Experimental archaeology as a resource for approaching formation processes of seed assemblages. First results and future perspectives

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RESUM
El propòsit d'aquest article és obtenir una primera aproximació a certs processos de formació del registre arqueobotànic.

Per a aquest experiment s'ha treballat amb dues species: *Triticum aestivum* s.l. (5130 restes) i Lens culinaris (1478 restes). El primer objectiu és avaluar com la combustió afecta les diverses propietats de les granes quan conjunts de restes són exposats a les mateixes condicions controlades. El segon és comparar dos contextos deposicionals: un en el qual les restes quedin exposades a les condicions atmosfèriques i un altre en el qual s'enterri les restes en fosses. Finalment, es pretenen analitzar els efectes produïts en les granes per l'ús de diferents tècniques de recuperació: excavant amb un paletí o amb un tornavís; i tractant el sòl per flotació o mitjançant el rentat per columna de garbells.

S'ha utilitzat un sistema de caracterització resta-per-resta per tal de descriure tots els canvis en les propietats de les granes després de cada fase de l'experiment. La carbonització de conjunts de diferent quantitat mostra algunes diferències que haurien de ser tingudes en compte quan s'interpreta el registre arqueològic.

Paraules Clau:
arqueologia experimental; processos de formació; carbonització; tècniques de recuperació de les mostres

ABSTRACT
The aim of this paper is to have a first approach to certain formation processes of the archaeobotanical record.

For the first experiment I worked with two species: *Triticum aestivum* s.l. (5130 items) and Lens culinaris (1478 items). The first objective is to evaluate how charring affects the several properties of the grains when big assemblages are exposed to the same controlled conditions. The second one is to compare two different depositional contexts: leaving the grains exposed to open air conditions and burying the assemblage inside pits. Finally, I aimed to analyze the effects produced on the grains by using different recovery techniques: excavating with a trowel or with a screwdriver; and treating the soil by flotation or by water-sieving.

A seed-by-seed characterization system was used in order to describe all the changes in the properties of the grains after each stage of the experiment. Charring of assemblages of different quantity of grains shows some differences that should be considered when interpreting the archaeobotanical record.

Keywords:
experimental archaeology; formation processes; charring; sample recovery techniques

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1. Introduction

Experimental works with grains have a long tradition in archaeobotany. Most of them have concentrated on the effects of charring on seeds and fruits in order to register their morphological and chemical modifications or their chances of preservation (see, for instance, Wilson, 1984; Boardman and Jones, 1990; Gustafsson, 2000; Jacomet 2003; Wright, 2005; Märkle and Rosch, 2008; Sievers and Wadley, 2008, among others). Moreover, several experiments have been undertaken in order to compare different systems of sample recovery and processing (for example, Wagner, 1982; Moulins, 1996; Wright, 2005). Nevertheless, other taphonomic agents, such as erosion, transportation, soil pH, trampling or bioturbation, have rarely been evaluated.

If carbonization has been the target of so many studies, why should we keep on experimenting? As Wilson (1984) wrote, *"(...) Any single heating episode in antiquity is thus likely to have left some seeds uncarbonized, whilst carbonizing others, while others again will have been burned to destruction"*. Such statement summarizes the complexity of the carbonization process. As the above mentioned experiments have already demonstrated, seeds and fruits get carbonized at different temperatures and after different periods of time, depending on several other variables (such as the quantity of oxygen present in the environment, moisture content, etc.). And, as Wilson said, the process of carbonization is rarely uniform when dealing with big concentrations of grain.

Recent works have quite successfully intended to find correlations between some properties of grains (size, shape and reflectance) and the heating temperature to which the items were exposed (e.g. Braadbaart, 2008; Braadbaart et al., 2004). Such approximations are an excellent starting point for a new methodology that allows establishing the thermal history of carpological assemblages. On the other hand, one variable has not been deeply considered: the quantity of grain that is being charred. We cannot assume that the results observed in single-grain experiments can be used for the interpretation of large assemblages like the ones found in archaeological sites.

