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ORIGINAL ARTICLE

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)

Ferran Antolín · Ramon Buxó

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Abstract In this paper we propose a methodological systematisation for the qualitative and quantitative characters and numerical description of carbonised cereal remains (basically caryopses) found at archaeological sites. The aim of this methodology is to study such remains after evaluating the significance of taphonomic processes, such as the degree of fragmentation, cause of fragmentation, overrepresentation of certain taxa, processes of erosion, transport and deposition, and combustion intensity. Attention is also paid to the fragmentation of the caryopses prior to charring, and a new method is presented for the calculation of the minimum numbers of individuals (MNI) of cereal caryopses. This methodology requires a seed-by-seed description in order to obtain fully quantified data of taphonomic importance, which is therefore time consuming, but at the same time achieves precise information of great value for the evaluation of the assemblage. Our case study has been the remains found in Layer 18 at the archaeological cave site of Can Sadurní (Begues, Barcelona province, Spain), one of the most important early Neolithic cereal assemblages on the Iberian Peninsula.

Keywords Cereals · Taphonomy · Neolithic · Fragmentation prior to charring · Minimum number of individuals · Burial offering

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F. Antolín (✉)
CSIC-IMF. Laboratori d'Arqueobotànica, Edifici B, Departament de Prehistòria, Facultat de Lletres, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain
e-mail: fantolin@imf.csic.es

R. Buxó
Museu d'Arqueologia de Catalunya, C/Pedret, 95, 17007 Girona, Spain
e-mail: rbuxo@gencat.cat

Introduction

The properties of the archaeological record are influenced in different ways by several formation processes. Thus, before any analysis of an assemblage takes place, it is necessary to evaluate the degree of influence of these processes (Schiffer 1983). Schiffer's statements have not had the same scientific consequences in the analysis of all the archaeological record. Seed assemblages are part of this record and their formation processes have to be analysed not only by the context in which they appear but also by the description of the state of their properties. At the moment, there are some papers in press where Schiffer's definition of the properties of the archaeological record has been adapted to seed records (Antolín in press a), and also about the relation of each property to the formation processes (Antolín in press b), but we will not be dealing with these aspects in this paper. Here, we will propose a systematic method for the description of caryopsis remains in order to demonstrate the potential of seeds themselves in taphonomical analysis, and the importance of this analysis for the interpretation of seed assemblages.

The proposal which we present in this paper aims to cover two essential aspects for evaluating the economic significance of carpological (seed and fruit) remains. We look, on the one hand, at the taphonomic aspects such as the intensity of the charring processes or the existence of post-depositional transport and erosive processes, and on the other hand, at economic aspects such as the detection of processing practices, like dehusking or fracturing of the cereal. The fragmentation of the seed remains or their state of preservation has occasionally been dealt with in archaeobotanical studies (Valamoti 2002; Bouby et al. 2005; Alonso et al. 2007; Alonso 2008), although normally only noting the appearance of certain characters of remains and not applying a seed-by-seed analysis, except for Bouby et al. (2005). Likewise, there are experimental studies on the charring of cereals (Braadbaart 2008) or olives (Margaritis and Jones 2008) that, while they have not concentrated solely on the biometric changes, have not focused on obtaining appearance patterns for the different observable characteristics such as the popping of the endosperm and concavisation of the seed sides, etc., which on the other hand, are noted in some of the cited studies.

An attempt at quantifying these aspects is found in Hubbard and al Azm (1990), but we believe that some of them must still be analyzed only at a qualitative level, since there is no complete and systematic experimental work that allows their quantification. Our proposal also aims to be quantitative, but with clear limitations because of the state of development of the research.

In order to show the value of this methodology, we have applied it to an exceptional archaeological assemblage, the concentration of cereal grains from Layer 18 at the cave of Can Sadurní (Begues, Barcelona province, Spain), which consists of more than 60,000 remains from what has been interpreted as a funerary deposit from the beginning of the early Neolithic (ca. 5400 cal yrs B.C.).

Materials and methods

Taphonomic study and description of the cereal remains

In order to arrange the description of the cereal remains we have designed a database on an Excel spreadsheet in which each item corresponds to a line, and each column is a variable in its analysis. We chose this system because of the simplicity of working with this program and also because of the possibilities it allows for working with the data both in Excel and for transferring it to other programs for statistical analysis. In the following, we will present the variables that we are using and show how these are recorded in the database. Some of the categories are filled in using text and others with numbers. The abbreviations can be changed and adapted to the language of the database, providing that the same ones are used consistently and the concepts with which they are associated are well defined. When the categories are filled in with numerical characters, they have a nominal value (1 = "yes", 0 = "no").

The variables we have taken into consideration are as follows: inventory number, archaeological site, year of excavation, location, chronology, structure or layer, stratigraphic unit or square, number of processed litres of soil, sieve mesh size, location reference in the store, taxon, part represented, number of remains, type of preservation, fragmented part, state of preservation of the pericarp, type of fragmentation, shiny surface, adherence of the embryo, germinated embryo, combustion effects, insect holes, length, width and thickness (Antolín 2008). Below, one can find a more detailed description of some of the variables.

Part represented

Type of remains: caryopsis, glume base, glume fragment, spikelet fork, etc. In addition, in the case of cereal caryopses, for which this aspect has been more widely studied, we can distinguish between two types of fragmentation (Bouby et al. 2005):

- Fragmentation which occurred prior to charring: detected by the type of section: bulging (Knörzer 1981; Valamoti 2002). This fragmentation can be caused accidentally during the processing of the cereal or intentionally during culinary preparation.
- Fragmentation caused after charring: the fragmentation can occur at various times after charring: from trampling, sedimentary pressure, erosion, the excavation process during recovery and processing of the samples, etc. (Schiffer 1983; Antolín in press b).

