fig. 3; Table 2) of light flotation fractions, selected by pinch or grab strategy (Lennstrom and Hastorf 1995), has been chosen for this first stage of study and has been sorted with the aid of an optical magnification instrument (a Leica S8 APO stereomicroscope). The heavy fraction of each light fraction flotation sample has been also examined.

Results

Although not numerically rich, relatively diverse assemblages of plant macroremains have been recovered (Table 3; Fig. 4). A preliminary list of taxa (amended here) was published previously (López-Dóriga, Diniz and Arias 2015). The assemblage has been mostly obtained from light flotation fractions; flotation has been very effective at this particular site, as the heavy fractions have not produced new determinable plant

Table 1 Available radiocarbon dates

Lab. reference	Method	Context	Material	Confidence	BP date	$\delta^{13}\text{C}$ (AMS)	IRMS		cal BCE date (95.4 % probability)	Bibliography
							$\Delta^{13}\text{C}$	$\Delta^{15}\text{N}$		
OxA-29113	^{14}C AMS	SU 613	Bone (<i>Homo sapiens</i>)	Medium	7238 ± 35	?	-17.2	11.3	6211–6031	Unpublished
Lu-2769	^{14}C AMS	45–50 cm	Shells	Medium	7150 ± 70	?	–	–	6006–5653/5923–5281	Larsson (2010)
OxA-29114	^{14}C AMS	SU 403	Shell (<i>Scrobicularia plana</i>)	Medium	7121 ± 35	?	–	–	5960–5666/5874–5275	Unpublished
OxA-24652	^{14}C AMS	SU 3/7	Shell (<i>Cerastoderma edule</i>)	Medium	7107 ± 37	?	–	–	5951–5653/5861–5256	Unpublished
OxA-24648	^{14}C AMS	SU 3/7	Shell (<i>C. edule</i>)	Medium	7084 ± 36	?	–	–	5917–5627/5830–5225	Unpublished
OxA-24650	^{14}C AMS	SU 3/7	Shell (<i>C. edule</i>)	Medium	7070 ± 35	?	–	–	5901–5620/5817–5212	Unpublished
OxA-24651	^{14}C AMS	SU 3/7	Shell (<i>C. edule</i>)	Medium	7053 ± 37	?	–	–	5890–5610/5806–5200	Unpublished
OxA-24649	^{14}C AMS	SU 3/7	Shell (<i>C. edule</i>)	Medium	7052 ± 35	?	–	–	5886–5611/5804–5200	Unpublished
Lu-2770	^{14}C AMS	65–70 cm	Shells	Medium	7050 ± 60	?	–	–	5921–5582/5831–5186	Larsson (2010)
Q-2493	^{14}C	Lower layer (3)	Shells	Medium	7040 ± 70	?	–	–	5921–5556/5829–5160	Arnaud (1989)
OxA-29235	^{14}C AMS	SU 3/7	Bone (<i>Meles meles</i>)	Medium	6962 ± 37	?	–	–	5974–5744	Unpublished
Q-2494	^{14}C	Middle layer (2)	Wood charcoal	Low	6780 ± 65	?	–	–	5807–5561	Arnaud (1989)
Q-2495	^{14}C	Middle layer (2)	Shells	Medium	6850 ± 70	?	–	–	5724–5393/5622–4930	Arnaud (1989)
OxA-26094	^{14}C AMS	SU 8	Bone (<i>Canis familiaris</i>)	Medium	6866 ± 33	?	–	–	5837–5672	Unpublished
OxA-29169	^{14}C AMS	SU 603	Soil	Low	6045 ± 39	?	–	–	5048–4840	Unpublished
OxA-29170	^{14}C AMS	SU 603	Soil	Low	5511 ± 34	?	–	–	4453–4344	Unpublished
Ua-425	^{14}C AMS	Burial 11	Bone (<i>H. sapiens</i>)	Low	5390 ± 110	?	–	–	4448–3984	Larsson (2010)
OxA-25905	^{14}C AMS	SU 204	Seed (<i>Triticum "nudum"</i>)	Intrusive	295 ± 60	?	–	–	–	Unpublished

Radiocarbon dates have been calibrated with the online version of OxCal 4.2 (Bronk Ramsey 2009), with the curve IntCal13 for samples of terrestrial origin, and Marine13 for samples in which the marine reservoir effect is relevant (marine samples and consumers) (Reimer et al. 2013). Where a mixture of shell and charcoal dates was used, the two charcoal dates were calibrated individually and then pooled with the uncalibrated shell date. The weighted mean of all dates was used for the plot. For the Sado Valley, two different ΔR values exist (Vale de Romeiras), $\Delta R = -170 \pm 60$ years (Soares and Dias 2006) and $\Delta R = 100 \pm 155$ (Martins, Carvalho and Soares 2008). Shell samples have been calculated with a 100 % marine reservoir offset. Confidence has been assessed following López-Dóriga (2014) based on Carvalho (2010), Waterbolk (1971) and Zilhão (2001).