The experiment that is being presented in this paper deals with three different taphonomic agents: first of all, carbonization, in order to understand not only single-grains' reactions to heating conditions but mainly grain assemblages' reactions; secondly, the depositional context, comparing the effects on the properties of grains after being buried for one month as opposed to being exposed to open air conditions; and finally, the system of recovery of the remains on the one hand, the excavation tool used (trowel or screwdriver) and, on the other hand, the soil processing method (flotation or water sieving). This experiment is intended to be the first one of a long series that aim to correlate the state of the properties of the grains that we recover in the archaeological record with the formation processes that originated them.

2. Materials and methods

A total number of 6,618 items were chosen for this experiment. The assemblage contained hexaploid naked wheat grain (main component) and chaff, some barley spikelets and lentil seeds. Lentils were simply bought at the supermarket. More interestingly, the cereal remains were collected in 2008 during the "Festa del segar i del batre" (Harvesting and Threshing fair) from La Fuliola (Lleida, Catalonia), where a demonstration of traditional threshing techniques takes place every year. The whole threshing, winnowing and sieving process was registered. The items come from one of the samples that were collected after the last stage of processing (fine sieving). For what concerns this paper, it should be specified that a threshing sledge and a threshing stone were used, both being pulled by a horse (see figure 1).

The experiment consisted on several phases: charring under controlled conditions, deposition of the grains for one month and recovery of the grains. At every stage of the experiment a complete seed-by-seed description was carried out in an Excel spreadsheet. The variables that have been considered are the following (for a complete definition see Antolín, 2010; Antolín and Buxó, 2011a): taxon, part represented, number of remains, type of preservation, number of parts (for instance, the number of grains in an aggregate), fragmented part, state of preservation of the pericarp, type of fragmentation, presence/absence of shiny surface, adhe-

Figura 1.- Threshing activities in La Festa del Segar i del Batre in La Fuliola (Lleida, Catalonia) (Pictures: Maria Bofill).

rence of the embryo, presence/absence of germinated embryo, presence/absence of morphological changes due to the effects of charring, evidence of mechanical activities (for example, cracked grains due to processing activities). This time-consuming method aims to get quantitative data to provide patterns on the state of the properties of the seed and fruit record after a long series of experiments that the author is currently undertaking.

A number of variables have been considered of major importance for the experiment:

1.Composition of the assemblage: it is essential for our purpose to have a complete description of the composition of the assemblage at every stage of the experiment in order to state the consequences of every taphonomic agent on it. Thus, three descriptions have been undertaken: one at the beginning of the experiment, another after the heat treatment and one more after the deposition and recovery of the grains.

2. Charring: for this study, a SELECT-HORN J.P.SELECTA muffle from the Inorganic Chemistry and Analytic Chemistry Laboratory of the University of Lleida was used in order to control the heating temperature. The grains were put between two layers of sand (to create an anoxic environment) in two aluminium trays (16x11x3.5 cm). They were heated at 150ºC for 20 minutes, then at 180ºC for 60 minutes, at 200ºC for 40 minutes and finally at 250ºC for 45 minutes.

3. Weathering: the possible effects of exposing the grains to open air conditions were analyzed by leaving the grains exposed to weathering for one month (from mid-December 2009 to mid-January 2010).

4. Depositional context: the vertical and horizontal distribution of the grains was limited by digging five different pits, each one treated as a different unit of analysis (see the point below). Four of them were re-filled with soil after depositing the grains and one was left open. Soil pH was measured.

5. Recovery and processing techniques: two systems have been compared, excavation with a trowel and with a screwdriver. Likewise, the effects of flotation and water sieving were analyzed. In order to be able to compare the different possibilities of combination of the soil recovery and the soil processing techniques, 4 different pits were dug, making all combinations possible (excavating with the trowel and flotation, excavating with the screwdriver and flotation, etc.). Flotation and water-sieving were carried out using a sieve of a 1 mm mesh size. The soil samples were measured and soaked in water before processing, as we usually treat our archaeobotanical samples.

Taxon	Part represented	Group 1	Group 2	Total
Hordeum vulgare	spikelet	8	3	11
Lens culinaris	cotyledon	1	6	7
	cotyledon fragment	1	3	4
	seed	1076	391	1467
	total nr. of items	1078	400	1478
Triticum aestivum s.l.	spikelet	1	1	2
	rachis fragment	34	24	58
	caryopsis	3903	1053	4956
	caryopsis with lemma	1		1
	caryopsis with palea	83	25	108
	caryopsis fragment	3	1	4
	TOTAL	5111	1507	6618

Figura2.- Description of the initial assemblage: taxa, part represented and number of items per group.