Preservation type

The way in which the remains have been preserved: by charring, mineralisation, waterlogging or desiccation.

Fragmented part

In the case of a cereal caryopsis fragment, the preserved part of the grain is specified using the nomenclature shown in Fig. 1. This information is necessary to be able to

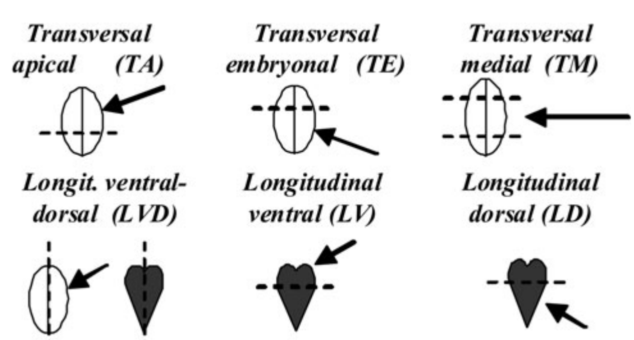

Fig. 1 Nomenclature of the different types of cereal caryopsis fragments (Antolín 2008)

calculate the minimum number of individuals (MNI), which we will present afterwards, and also to allow us to establish the correspondence between the different types of complementary fragmentation, especially between transversal apical and transversal embryonal fragments, in such a way that a majority presence of one type with respect to its complementary type can be used in combination with other evidence, as an indication that the remains were not fractured in situ.

The state of preservation of the pericarp

We use the following adjectives to refer to the state of preservation of the external surface of the grains (Fig. 2a):

– intact: absence of signs of erosion
– semi-intact: occasional signs of erosion
– semi-degraded: significant signs of erosion
– degraded: general erosion
– over-degraded: complete loss of the pericarp and the testa

Type of fragmentation

We differentiate between two types of caryopsis section.

The first is regular, straight and uniform. It is normally associated with fragmentation of human origin caused during excavation and sample processing (Knörzer 1981). The other is irregular, uneven and oblique, which is possibly caused by non-human post-depositional processes.

Shiny surface

Experimental studies link the shiny surface on cereal caryopses to their having been soaked before combustion (Valamoti 2002), although other experiments also show a correlation between vitrinite reflectance of pulse seeds and the temperature to which they were heated (Braadbaart et al. 2004).

The embryo

There are two more aspects to take into account with respect to seed embryos:

– The presence or absence of the embryo adhering to the caryopsis (Fig. 2e): this aspect has already been studied in experiments by other authors (Hall 2008) and it is of special interest at archaeological sites where there are large numbers of detached embryos or caryopses without embryos. Despite the fact that we do not know what causes this, for example incomplete charring and eventual loosening of the embryo, boiling of the seeds or other causes, we believe that after further experiments it will probably be of significant social and economic meaning.
– Embryo germination: the detection of germinated grains allows us to suggest intentional germination practices that were necessary for making fermented drinks or for storage practices. This aspect has already been noted by many authors (van der Veen 1989).

Degree of change due to the effects of charring

The charring process causes observable effects in cereal grains, such as their expansion, deformation, popping of the endosperm material, etc. Experimental studies have shown that it will probably be possible to find patterns that will allow us to interpret the changes undergone by the remains, and thus to gain knowledge of the conditions under which they were charred (Braadbaart 2008). Nevertheless, as far as the current state of research goes, it is not possible to analyze charring in a quantitative way. Therefore, these variables can only be analysed quantitatively at

Fig. 2 Examples of the classification of seed remains (Antolín 2008): **a** (from left to right) over-degraded, degraded, semi-degraded, semi-intact and intact caryopses; **b** aggregated caryopses; **c** popped grains; **d** grain fragments produced prior to charring; **e** (from left to right) caryopsis without an adhered embryo and caryopsis with an adhered embryo

the moment, in combination with the experimental results, to differentiate large fires, toasting, accidental burning or other processes that have resulted in charred seed remains.

Thus, it has been considered necessary to record the following variables (based on Braadbaart 2008). Each considered variable has a column assigned to it in our Excel table and its presence or absence is indicated numerically, as we explained above.

- Popped grains/protrusions (Fig. 2c): these usually appear in experiments heating cereals at temperatures of over 250°C, when the heating rates in °C/min are high (Braadbaart 2008). We differentiate between popped grains, a concept that defines the expansion of the endosperm of the grain, generating characteristic longitudinal striations but without allowing the endocarp substances to come out, and protrusions, a concept used to designate the visible popping of endosperm material out of the pericarp.
- Aggregated grains: grains forming clumps (Fig. 2b), adhered to each other (Bouby et al. 2005).
- Adhered particles: adherence of organic or mineral particles to the pericarp of the caryopses as a consequence of charring.
- Grain still attached to the spikelet or the chaff: this indicates, first, the absence and or inefficiency of dehusking and, secondly, exceptional charring conditions.
- Concave sides: experimental studies associate this with the high temperatures reached, as well as high heating rates.
- Pressure deformation: this deformation is characteristic of seed assemblages burnt in confined space inside containers; it leads the grains to deform each other due to swelling as the temperature rises.
- Total deformation of the grain: associated with high heating rates.