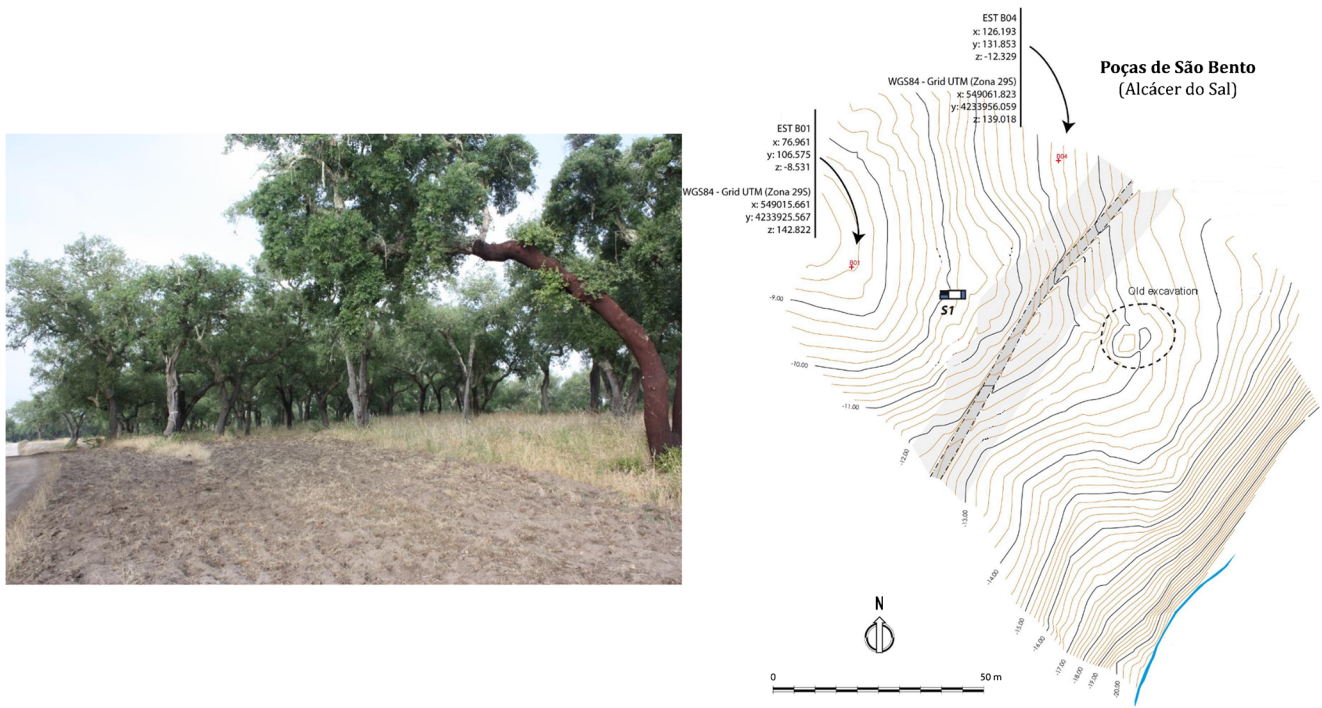


Fig. 2 *Left:* General view of the central area of Poças de São Bento before the intervention. Photograph by Mariana Diniz. *Right:* General topography of Poças de São Bento and location of trench 1 (S1) within the Sado-Meso project. Image by Luis Teira

remains. A high number of plant remains has been recovered in such a fragmentary and eroded state of preservation that their taxonomical determination is impossible by macroscopical observation alone. Preservation of the determinable plant macroremains is heterogeneous: whilst very fragmentary and eroded remains are present, some seeds are very well preserved. In fact, bad preservation involves more often erosion than fracture, as the indices of fragmentation are average. Other types of remains that have been recovered within the light flotation fractions were as follows: uncharred

seeds, mycorrhizal fungi sclerotia (sp. *Cenococcum geophilum*), termite and rodent coprolites and insect parts.