3. Results

Initial description of the assemblage

A total number of 6,618 items were identified and described (see figure 2). Of those, 5,130 remains belonged to naked wheat, mostly grain (fig. 3a) but also 58 rachis fragments (fig. 3b). 1,478 were lentil seeds and 11 were hulled barley spikelets (fig. 3c). The latter can be considered as contaminations of the wheat harvest that survived until the last stage of processing. 100% of the remains had an intact surface and grains still had the embryo and apical hairs. 4 grain fragments were found (fig. 3d), 9 grains had been cracked during threshing (fig. 3e) and 2 had been slightly peeled/abraded (fig. 3f). As for the lentils, 4 cotyledon fragments and 7 loose cotyledons were counted (fig. 3g). Most of the lentil seeds had an intact testa (93,7%), but a small percentage (4,9%) presented a slight fragmentation of the testa, while less than 2% of the items showed greater affectation (fig. 3h).

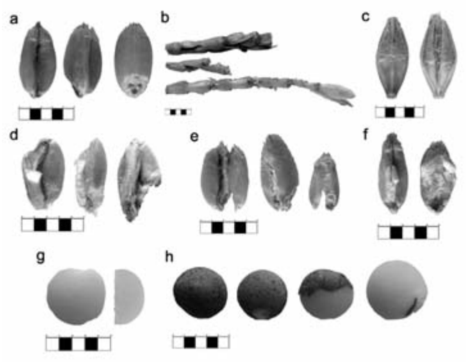

Figura 3.Photos of the assemblage before charring: a naked wheat grains; b naked wheat rachis fragments; c barley grains; d fragments of naked wheat grains; e cracked grains of naked wheat; f naked wheat grains with peeled or abraded surface; g lentil cotyledon and fragment of cotyledon; h lentil seeds with different states of preservation of the testa.

The whole assemblage was split in two parts (see figure 2): one with 5111 remains which were destined to be buried in 4 pits (Group 1), while the other one contained 1507 remains that were to be exposed to open-air conditions (Group 2). These two groups would allow a first comparison of the effects of charring on grain assemblages of different size.

Description of the assemblage after charring

Charring had different effects on both assemblages. At a general level, the volume of the assemblage doubled, from 190 ml before charring to 380 ml after charring. Swelling of the grains was observed in all taxa.
The grains from the smaller assemblage got completely charred but the ones from the larger one presented different degrees of carbonization. The results of the latter are presented in figure 4. Around 12% of the remains showed signs of not being completely carbonized (fig. 5a). Chaff fragments were completely carbonized in Group 2 but 12% of these remains in Group 1 were also only partially carbonized. 100% of the lentil seeds from Group 1, but less than 70% in the bigger assemblage, appear with a broken testa (see fig. 5b). The remaining percentage of lentil seeds from Group 2 appears with an intact testa (see fig. 5c). Most of the barley grains were totally charred but two of them presented only slight signs of carbonization. Glumes were preserved in intact conditions (see fig. 5d).

Taxon	1	2	3	4	Total
Hordeum vulgare	6		1	1	8
Triticum aestivum	3744	232	154	45	3418
Total	2994	232	154	46	3426
%	87,39	6,77	4,50	1,34	

Figura 4. Degree of carbonization of the grains belonging to Group 1. Values 1 to 4 with an ordinal value, being 1 "completely charred" while 4 refers to only "slightly charred" .

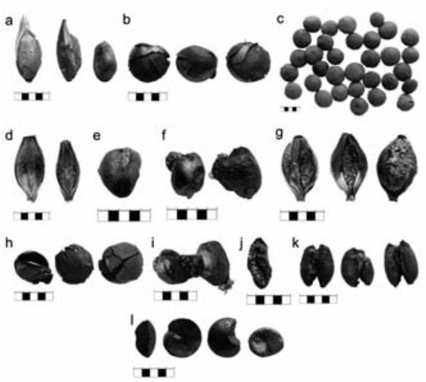

Figura 5. 5 Photos of the most relevant consequences of charring observed on the grains: a incompletely charred naked wheat grains; b swelled lentil seeds with broken testa; c incompletely charred lentil seeds with intact testa; d incompletely charred barley grains; e popped naked wheat grain; f naked wheat grains with protrusions; g distorted barley grains; h lentils with cracked surface and split cotyledons; i naked wheat grain aggregates; j naked wheat grain fragment after charring; k cracked naked wheat grains after charring; l single lentil cotyledon and fragments of cotyledon.