Numerical description: a proposal for counting the minimum number of individuals (MNI)

There are two basic methods of counting the number of individuals from cereal caryopses (Hillman et al. 1996). One is based only on the identification and counting of whole grains, assuming that they are present at the same relative percentages as those of fragments. This system is of no use for a taphonomic approach such as ours, since there are several agents that are detected by the degree and type of fragmentation per taxon. It should only be used, then, when whole seeds are representative of the complete assemblage and when it is obvious that there has not been any kind of erosion, transport or deposition of the remains, for example when a charred grain store is found in situ, with an intact container protecting it. The second method is based on identifying the presence of a diagnostic criterion, the embryo, as proposed by Jones (1990) and well received in the discipline. However, this type of counting has several drawbacks: on the one hand, no distinction is made in publications between whole caryopses and fragments, since fragments with embryos are recorded along with complete caryopses, which means that part of the basic taphonomic information is not specified; secondly, the rest of the fragments are not taken into account in the subsequent data handling, which means they are not included in the general interpretation of the assemblage; and finally, as a consequence, it provides a smaller or equal minimum number of individuals to that which would be obtained by taking into account all the fragments. This method is therefore unsuitable for the accurate description that our questions posed about the assemblage of Can Sadurní. Yet, it must be clarified that Jones's system is absolutely appropriate for daily archaeobotanical work, since it is fast and uncomplicated.

We therefore propose here an exclusive counting system for cereals that is not only more exact but—above all—also allows taphonomic interpretations to be carried out. In order to make the calculation, we need to take into account the different possible types of fragmentation described above (Fig. 1). The number of whole caryopses is added to the highest number of the transversal fragments, considering that a seed cannot generate more than one of each, to the highest number of the longitudinal fragments (longitudinal dorsal and longitudinal ventral), for the same reason mentioned above, and to them we add the number of longitudinal ventral-dorsal fragments divided by two, as each grain can give rise to two longitudinal ventral-dorsal fragments (Antolín 2008; Antolín and Alonso 2009; Antolín et al. in press b). We believe this system makes up for the deficiencies of the other techniques. Below, our results are compared to the ones that would have been obtained with Jones's system.

For the analysis of the results we will not be using any system of numerical description or data standardisation that has not been explained or discussed by other authors (Hastorf 1988; Miller 1988; Popper 1988, among others).

The case study: the seed assemblage of the cave of Can Sadurní

The cave of Can Sadurní is on the side of a small hill in the calcareous massif of the Serra de Garraf, overlooking the fertile plain of Begues (Barcelona province, Catalonia, Spain; Fig. 3). During the excavations carried out in the cave over the last 30 years, up to 21 different archaeological strata have been identified, with a chronology going from approximately 11000 cal yrs B.C. up to the last century (Blasco 1993; Blasco et al. 1983, 1999, 2005a, b; Edo

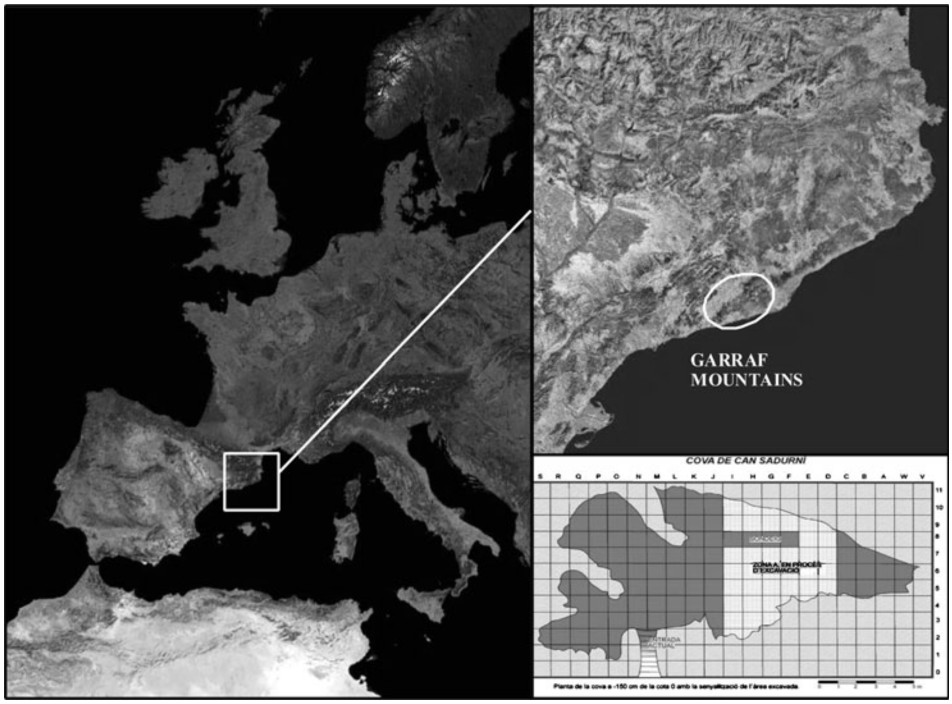

Fig. 3 Ground plan and location of the cave of Can Sadurní in the setting of the Massís del Garraf in Catalonia (Spain), with the area of the 1 × 4 m test trench delimited