Discussion

Preservation

It is a well-known fact that preservation by charring, indispensable for the recovery of ancient plant remains in a dry

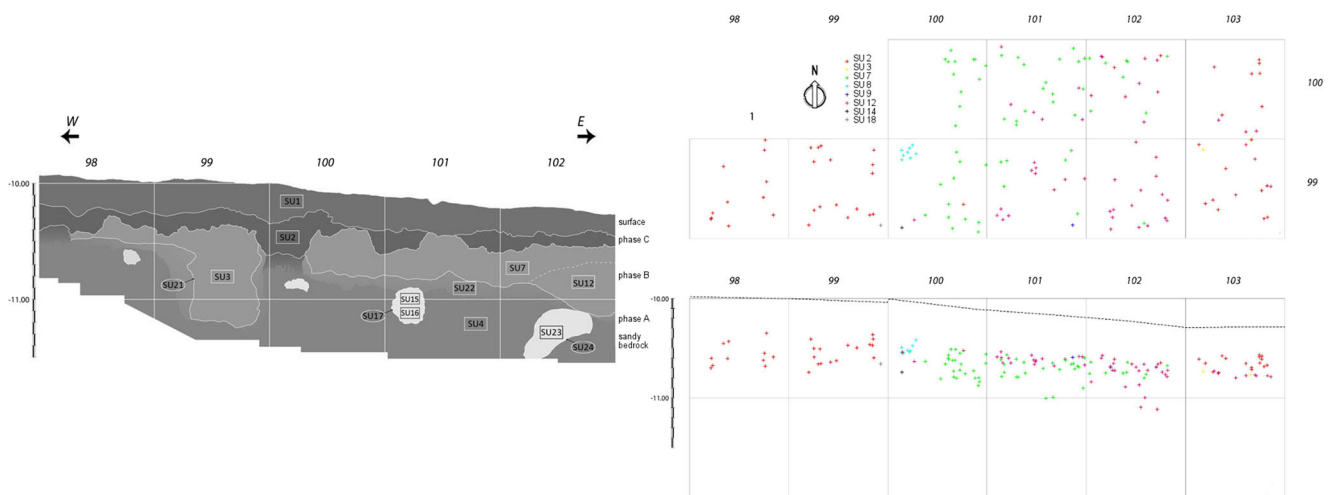


Fig. 3 *Left:* Profile of the north section in trench 1. *Right:* Vertical (*top*) and horizontal (*bottom*) aleatory distributions of flotation samples by SU from trench 1. Images by Luis Teira

Table 2 Archaeobotanical sampling strategy developed at Poças de São Bento

	Trench 1				Phase C (second phase) SUs 2, 9, 14 and 18	Whole sequence
	SUs from phase B (first phase)					
	3/7	8	12	Total		
No. of assessed samples	237	13	260	510	238	748
Excavated % sampled	100 %	100 %	100 %	100 %	100 %	100 %
No. of analysed samples	120	13	55	188	68	256
% of analysed samples	67 %	100 %	21 %	57 %	29 %	56 %

environment such as this, produces a bias towards certain plants and plant parts (e.g. Zapata Peña 2000). In addition, there are factors which influence the preservation of charred plant remains in a site like this. On the one hand, shell-middens are far from ideal deposits for the preservation of charred plant macroremains which become easily eroded in soils with a high level of calcium carbonate (Braadbaart, Poole and van Brussel 2009). On the other hand, because of the Mediterranean climate, with its very hot and dry summers, carbonised remains near the surface may have dried out and broken up when exposed to percolating moisture during the wet autumn and winter (Hansen 2001). However, the existence of multiple charring and deposition events being responsible for the assemblage, most likely in tertiary position (Fuller, Stevens and McClatchie 2014), can also explain these heterogeneous states of preservation, particularly when differences are seen at the horizontal distribution.