14,65% of the cereal grains of the bigger assemblage are popped or show protrusions (see fig. 5e and 5f), while 17,73% show these features in the smaller assemblage. All the barley grains from the smaller assemblage showed severe distortions (see fig. 5g). The percentage of popped seeds of free-threshing wheat is very similar among both groups (see Figure 6).

Lentils also show some affectation due to the exposition to high temperatures: cracking of the surface and cotyledon splitting (see fig. 5h). The first one is characterized by clear cracks on the seed surface, whereas the second one consists in the opening or splitting of the edges of the cotyledons without se-

Taxon	Group 1				Group 2			
	Popped grains		Grains with protrusions		Popped grains		Grains with protrusions	
	N.	%	N.	%	N.	%	N.	%
Hordeum vulgare			4	57,14			3	100
Triticum aestivum	538	13,49	71	1,78	147	13,64	69	6,40
Total	538		75		147		72	

Figura 6. Number and percentage of popped grains and grains with protrusions of Group 1 and Group 2 after the heat treatment .

parating completely. Both phenomena are often found in the same seed: 6 seeds (one from Group 1 and 5 from Group 2) show evidences of cracking; of these, only one from Group 2 does not present split cotyledons. There are no cases of seeds with split cotyledons that do not show cracks on the surface.

Aggregates of grains are present in both assemblages (fig. 5i). The percentage is a bit higher in Group 1 (see fig. 7) and the number of items per aggregate is also higher in Group 1 (see fig. 8). These aggregates are generated due to the explosion of the endosperm of the grains.

Taxon	Group 1	Group 2	Total
Lens culinaris	12	3	15
Triticum aestivum	281	54	380
Total	293	57	395
%	5,7	3,8	

Figura 7. Absolute number and percentage of aggregated grains per taxon and per group.

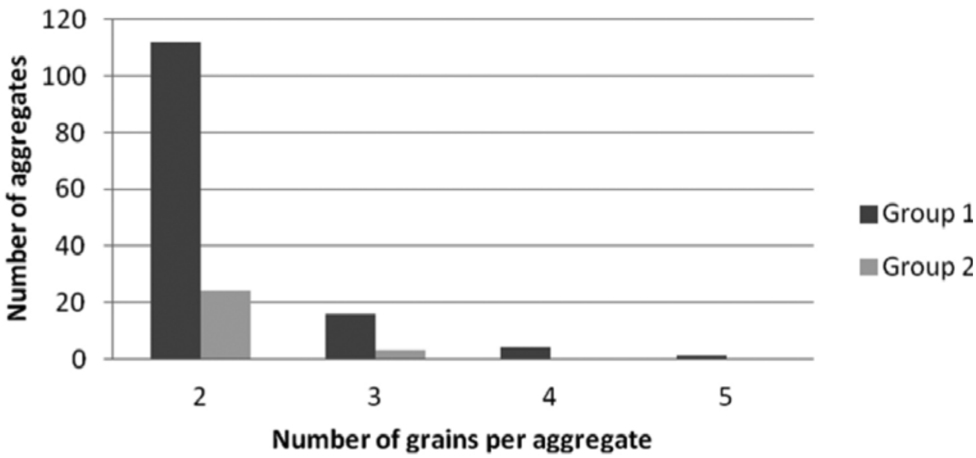

Figura 8. Number of aggregates according to the number of grains of each aggregate in each group.