et al. 1986; Antolín 2008). In this paper we present the results obtained from Layer 18, which corresponds to the earliest Neolithic phase found in the cave and which represents one of the earliest dates for the Neolithic in the northeastern Iberian Peninsula (5475–5305 cal yrs B.C.; Blasco et al. 2005a). Layer 18 is so far a unique case in the area, as it is a funerary deposit. The remains of between seven and 11 individuals have been found, according to the DNA studies (C. Gamba and E. Fernández, personal communication). These remains were accompanied by rich offerings of several pottery vessels full of carbonised seeds, the intentional deposition of sheep extremities, plaques made of sea shells and other elements (Blasco et al. 2005a). The pottery vessels had been broken in situ, since pieces of the same vessels were close to one another, and signs of fire can be found in nearly all the archaeological materials found around them, including large amounts of charcoal, although we cannot assume at the moment that the fire took place at the same place where the assemblage was found, since the soil micromorphological analysis of one sample from the northeastern profile of the trench seems to show no or very low evidence of burning and a lack of ashes (Antolín et al. in press a). The actual working hypothesis is that there may have been a fire, perhaps for ritual purposes, that affected the offering of vessels containing seeds, part of the human remains (only cranial fragments are burnt), and grave goods (Antolín et al. in press a). The interest of the material for our study is that it was intentionally deposited and so it results from a specific action, which not only gives the results a social significance of high interest but also allows an approximation of the processes that were carried out to prepare the cereal grains for the offering (it would be a class A assemblage according to Hubbard and Clapham, 1992). At the same time, since pottery vessels were not found intact, but broken, the taphonomic history of the assemblage is seen as a very important aspect in order to determine its significance.

The results are from two excavation phases: on the one hand a 1 × 4 m test trench excavated between 1998 and 2004 (squares F8, G8, H8 and I8) and, on the other, the 2008 rescue excavation of part of a fifth square (I7, see Fig. 3). All of the sediment was floated using various sieves for collecting floating residues with a minimum mesh size of 0.5 mm. The sediment from the first excavation phase was recovered and processed by the excavation team and the record was considerably affected by the archaeological and laboratory work. For this reason, some of the taphonomic variables were not taken into account beyond a qualitative level, so that the record was considerably distorted. However, its study allowed us to put forward some initial hypotheses (see Antolín 2008; Antolín et al. in press b) and to create the database presented in this paper. It was in the second phase of the excavation that we were able to control the sediment processing and the recovery of the remains. For identification we used a binocular microscope and we based our findings on biometric criteria to distinguish between the different taxa, at all times referring to our own seed reference collection and the different reference atlases available and the specialist literature (for cereals, van Zeist 1970; Renfrew 1973; Zohary and Hopf 2000; and for the other taxa, Schoch et al. 1988; Cappers et al. 2006; Bojnansky and Fargasova 2007). Nomenclature of cereal names follows Zohary and Hopf (2000) for cereals and the *Flora Manual dels Països Catalans* (Bolós et al. 2005) for the wild plants. Given that what we present here corresponds to only 5 m^2 of excavation, the results must be considered as preliminary and their interest lies in the system of characterisation and quantification applied to them.

A total of approximately 60,000 plant remains were recovered. Of them, 887 come from a single litre of processed sediment from square I7, while the others correspond to squares F8, G8, H8 and I8, excavated during the first phase. Of this latter assemblage we studied approximately 70% of the remains, 41,908 to be precise.

Results

As can be seen in Table 1, we identified 14 different taxa, five of which are domestic cereals (*Hordeum vulgare*, *H. vulgare* var. *nudum*, *Triticum aestivum/durum/turgidum*, *T. dicoccum*, *T. monococcum*), five are synanthropic plants (*Avena* sp., *Chenopodium album*, *C. hybridum*, *Lathyrus* sp., *Polygonum* sp.) and four are other wild plants (*Arbutus unedo*, *Pinus* sp., *Quercus* sp., *Rubus idaeus*). In Table 2, the number of remains by type of fragmentation and the number of whole grains is shown by taxon, as well as the calculation of the remaining MNI.

Taphonomic aspects

As can be seen in Fig. 4a, the fragmented remains make up more than 80% of the assemblage in all the squares except I7, in which the percentage is somewhat lower. The high rate of fragmentation is clearly observed when calculating the ratio between the number of remains and the MNI (see Table 1), which is 5.506, a very high figure.

The majority of this fragmentation occurred after charring, as can be seen in Fig. 4b. The type of section by taxon was studied for square I7 (Fig. 4c) and we can see a clear predominance of the regular section; the barley remains have only irregular fractures, but they are also the least numerous and therefore statistically insignificant.

However, not only the fragmented remains are important in a taphonomic analysis. The presence of complete elements is also very significant. Figure 4d shows how naked wheat has a much higher percentage of whole grains than the rest of the taxa in all the squares.

The post-depositional effects prior to the excavation are shown in Fig. 4e, where we can see how more than 50% of all the plant remains from square I7 show significant signs of degradation. The barley remains have a somewhat lower percentage, although since we are dealing with a very low number of remains, just ten, in reality they are statistically insignificant.

We studied the effects of charring on the remains from square I7 and, as can be seen in Fig. 4f, they do not show marked effects of heat; the case of barley is once again distorted by the low number of remains, although we should take into account the fact that barley is more sensitive than glume wheats to the effects of charring (Boardman and Jones 1990).

The large percentage of remains in which the embryo is detached is shown in Fig. 4g. Nevertheless, we cannot interpret this information because we do not know what causes the embryo to separate from the seed, a question we hope to be able to answer in the future.

To conclude with the taphonomic aspects, the percentage of fragmentation prior to charring with respect to the MNI for each square and by taxon is shown in Fig. 4h. The quantification of these data and their standardisation to calculate the MNI allow us to compare the results and obtain surprising differences between taxa. Mainly glume wheats show this type of fragmentation. *Triticum monococcum* (einkorn) has a significantly higher constant percentage than *T. dicoccum* (emmer).