Plant macroremains have been recovered and distributed through the archaeological stratigraphical units mixed with other archaeological material. The remains are generally small in size, never more than 5 mm and most often less than 2 mm, a fact which supports the brooming hypothesis (Antolín i Tutusaus 2010a): very small remains result dispersed upon regular sweeping of functional areas (McKellar hypothesis, Miksicek 1987). This, however, does not seem to match the character of the site as a midden in which occupation floors have not been identified yet. More likely, this small size of the plant macroremains could also be a result of the climate which promotes charcoal cracking (Hansen 2001), which might also account for the sparseness of the determined finds (but not the undetermined) over all the sequence. These types of dispersed distributions have been proven upon radiocarbon dating to be often subjected to intrusive charred materials (Crombé et al. 2013), particularly in palimpsest-like sites where fertile archaeological stratigraphical units are vertically contiguous with one another; this probably accounts for the lack of taxonomical difference between the different stratigraphical units (ancient plant macroremains have probably been displaced throughout the sequence) and the percolation of uncharred modern specimens to the lower units. Because of the dispersed distribution of plant

remains, the difficulties in their taphonomical analysis and the potential multiple uses of each plant taxon, the possible functional origins of the plants can be merely hypothesised. Whilst bioturbation by plant roots and burrowing animals probably explains the introduction of modern biological remains (among which are the uncharred seeds, mycorrhizal fungi sclerotia and termite and rodent coprolites) in the archaeological stratigraphical units, which the recent introduction of charred ones is highly improbable. On the one hand, burrowing animals might intentionally transport uncharred seeds for their consumption but not charred ones, unless accidentally. On the other hand, no correlation exists between the uncharred seeds and the charred ones, although some taxa appear in both states of preservation, most uncharred seeds are not preserved in a charred form and vice versa. The existence of natural fires, which could eventually carbonise different plant parts (Scott 2010) and less often seeds (Miksicek 1987), has not been detected in the form of an ash or a charcoal layer in the excavated sequence. In addition, radiocarbon dating of non-woody plant macroremains has been tried in several instances: three remains from the studied area, trench 1 (a *Pinus* sp. bract scale fragment and two *Setaria* sp. and *Lolium* sp. grains) could not be successfully dated due to insufficient carbon; another grain from another excavation area (trench 3), with a taxonomical identification which suggested it was intrusive (*Triticum* “*nudum*”), has proved to contain enough carbon and has been dated to a modern chronology. This could not be used as a proof of the age of the charred plant remains, but together with the previous arguments, it supports their presumed ancientness.

As in the case of carbonised seeds, charred termite faecal pellets and fungi sclerotia are quite likely ancient remains. Termite faecal pellets might have been accidentally charred when deadwood was used as fuel or termites themselves might have been cooked for eating. *C. geophilum* fungi sclerotia are ectomycorrhizal fungi, these are, fungi which thrive in forest soils in symbiosis with different plant roots, mostly from woody species, and among them is pine. Their preservation by charring might be accounted for by two potential explanations: either they were attached to underground plant parts which could have been cooked and, if charred, have not been preserved (tubers

Table 3 Characteristics of the types of plant remains recovered per phase and fragmentation and species richness indices