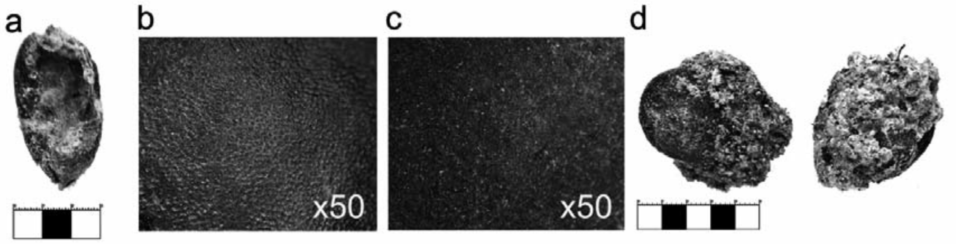

Figura 9. Photos of the most relevant consequences of the deposition and recovery of the grains: a decomposing naked wheat grain; b reticulate pattern of the inner side of a charred lentil cotyledon; c plain surface of the inner side of a lentil cotyledon separated after charring; d concretions produced on naked wheat grains from Group 2

Grains that had suffered fragmentation or cracking during threshing were clearly detected after charring (fig. 5j). Characteristic bulging sections, such as the ones described by other authors (e.g. Valamoti 2002), have appeared on the caryopsis fragments produced during threshing. Cracked grains are not always easily identified, since they can be mistaken for grains with protrusions. Usually, the grain splits at the hilum part and popping of the endosperm is visible (see fig. 5k). Peeled/abraded grains can be detected by the straight cut that can be observed on the grain and the subsequent popping of the endosperm due to charring, leaving a smooth and shiny surface.

Fragmentation prior to charring is more difficult to detect on carbonized remains of lentil, at least when fragments are exposed to the heat treatment that we have applied. Post-charring fragmentation usually shows a more porous surface, while fragmentation produced prior to charring presents a compact, shiny surface (fig. 5l).

Final description

No seed-by-seed description was undertaken for the final description of the assemblage since the general affectation of the remains was very low. General qualitative appreciations are given.

No erosion or degradation was observed on the surface of the grains. Hairs and embryos remained attached to the grains. One grain from Group 1 already started to decompose (fig. 9a).

An extremely low number of fragments occurred as a result of the process of recovery of the grains. These were only produced in the samples that were treated by water-sieving: 3 items in total (see figure 10). In all cases, the section of the fragments is of irregular type (uneven).

Some lentils were fragmented into two cotyledons. As can be observed in fig. 9b and 9c, cotyledons that were already separated when exposed to high tem-

Pit	Recovery techniques applied	pH	Number of fragments obtained
1.a	screwdriver+flotation	8.75	
1.b	screwdriver+water-sieving	9.14	2 fragments
1.c	trowel+water-sieving	8.77	1 fragment
1.d	trowel+flotation	8.73	

Figura 10. Recovery techniques applied to the different pits in which grains were covered with soil during the experiment. Soil pH of and the number of caryopsis fragments are presented

peratures show a clear reticulate pattern on their surface. Such pattern is not observed in the ones that separated after the heat treatment.

Group 2, which was not covered with sediment, had some new soil naturally deposited, which resulted in the formation of concretions that affected the grains (fig. 9d). Also some grains were involuntarily displaced by snails.

4. Discussion

Some interesting elements for further discussion can be drawn from this experiment.

On the initial assemblage

There are elements in the composition of the initial assemblage, especially concerning the cereal remains, that can be related to the threshing techniques applied during the wheat harvest.

The presence of cracked and peeled/abraded grains along with fragments of grains should be interpreted as consequences of the processing techniques. It was observed how a threshing board and a threshing stone were used in La Fuliola. Thus, it is highly possible that the types of features we have observed on the grains are associated with such aggressive techniques. Still, it should be a matter for future research, since we should not rule out the possibility that other threshing techniques, such as animal trampling, could cause the same effects on the grains. We must consider, then, that some fragmentation and cracking of the grains can be expected in large grain assemblages and it does not need to be the result of any type of culinary process (such as the making of bulgur). It is also interesting to know that such aggressive threshing techniques did not cause damage on the surface of the grains and that the embryos (often lacking in archaeobotanical assemblages) also remained attached to the grains after all the threshing, winnowing and sieving process.

The presence of hulled barley shows

how its spikelets can survive as contaminants until the very last stage of the cereal threshing process. In an archaeological case, such low percentages of barley could respond to different practices. Maslins, for example, are frequently separated during sieving (see Jones and Halstead, 1995), which is unlikely to produce two perfectly separated different products. In this case, if one had harvested naked wheat and barley the final product would be one assemblage of barley with some wheat grain contaminations and one wheat grain assemblage with barley intrusions.