Taxonomic variability

99.7% of the total identified MNI corresponds to cereals (Fig. 5a) and more than 90% are *Triticum* sp. Among the cereals, in terms of relative percentages (Fig. 5b), glume wheats predominate in the assemblage, particularly emmer. Naked wheat also has a major presence, although this should be qualified, due to the question of over-representation which we have already mentioned. On the other hand, barley, both hulled and naked, appears almost fortuitously, although with a certain consistency. The presence of chaff remains is also very low and we were only able to identify fragments belonging to glume wheats. It is also important to emphasise that we were unable to find any rachis fragments.

There was very little presence of synanthropic plants, barely ten remains in the studied record. The rest of the wild plant remains are also numerically insignificant in the recovered assemblage (see Table 1).

Discussion

Taphonomic analysis

The results of the taphonomic analysis show that there is a very high percentage of grain fragmentation after charring, even in square I7, for which the recovery, sieving and

Table 1 Results of the seed identification: taxa, part represented, MNI, the number of remains per quadrant and the totals

	Taxa	Represented part	F8	G8	H8	I7	I8	Total
DOMESTIC PLANTS	*Hordeum vulgare*	Caryopsis fragment	59	34	84	6	38	221
		Pre-charring caryopsis fragment	2	2	1		1	6
		Caryopsis	34	7	68	7	11	127
		MNI	**67**	**23**	**105**	**10**	**50**	**255**
		Total remains	95	43	153	13	50	354
	Hordeum vulgare var. *nudum*	Caryopsis fragment	8	3	14		3	28
		Caryopsis	7	3	18		1	29
		MNI	**11**	**4**	**27**		**4**	**46**
		Total remains	15	6	32		4	57
	Hordeum sp.	Caryopsis fragment	10	19	1		1	31
	Hordeum/Triticum	Caryopsis fragment	134		2			136
	Triticum aestivum/durum	Caryopsis fragment	75	36	221	15	25	372
		Pre-charring caryopsis fragment	2		1		3	6
		Caryopsis	425	241	1,147	75	71	1,959
		MNI	**486**	**261**	**1,273**	**85**	**87**	**2,192**
		Total remains	502	277	1,369	90	99	2,337
	T. dicoccum	Caryopsis fragment	1,158	229	932	35	42	2,396
		Pre-charring caryopsis fragment	107	23	90	13	3	236
		Caryopsis	1,102	333	1,106	95	93	2,729
		Glume base	1					1
		Glume base fragment					12	12
		Spikelet fork	10	7	16	6	16	55
		Spikelet fork fragment		1		2		3
		MNI	**1,772**	**459**	**1,663**	**122**	**118**	**4,134**
		Total remains	2,378	593	2,144	151	166	5,432
	T. dicoccum/monococcum	Glume base	11	20	15		13	59
		Spikelet fork	3	9	2		2	16
		Total remains	14	29	17		15	75
	T. monococcum	Caryopsis fragment	87	45	207	18	50	407
		Pre-charring caryopsis fragment	35	34	130	24	3	226
		Caryopsis	95	97	379	32	45	648
		Glume base	1		8	1		10
		Spikelet fork			5		3	8
		MNI	**157**	**140**	**541**	**53**	**70**	**961**
	Triticum sp.	Total remains	218	176	729	75	101	1,299
		Embryo	13	2	18	4	55	92
		Caryopsis fragment	5,336	6,963	11,243	484	8,019	32,045
		Pre-charring caryopsis fragment	77	91	276	65	223	732
		Glume base		1		5		6
		Total remains	5,426	7,057	11,537	558	8,297	32,875
SYNANTHROPIC PLANTS	cf. *Avena* sp	Caryopsis fragment					1	1
	cf. Umbelliferae	Mericarp					1	1
	Chenopodium album	Nutlet					1	1
	Chenopodium hybridum	Nutlet		1				1
	Lathyrus sp.	Cotyledon fragment			1			1
	Papilionaceae	Cotyledon fragment	1		3			3
	Polygonum sp.	Fruit fragment			1			1
	Arbutus unedo	Fruit fragment		2	3			5
OTHER WILD PLANTS	Unidentified fruit	Fruit stone fragment		1	1			2
	Pinus sp.	Cone scale fragment			3			3
	Quercus sp.	Acorn fragment	1					1
	Rubus idaeus	Kernel					1	1
	Unidentified	Fragment	90	11	37		22	160
		Complete			17			17
		Total remains	90	11	54		22	177
		Total remains	**8,874**	**8,215**	**16,050**	**887**	**8,759**	**42,785**
		Total MNI	**2,585**	**902**	**3,658**	**262**	**355**	**7,770**

Table 2 Number of remains per taxon according to the fragmented or represented part and the calculation of the MNI per quadrant