Taxa	Ecological characterisation		Potential uses				Plant part preserved	Phase B (1st phase: 6000-5000 cal BCE)	Phase C (2nd phase: ca. 4600 cal BCE)	Recovery chances Ethnobotanical-Preservational
	Prevalent habitat	Life cycle	Fruit ripening	Prevalent dispersal mode	Fo	Cos				
<i>Anagallis arvensis/ monelli</i>	Nitrophilous	A-P	Su	Zoo	Yes	Yes	Yes	Seed	•	Medium
cf. <i>Celtis australis</i>	Rocky areas	P	Au	Zoo	Yes	Yes	Yes	Endocarp	•	High
<i>Chenopodium album</i>	Nitrophilous	A	Su-Au	Auto	Yes	Yes	Yes	Seed	•	Medium-High
Compositae	Cosmopolitan	A-B-P	Su	Anemo-Zoo-Auto	Yes	Yes	Yes	Seed	•	Medium
<i>Coronilla sp./ Galega sp.</i>	Grassland	A-P	Su	Anemo-Zoo	Yes	Yes	Yes	Seed	•	Medium-High
tp. <i>Echium sp.</i>	Grassland-Shrubland	A-B-P	Su-Au	Auto	Yes	Yes	Yes	Mericarp	•	Medium-High
cf. <i>Ficus carica</i>	Sunny areas	P	Sp-Su-Au	Zoo	Yes	Yes	Yes	Seed and mesocarp	•	Medium-High
cf. <i>Geranium sp.</i>	Nitrophilous	A-B-P	Su-W	Auto	Yes	Yes	Yes	Seed	•	Medium
Gramineae	Grassland	A-B-P	Su	Auto-Anemo	Yes	Yes	Yes	Caryopsis	•	High
<i>Linaria sp.</i>	Open areas	A-B-P	Su - Au	Auto	Yes	Yes	Yes	Seed	•	Medium
<i>Lolium sp.</i>	Grassland	A-P	Su	Anemo	Yes	Yes	Yes	Caryopsis	•	High
<i>Mahva sp.</i>	Nitrophilous	A-B-P	Su	Auto	Yes	Yes	Yes	Seed	•	Medium
<i>Malva sp./ Lavatera sp.</i>	Nitrophilous	A-B-P	Su	Auto	Yes	Yes	Yes	Seed	•	Medium
<i>Pinus pinea</i>	Forest	E-P	Sp-Su	Auto	Yes	Yes	Yes	Bract-scale fragment, nutshell	•	High
cf. <i>Pistacia lentiscus</i>	Shrubland	E-P	Au	Zoo	Yes	Yes	Yes	Nutshell	•	High
<i>Plantago sp.</i>	Grassland	A-P	Su	Anemo	Yes	Yes	Yes	Seed	•	Medium-High
Polygonaceae	Nitrophilous	A-B-P	Su-Au	Zoo-Anemo-Auto	Yes	Yes	Yes	Nutlet	•	Medium-High
<i>Oxycoccus sp.</i>	Forest	E-D-P	Au	Auto-Zoo	Yes	Yes	Yes	Pericarp fragment	•	Medium-High
<i>Rumex sp.</i>	Nitrophilous	A-B-P	Su-Au	Zoo-Anemo-Auto	Yes	Yes	Yes	Nutlet	•	Medium-High
<i>Urtica membranacea</i>	Nitrophilous	A-P	Su-Au	Anemo	Yes	Yes	Yes	Achene	•	Low-Medium
tp. <i>Viola sp.</i>	Nitrophilous	A-P	Sp	Zoo	Yes	Yes	Yes	Seed	•	Low-Medium
No. of samples with plant macroremains									Phase B	Phase C
No. of samples with non-woody plant macroremains									188	68
No. of samples with non-woody plant macroremains in both fractions									133	256
No. of samples with non-woody plant macroremains in the light flotation fraction									11	189
No. of samples with non-woody plant macroremains in the heavy flotation fraction									118	18
% of samples with non-woody plant macroremains									3	48
No. of determined plant macroremains (NDR)									71 %	1
Minimum number of individuals (MNI)									145	82 %
Fragmentation index (MNI/NDR)									83	72
Minimum number of species (MNS)									0.57	46
Species richness index (MNS-MNI)									11	0.64
									10	17
									0.65	0.59
										1

Scientific nomenclature follows Flora Europaea (Tutin et al. 1964–2001). The ecological and ethnobotanical characterisation follows Flora iberica (Flora iberica 1986+), complemented with other specific references for fruit ripening times (Fern 1992–2010), prevalent dispersal modes (Bonet and Pausas 2004; Paula and Pausas 2009) and potential uses (Fern 1992–2010). The recovery chances assess the potential of appearance of the plant part identified in the charred archaeological record, according to two types of proxies (ethnobotanical and preservational). When considering the likelihood of seeds and fruits becoming carbonised from the ethnobotanical point of view, the following criteria have been followed: chances are rated as high when the seed or fruit itself might be processed with fire (e.g. for storage), chances are rated as medium when another part of the plant than the seed or fruit is processed with fire (e.g. plants with medicinal uses in which the vegetative plant parts might be decocted to make infusions) and chances are rated as low when no part of the plant is known to be possibly processed with fire (e.g. consumption is in a raw state and no medicinal uses are known for the plant). Taphonomical criteria regarding carbonisation and fragmentation originating from controlled experiments have been considered for deciding upon the chances of plant remains to be archaeologically preserved in a charred state (Braadbaart and Poole 2008; Stewart and Robertson 1971; Wilson 1984); the plant remain is rated as having high preservational chances if it is highly resistant to fire exposure (for long intervals or relatively high temperatures; e.g. nutshell or dense seeds), and fragmentation does not easily occur or, if occurring, does not prevent identification; it is rated as medium if only one of the previous premises is met (e.g. dry seeds), and it is rated as low if none of the premises are met (e.g. fruits or oily seeds)

Life cycle: A annual, B biannual, P perennial, E evergreen, D deciduous. Fruit ripening: Au autumn, W winter, Sp spring, Su summer. Dispersal mode: Auto autochory or barochory, Anemo anemochory, Zoo epizoochory or endozoochory. Potential uses: Fo food, Cos cosmetic, Med medicine, Sym symbolical, Tech technological

and rhizomes are usually rich in water and are less able to survive charring) or they could have been dispersed in the soil and become accidentally charred by hearths (which might have not been recognisable hearths, Groenendijk 1987).