About the heating treatment process

The quantity of grains exposed to the heating treatment is an important variable in the charring process. Different results are to be expected, being the smaller assemblages more likely to become completely charred, while bigger assemblages would need a much longer exposition to heat in order to show a homogeneous degree of carbonization.

Popping of the grains and the appearance of protrusions seems to be more frequent in the smaller assemblage, while most aggregates appear in the bigger one. In any case, percentages under 20% are to be expected when assemblages are charred at low temperatures and at low heating rates such as ours. The formation of aggregates is probably linked to the present number of grains. The possibilities of aggregate formation increase when assemblages are bigger. Since aggregates are formed due to the explosion of the endosperm out of the grains, sticking to nearby items, they are fragile and we should consider the possibility that they don't survive as such in the archaeobotanical record. This variable is, then, less reliable than others. Around 5% or less of the items form aggregates in the heating conditions that we have created.

Uncharred grains can appear together with grains with protrusions. Thus, the sole presence of grains with protrusions in an archaeological assemblage doesn't ensure that it was completely charred and preserved. One should assume that our assemblages are hardly ever the same deposit that once was exposed to heat. The bigger the assemblage the higher are the possibilities of having incompletely charred wheat grains and chaff. In our case, around 12% of the wheat remains of the original deposit of Group 1 would have not survived in a dry site for a long time, at least in a recognisable way. The percentage rises up to the 30% when considering lentil seeds. These results confirm that charring of lentil seeds is possible at low temperatures, but also that lentil seeds can be more seriously underrepresented in the archaeological record than cereals.

Lentils have high possibilities of losing their testa due to charring since the swelling of the cotyledons fragments it. Some lentils showed cracks on the surface or split cotyledons. These effects were more frequent in the smaller group. Nevertheless, the number of affected seeds was very low.

Barley spikelets can completely distort at low temperatures and if it wasn't for the good preservation of the glumes they would be unidentifiable.

On the context of deposition

Formation processes have had very little effect during the period of deposition, recovery and processing of the remains. Covering the grains with soil actually protected them and the soil was still very loose when excavation took place, which resulted in a very low fragmentation rate.

Short-term exposition of grains to open-air conditions can leave no traces but the formation of soil concretions. This is an interesting feature that will be targeted in future experimentations, since recognizing exposition of the grains to open-air conditions and natural sedimentation is important to understand the taphonomy of an assemblage.

On the applied recovery techniques

No differences have been observed when comparing excavation with screwdriver or with a trowel. The soil was too loose due to the short time of exposition. Thus, grains were not fragmented during excavation.

Concerning the washing method, water-sieving is probably more aggressive to grains than flotation, but no definite conclusions can be drawn from our experiment.

5. Conclusions and future perspectives

The experiment that we have presented in this paper is of great interest for everyday archaeobotanical analyses. Taphonomy is an essential part in the analysis of the seed and fruit record and our discipline still has a long way to go compared to others such as archaeozoology.

It has been shown how the quantity of grain must be considered as an important variable during charring. A seed-by-seed description of the assemblage under study seems the best option in order to get quantified data to work with. This description can help us to get a rough approximation to the heating temperature to which the assemblage was exposed (some first attemps on archaeobotanical materials can be seen in Antolín and Alonso, 2009; Antolín and

Buxó, 2011a; Antolín and Buxó, 2011b).

The possibility of detecting the effects of certain types of threshing techniques on the state of the properties of the grains is also of interest and should be targeted in future ethnographical and experimental works.

Our experiment doesn't allow definite conclusions on the depositional context and the recovery techniques applied.

For the improvement of future experiments several observations must be highlighted.

• In order to obtain some patterns of affectation of the assemblages, several other carbonization experiments should be carried out both repeating the heat treatment applied in this experiment and also at other temperatures and heating rates, always comparing at least two different volumes of grain.

• Covering of the grains with soil for a short period doesn't generate a typical archaeological consolidated layer. Thus, possible fragmentation is minimized and the whole experiment fails. This period should be increased and it would probably be more interesting to let the pits fill naturally with soil and eventually excavate them in order to reproduce a more realistic situation.

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References

ANTOLÍN, F. (2010): Les propietats del registre carpològic: el punt de partida per a l'estudi de la seva representativitat arqueològica, *Cypsela*, 18, 299-306.