Taxa	Preserved part	F8	G8	H8	I7	I8	Total
Hordeum vulgare	Longitudinal ventral	2					2
	Longit. ventral-dorsal	1	1	2			4
	Transversal apical	17	11	36	1	14	79
	Transversal embryonal	11	15	16	3	14	59
	Transversal medial	30	9	27	2	11	79
	Complete caryopsis	34	7	68	7	11	
	other			4			4
	MNI	**67**	**23**	**105**	**10**	**25**	**230**
H. vulgare var. *nudum*	Longit. ventral-dorsal					1	1
	Transversal apical	4	1	9		2	16
	Transversal embryonal	2	1	2			5
	Transversal medial	2	1	3			6
	Complete caryopsis	7	3	18		1	
	MNI	**11**	**4**	**27**		**4**	**46**
Triticum aestivum/durum	Longitudinal dorsal			2			2
	Longitudinal ventral	3		2	2	1	8
	Longit. ventral-dorsal	26	11	62	8	6	113
	Transversal apical	45	11	93	4	12	165
	Transversal embryonal	2	14	58	1	9	84
	Transversal medial	1		5			6
	Complete caryopsis	415	241	1,147	75	71	
	MNI	**476**	**261**	**1,273**	**85**	**87**	**2,182**
T. dicoccum	Longitudinal ventral	1					1
	Longit. ventral-dorsal	156	20	118	5	5	304
	Transversal apical	591	100	498	16	16	1,221
	Transversal embryonal	440	116	358	24	22	960
	Transversal medial	76	16	48	3	2	145
	Complete caryopsis	1,102	333	1,106	95	93	
	other	1					1
	MNI	**1,772**	**459**	**1,663**	**122**	**118**	**4,134**
T. monococcum	Longit. ventral-dorsal	2		4	2	1	9
	Transversal apical	56	32	160	20	21	289
	Transversal embryonal	61	43	152	15	24	295
	Transversal medial	3	4	21	4	7	39
	Complete caryopsis	95	97	379	32	45	
	other				1		1
	MNI	**157**	**140**	**541**	**53**	**70**	**961**

storing processes were done appropriately; nevertheless, for this square the fragmentation is lower and a higher percentage of it occurred prior to charring (see Figs. 4a, b). In any case, the high proportion of fragmented grains results in a lower degree of representativity of the assemblage, even though it is somewhat lessened by our MNI counting system, as we will show below. More than 30,000 remains were only identified to genus level, which surely distorts the relative percentages of the identified remains. Besides, this fragmentation seems not to have affected all taxa equally, since naked wheat has consistently higher percentages of complete caryopses. One possible reason for this may be that naked wheat grains are more resistant to certain taphonomic processes, or that there is some relation to the fact that it is a free-threshing wheat and is much easier to process/dehusk. However, there might also be simple identification problems. In any case, the fact is that the lower proportion of fragmentation results in an over-representation of naked wheat in the assemblage, as the greater presence of whole remains means that they are

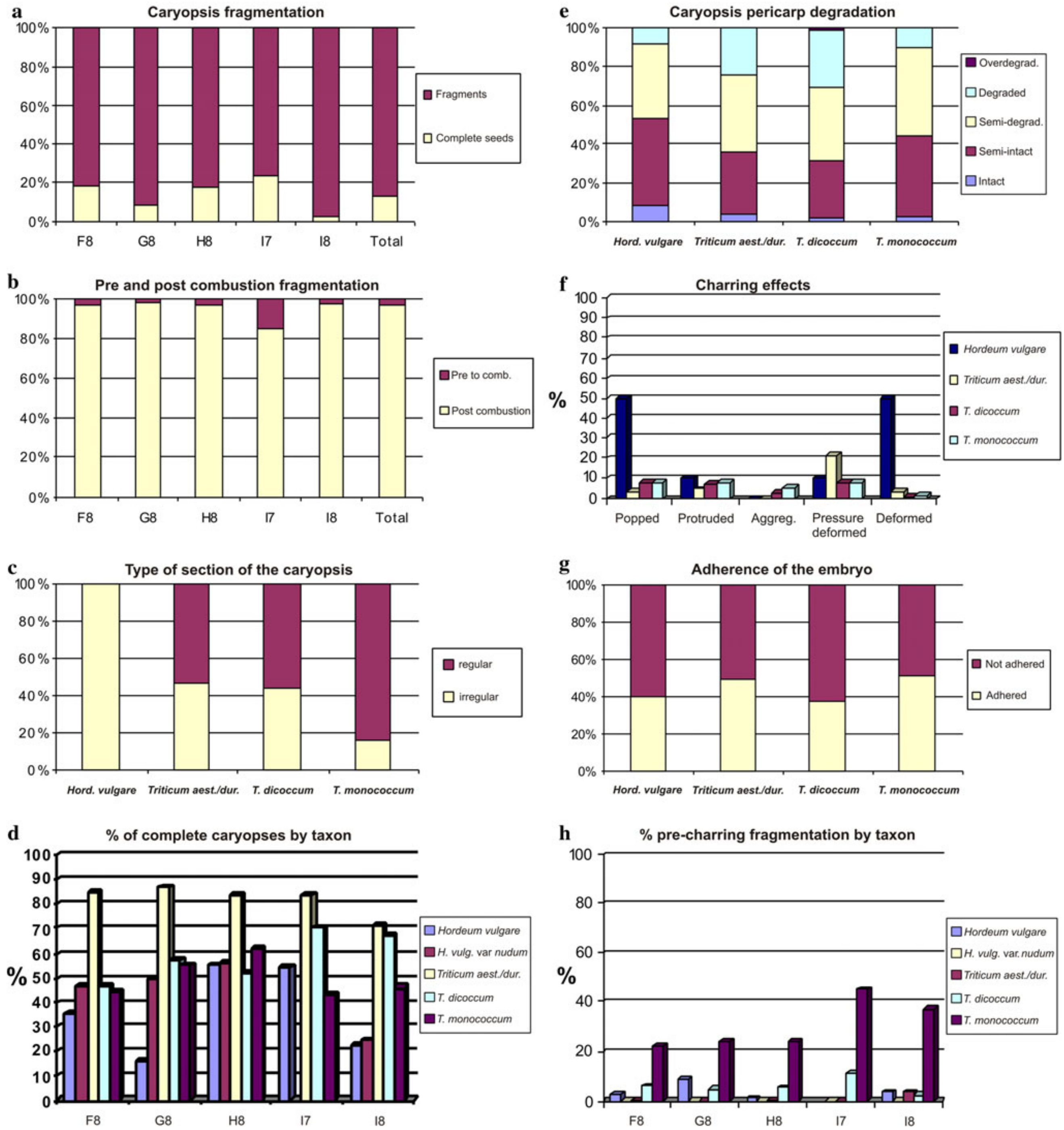

Fig. 4 Taphonomic aspects of the assemblage (when squares do not appear in the graphs, these only show the results of square I7)

more likely to be recovered and identified, giving a larger MNI. These facts, therefore, should be taken into account when evaluating the relative importance of the different taxa in the assemblage.