Function

It is also a well-known fact that plant remains can enter a site in many different ways (van der Veen 2007), related or unrelated to their actual use. Very few certainties can possibly be established when interpreting the presence of wild plant remains in archaeological sites, although pathways for a better assessment are being developed (Berihuete-Azorín 2016).

The plant macroremain assemblage from Poças de São Bento suggests the potential exploitation of the typical Holocene open Mediterranean pine woodland (van der Schriek et al. 2008). Wild grasses from open grassland areas (*Lolium* sp., Gramineae) were present in sediments from both occupation periods (phase B and phase C). Evidence for the intensive exploitation of undomesticated small-grained wild grasses in prehistorical times is well known from other regions (e.g. Weiss et al. 2004). However, the dispersal mode for most wild grasses is anemochory (wind transportation), which means that their potential arrival in a hearth in the site by chance cannot be excluded. Spikes and grains could have been gathered in summer by cutting, uprooting, beating or hand plucking (Hillman 1984–1986) and then stored, depending on the intended use of the plant or plant parts. Seeds might have been used for food, whilst the straw could have been left in the fields or could have been employed for different manufactures, such as building, weaving and bedding. (Mingote-Calderón 1987). No grass chaff has been recovered surrounding the grains, and two reasons might be behind this phenomenon: chaff was present but did not survive the charring event, as it is less likely than grains to survive (Boardman and Jones 1990), or was destroyed upon deposition or chaff was absent because the grain was already dehusked when charred, such as would happen in the later stages of processing (van der Veen 2007). Grains could have been roasted to help dehusking, for drying and storing or for some sort of culinary preparation. The grains could be stored in aboveground facilities, in which case they could be easily consumed piecemeal as needed, or in underground storage pits, which would allow for a long-term storage period of at least a year.

Other herbaceous plants have a testimonial presence in the site, and their interpretation might be controversial, because the natural ways in which they might have arrived at the site are various, and their potential uses are also diverse. These are plants from grasslands (*Anagallis arvensis/monelli*, *Geranium* sp., *Linaria* sp., *Plantago* sp.) which would have been ripe by the same time as wild grasses and, if intentionally gathered, could have been prepared for immediate consumption or delayed medicinal use. Even if they were not intentionally

gathered, as they are edible, they might have been consumed if accidentally gathered (Hillman, Legge and Rowley-Conwy 1997), as these plants might be eaten as green vegetables and prepared into medicines. These uses would leave few chances for the seeds to be carbonised, so their rarity cannot be used as evidence of their accidental presence. Several nitrophilous habitats (*A. arvensis/monelli*, *Chenopodium album*, *Geranium* sp., *Linaria* sp., *Malva* spp., Polygonaceae, *Rumex* spp., *Urtica membranacea*, *Viola* sp.) point to the existence of rich humid soils such as would be found in either the floodplain of the valley or the immediate environment of the site, favoured by the creation of disturbed habitats by human activities such as garbage disposal. Slope-thriving plants, such as *Echium* sp., *Geranium* sp. and *Plantago* sp., might have been gathered on valley slopes. All these plants would fruit between spring and autumn, and their vegetative parts could have been consumed raw as green vegetables or they could have been dried for storage and kept to be used piecemeal for other purposes (medicinal, dyes) (Fern 1992–2010). *U. membranacea* might have been intentionally exploited for its fibres, which have traditionally been used for textile production (Pinto Carvalho 2005). However, despite being potentially useful, remains of these taxa might be accidentally present in the charred assemblage, either because they were growing near the site or because they could have been present either in dung or stomach contents of other animals which might have been exploited or might have left their droppings near the site (Vaquer and Ruas 2009).