ANTOLÍN, F. & ALONSO, N. (2009): A Mourela (As Pontes, A Coruña): evidencias carpológicas de las prácticas de roza y del procesado y consumo de cereales en el monte gallego (siglos VII-XVII), in BONILLA, A. & FÁBREGAS, R. (eds.), Círculo de engaños. Excavación del cromlech de A Mourela (As Pontes de García Rodríguez, A Coruña), (pp, 57-68). Santiago: Andavira.

ANTOLÍN, F. & BUXÓ, R. (2011a): Proposal for the systematic description and taphonomic study of carbonized cereal grain assemblages. A case study of an early Neolithic funerary context in the Cave of Can Sadurní (Begues, Barcelona province, Spain), *Vegetation History and Archaeobotany*, 20, 53-66.

ANTOLÍN, F. & BUXÓ, R. (2011b): L'explotació de les plantes al jaciment de la Draga: contribució a la història de l'agricultura i de l'alimentació vegetal del neolític a Catalunya: in BOSCH, J., CHINCHILLA, J., TARRÚS, J. (coord.), El poblat lacustre del neolític antic de La Draga: Excavacions de 2000-2005. Girona: CASC-Museu d'Arqueologia de Catalunya (Monografies del CASC, 9), 147-174.

BOARDMAN, S. & JONES, G. (1990): Experiments on the effects of charring on cereal plant components, *Journal of Archaeological Science*, 17, 1-11.

BRAADBAART, F. (2008): Carbonization and morphological changes in modern dehusked and husked Triticum dicoccum and Triticum aestivum grains, *Vegetation History and Archaeobotany*, 17, 155-166.

BRAADBAART, F., VAN DER HOST, J., BOON, J.J., VAN BERGEN, F. (2004): Laboratory simulations of the transformation of emmer wheat as a result of heating, *Journal of Thermal Analysis and Calorimetry*, 77, 957-973.

GUARINO, C. & SCIARRILLO R (2004): Carbonized seeds in a protohistoric house: results of hearth and house experiments, V*egetation History and Archaeobotany*, 13, 65-70.

GUSTAFSSON, S. (2000): Carbonized cereals grains and weed seeds in Prehistoric houses - an experimental perspective, *Journal of Archaeological Science*, 27, 65-70.

JACOMET, S. (2003): Und zum Dessert Granatapfel - Ergebnisse der archäobotanischen Untersuchungen, in HAGENDORN, A. et al. (eds), Zur Frühzeit von Vindonissa. Auswertung der Holzbauten der Grabung Windisch-Breite 1996-1998. *Veröffentlichungen der Gesellschaft Pro Vindonissa*, 18, 173-229.

JONES, G. & HALSTEAD, P. (1995): Maslins, mixtures and monocrops: on the interpretation of archaeobotanical crop samples of heterogeneous composition, *Journal of Archaeological Science*, 22, 103-114.

MÄRKLE, T. & ROSCH, M. (2008): Experiments on the effects of carbonization on some cultivated plant seeds, *Vegetation History and Archaeobotany*, 17 (Suppl 1), 257-263.

de MOULINS, D. (1996): Sieving experiment: the controlled recovery of charred plant remains from modern and archaeological samples, *Vegetation History and Archaeobotany*, 5, 153-156.

SIEVERS, C. & WADLEY, L. (2008): Going underground: experimental carbonization of fruiting structures under hearths, *Journal of Archaeological Science*, 35, 2909-2917.

VALAMOTI, S.M. (2002): Food remains from Bronze Age Archondiko and Mesimeriani Toumba in northern Greece?, *Vegetation History and Archaeobotany*, 11, 17-22.

WAGNER, G.E. (1982): Testing flotation recovery rates, A*merican Antiquity* 47(1), 127-132.

WILSON, D.G. (1984): The carbonisation of weed sedes and their representation in macrofossil assemblages. In: VAN ZEIST, W. & CASPARIE, W.A. (eds), Plants and ancient man. Studies in palaeoethnobotany, (pp. 201-206). Rotterdam: A.A.Balkema.

WRIGHT, P.J. (2003): Preservation or destruction of plant remains by carbonization?. *Journal of Archaeological Science*, 30, 577-583.

WRIGHT, P.J. (2005): Flotation samples and some paleoethnobotanical implications, *Journal of Archaeological Science*, 32, 19-26.