The observed fragmentation could have been caused both during the excavation process, since there are high percentages of regular sections, and during ancient post-depositional processes. The fact that the remains recovered from square I7 show significant percentages of irregular sections demonstrates that careful recovery techniques have not resulted in a much less fragmented assemblage. Therefore, it seems to indicate that the fragmentation is due to ancient post-depositional processes. This fact, linked to the state of preservation of the pericarps of the grains from the same square, which are significantly degraded, leads us to suggest the existence of some kind of erosion in the

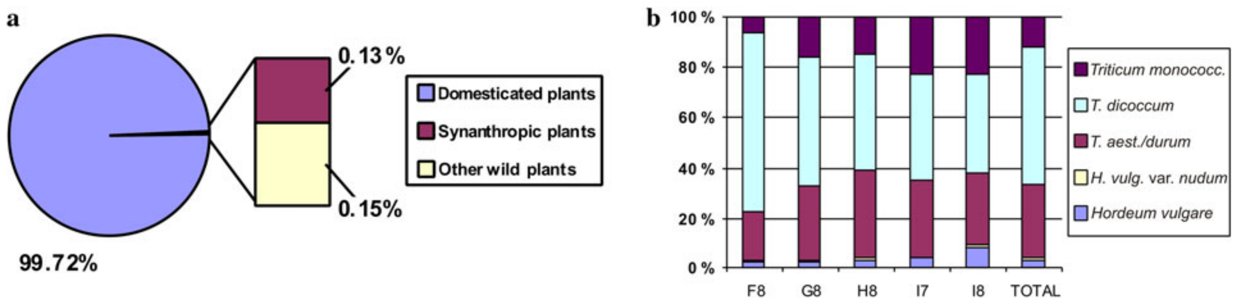

Fig. 5 Taxonomic variability of the assemblage

assemblage. This happened some time during the displacement process of the vessels that contained the grains, which eventually broke and dispersed their contents. Whether this was an intentional ritual or not still remains unclear. Therefore, the assemblage cannot be considered as being in situ. However, we cannot specify the degree of displacement based on the study of the remains from a single square, and we hope that future studies will help to clarify this aspect.

We believe that a good argument for the assemblage having been burnt soon after its deposition can be found in the absence of germinated seeds and those eaten by insects, as would have normally have happened under the damp conditions inside the cave, as seen in other similar cases (Bouby et al. 2005).

The slight evidence of the effects of heat on the caryopses probably corresponds to low temperature charring conditions at 250–350°C and a relatively short exposure to heat. The pressure deformation, although low, leads us to think that the remains could have been charred inside the vessels. This would have created a low oxygen environment, thus preserving the seeds in the condition in which they have reached us today. Also, the presence of seed aggregates may suggest this. If we take into account the few signs of charring that indicate high temperatures, we can confirm that the conditions of carbonisation do not appear to be the reason for the rarity of chaff remains, which are definitely less resistant to high temperatures or long exposure to heat (Boardman and Jones 1990). Since this possibility has been ruled out, the rarity of agricultural by-products leads us to believe that the assemblage had already been carefully cleaned before being deposited.

Finally, one of the most interesting results of this study is that part of the fragmentation took place prior to charring. Glume wheats show the most constant and significant percentage of fragmentation. In addition, we observe a low percentage in the assemblage with fragmentation prior to charring. This means we can rule out the possibility that there was an intentional fracturing of seeds for the production of *bulgur*-type foods such as cracked wheat. In contrast, it leads us to think that its appearance could be due to dehusking. Moreover, einkorn shows significantly higher percentages of fragmentation. This information is particularly important in an assemblage in which we find a mixture of different cereals. Without considering the degree of fragmentation, this would be interpreted as evidence of the mixed cultivation of the different cereals to ensure the success of the harvest. If the detected cereals really had been reaped and processed together, our data would suggest that during dehusking, the einkorn would have been less resistant and would have fragmented more easily. This hypothesis is difficult to accept in this context, in which einkorn is found in much smaller amounts than emmer. It seems to be much more likely that the differential fragmentation means that the wheat taxa were processed separately and that they were therefore also obtained separately. The different percentages of both species could even indicate different dehusking techniques. The experimental work of Meurers-Balke and Lüning (1992) showed that when dehusking is carried out using a stone mill, between 20 and 40% (sometimes more, depending on several variables like the number of working actions and pre-treatment methods) of the grain is fragmented, whereas when a mortar is used, this percentage is less than 5%. Therefore, our results suggest that the einkorn was dehusked in a stone mill and the emmer with another less aggressive, mortar-type system. In fact, a quern stone with very dense signs of wear of the cereal processing type was recovered among the rest of the funerary offers (Ache 2008).

In conclusion, thanks to the quantitative study of grain fragmentation, we can hypothesise that the naked wheat (practically without any case of fragmentation prior to charring), emmer and einkorn may have been cultivated and processed independently. Moreover, the technique or techniques used for the dehusking caused the fragmentation of some of the grains, which could indicate the use of different dehusking methods.