The case of *Echium* sp. could be different. The leaves of plants in this genus might be eaten as green vegetables, the oils in their seeds used for culinary purposes and the whole plants have a wide series of medicinal applications (Fern 1992–2010); their seeds, however, are not usually transported by the wind or by animals, and therefore, an accidental arrival is more unlikely. Some of the plants present have reproductive dispersals consisting of the distant ejection of the seed from the plant (*Geranium* sp., but contrary to most wild legumes, not *Coronilla* sp./*Galega* sp.), which could account for the accidental presence of the seeds of these taxa in the site, if by chance they had fallen near open-air hearths. Otherwise, they might have been gathered in spring or summer before full maturity, whilst the whole plant might have been eaten as a green vegetable, the oils extracted from the seeds of some legumes have traditionally been exploited (Fern 1992–2010). These plants are also appreciated in folk medicine because of their very diverse pharmaceutical properties.

Fruits from different Mediterranean trees would have been gathered between spring and autumn but could have been stored much longer (Riddervold and Ropeid 1988). The problem with fruits, particularly fleshy ones, is they tend to be dispersed by endozoochory (ingestion by animals). Birds, lizards and other frugivorous animals (specialised or non-specialised) eat whole fruits (Torroba Valmori 2013), of which the meat is digested and the seeds and stones are usually excreted, either within

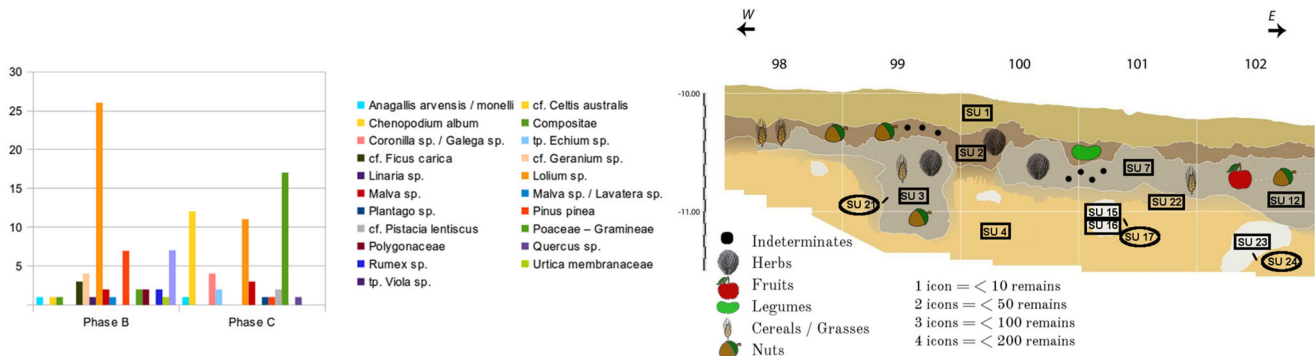


Fig. 4 Left: Abundance of plant taxa (by NMI of seeds or fruits) by phase. Right: Abundance of plant remains per category by SU in section

droppings (in mammals such as foxes, badgers, boars, martens, deers or rabbits) or regurgitated pellets (some birds, such as corvids and gulls) (Debussche and Isenmann 1989). *Pinus pinea* cones might have been gathered unripe in spring to avoid animal competition for the nuts and could have been opened later in the heat of a hearth (Badal García 2001). Acorns from different oak species (*Quercus* sp.) would have also been available (van der Schriek et al. 2008), but evidence for their exploitation is scarce; they would also have been gathered in a particular season, autumn, but their storable life might have been prolonged by drying. Figs (*Ficus carica*) would have been gathered in either spring or summer and autumn, but as they also have excellent storable qualities, they could be the object of delayed consumption or even exchange. *P. pinea* cones might result as charred when exposing them to the fire for opening, to prolong the storable life of the nuts by roasting or for extracting the resin. Cases of owls regurgitating pellets containing pine (*Pinus monophylla*) shells have been reported (Rhode and Madsen 1998), but this does not seem to occur in the Iberian Peninsula; most of the *Pinus* remains recovered are cone bract scale fragments and only a few shell fragments: therefore, the non-anthropogenic contribution of these remains is very unlikely, limited to the possibility of the deciduous cones being buried in the soil on top of which a hearth might have been made. Equally, acorns from oaks (*Quercus* sp.) might have been gathered and processed with fire for consumption in foodstuffs or beverages, to prolong their storage life or to produce tans or mordants with which to treat leathers and cloths. Figs (*F. carica*), in turn, might become charred when drying (usually dipped in boiling water and then baked) or be transformed into medicines; however, fig seeds are dispersed by many frugivorous animals which might have been hunted and processed in the site, leaving an opportunity for their stomach contents to be exploited (Buck and Stringer 2014) or discarded. The presence of a fragment of fruit flesh with a seed imprint suggests the former explanation in this case. The case of other fleshy fruits, such as European hackberry (*Celtis australis*) and lentisc (*Pistacia lentiscus*), is more difficult to ascertain. Fragments of the endocarp of these taxa, together with others which have not been identified, have been recovered in relative abundance. The

fruits might have been brought either intentionally, perhaps eaten and their endocarps discarded into the fire, or accidentally, within the stomach contents of hunted animals, which might or might not have been exploited (Buck and Stringer 2014). The seeds from both taxa, however, are rich in oils which have traditionally been used for culinary purposes (Fern 1992–2010; Flora iberica 1986+); the extreme fragmentation of the endocarps might have been produced by pressing the uncharred endocarps in order to extract the oils or perhaps is just a post-depositional result (Hansen 2001).

Neolithisation

The exploitation of plant resources has been revealed in shell-middens from other world regions (e.g. Mason and Hather 2000; Reddy and Erlandson 2012; Roksandic 2014), but data from the Atlantic coast of the Iberian Peninsula is still scant. In addition, several methodological issues affect the reliability of the interpretation of the importance of those pieces of evidence (Berihuete-Azorín 2016). Although direct data about plant resource exploitation in the Early Neolithic in Portugal is also scarce, limited to two sites in the Estremadura region (López-Dóriga and Simões 2015) at about 150 km further north-west from the Sado area, some points for general comparison can be brought forwards. The most conspicuous element is the probable intensive exploitation of wild grasses (*Lolium* sp.) in the Sado, at the same time, in which the Neolithic populations were putting into cultivation (possibly for the first time), the exotic cereals just arrived from the Mediterranean region. The way in which both of these resources has to be processed (gathered, dehusked, ground, etc.) was very similar. The evidence for the exploitation of wild herbaceous plants is very limited in both cases, but they are much less abundant in Early Neolithic sites. On the contrary, the role of wild fruits (both local and non-local in the Early Neolithic) in those sites seems to have been relevant. These elements of comparison might serve as a point of discussion to debate whether these Mesolithic shell-middeners were adopting available local resources to the possibly new

trend of exploiting grass grains or were continuing their traditions independently from what the coastal farmers were doing, or whether those Early Neolithic populations were locals used to the exploitation of grasses merely who started adopting exotic resources (cereals) to their traditional subsistence patterns, or whether the existence of similarities between the two groups is a result of mere chance and concurrent trends of resource exploitation patterns between human populations and deposition of charred plant remains in archaeological sites. Given the present limited data, it is difficult to tell whether these broad differences and similarities are a result of radically different plant resource exploitation patterns or merely as a result of taphonomy. Hopefully, this data will be complemented with further analyses in the area and other shell-middens in Portugal (e.g. Wollstonecroft et al. 2006) and a better understanding of the role of plant resources in the Mesolithic-Neolithic transition will be achieved.

Conclusion

This paper proves that charred plant remains might be preserved in shell-middens, despite concerns about the adversity pH of such environments (Braadbaart and Poole 2008), particularly in open-air sites and Mediterranean climates (Hansen 2001), and despite widespread assumptions on the functional specialisation of shell-midden sites in which other resources than shells are not hoped to be found and (unfortunately, for that very same reason) very frequently not appropriately sampled, contributing to a circular argumentation on the absence of plant remains in shell-middens. This paper shows how the last hunter-gatherers in the shell-middens of the Sado valley in Portugal could have carried out an intensive and diversified exploitation of the wild plant resources available in the environment, with particularly incidence in wild grasses, precluding the adoption of cereals with very similar processing requirements for consumption. However, the functional interpretation of the plant remains recovered is a problematic subject (Berihuete-Azorín 2016), due to reasons inherent to the characteristics of tertiary archaeobotanical assemblages in general (Fuller, Stevens and McClatchie 2014) and to characteristics of the plant taxa in particular, which could have arrived to the site from more than one way (Wright 2010). Taphonomy plays a very important role in Neolithisation discussions (e.g. Berger and Guilaine 2009; Zilhão 2011), but it rarely includes solid discussions about the preservation of plant remains and how their analysis can contribute to the understanding of the site formation processes.

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