Evaluation of the proposed system of counting the MNI

The results of the calculation of the MNI are shown, both following our proposed system and Jones's system (Jones

Table 3 Results of the calculation of the MNI per taxon and quadrant using both our proposed system and the system of counting remains with embryo ends (Jones 1990)

Taxon	Preserved part	F8	G8	H8	I7	I8	Total
Hordeum vulgare	MNI	67	23	105	10	25	230
	Remains with embryo	45	22	84	10	25	186
	Percentage loss	**32.84**	**4.35**	**20**	**0**	**0**	**19.13**
Hordeum vulgare var. *nudum*	MNI	11	4	27		4	46
	Remains with embryo	9	4	20		1	34
	Percentage loss	**18.18**	**0**	**25.93**		**75**	**26.09**
Triticum aestivum/durum	MNI	476	261	1,273	85	87	2,182
	Remains with embryo	417	255	1,207	76	80	2,035
	Percentage loss	**12.39**	**2.30**	**5.18**	**10.59**	**8.05**	**6.74**
Triticum dicoccum	MNI	1,772	459	1,663	122	118	4,134
	Remains with embryo	1,542	419	1,464	119	115	3,659
	Percentage loss	**12.98**	**8.71**	**11.97**	**2.46**	**2.54**	**11.49**
Triticum monococcum	MNI	157	140	541	53	70	961
	Remains with embryo	156	140	531	47	69	943
	Percentage loss	**0.64**	**0**	**1.85**	**11.32**	**1.43**	**1.87**

The difference between the two systems is indicated as a percentage

1990) (Table 3). With the quantifying system of Jones (1990), percentages are lower which depends on several factors: one is the taxon, and naked wheat and einkorn show low percentages of loss while emmer and barley show more. A second is the total number of remains, and generally the degree of loss is higher when the total number of remains is low. A third factor can be the taphonomic agents that affected the assemblage, and when remains become fragmented in situ the correspondence index between complementary fragments is expected to be high and, as a consequence, the degree of loss will be very low. Although these results cannot be considered as a reference for all archaeobotanical studies, it must be noted that using the traditional system of counting only remains with their embryo ends present results in lower MNIs, the range of which is between 5 and 25%, and moreover, the proportion is different for individual taxa. We think that our system gives more accurate MNIs.

The quantifying system proposed here probably does not only give more accurate MNIs, but also—and maybe more importantly - allows better results in taphonomic analysis. With the "traditional" counting system we would only have obtained 6,013 individuals in the assemblage instead of 7,770, which is 22% less (see Table 1).

This might not be statistically significant in large assemblages but archaeobotanists should consider the differences arising from the application of different counting systems. The system proposed here is of use in special assemblages such as the one presented here, with much fragmentation. Because our method considers all types of fragments, it is very likely that the total MNI rises and a statistically significant number of remains is achieved. But it can also be useful in secondary types of assemblages such as pit fills, where the correspondence between complementary fragments is very likely to be low and, as a consequence, our counting system can significantly increase the final MNI.

Taxonomic diversity

The taphonomic conclusions that we have obtained show unequal grades of representativity of the results obtained for each taxon. Thus, we can confirm that the relative percentages of the different cereal taxa counted are to be reconsidered, especially those of wheats. They probably do not represent the real importance of each taxon in the assemblage. First of all, naked wheat is overrepresented. In addition, more than 30,000 remains could not be identified to species level. This may completely distort the proportions in our assemblage. For this reason we believe that it is not possible to speak of the relative importance of each taxon in the presented assemblage.

The presence of both naked and hulled barley is a different case, since most of the unidentified cereal fragments clearly belonged to *Triticum* sp. (wheat), and we cannot state that fragmentation has affected them so dramatically. Barley appears in such low percentages that it is difficult to consider the possibility that it was harvested intentionally. There are, then, two possibilities for its appearance; either it may have been growing as a weed, or maybe it came from cereal crops grown previously on the same field. In any case, it is still surprising that barley grains are so constantly present even when the assemblage seems to be absolutely clean of impurities.

As for the synanthropic plants, all the taxa recovered are either segetals (weeds) or ruderal plants which could have come from the cornfields. Only the presence of *Chenopodium hybridum* stands out, as it is characteristic of damp climates or well-irrigated fields. Micromorphological studies of sediments (M. Bergadà, personal communication) indicate that the period in the 6th millennium cal B.C. in which the assemblage was deposited was wetter than today and that it is therefore possible that the vegetation was significantly different to that currently found in the area (Blasco et al. 1999).

Finally, regarding the rest of wild plants, most of the taxa could have been part of the fuel used to burn the whole ritual deposition, as the anthracological (charcoal) study showed mainly deciduous and evergreen oak (*Quercus ilex/coccifera*) charcoal, as well as *Arbutus* (strawberry tree) (Antolín 2008; Antolín et al. in press b).

Other cereal concentrations of the early Neolithic period from the eastern coast of the Iberian Peninsula

To date, Can Sadurní appears to be truly unique in the Neolithic of the Iberian Peninsula, as there are no other studies of archaeobotanical assemblages of this period from a funerary context. One of the few comparable assemblages was studied by M. Hopf (1966) from Cova de l'Or (Beniarrés, Alacant Province; ca. 5600 cal yrs B.C.). Two samples of this find were studied. One of them was mainly composed of barley and, to a lesser extent, naked wheat and emmer. In the second sample, however, there was mainly naked wheat, with significantly smaller amounts of emmer and barley. Einkorn was the least common cereal in both samples, not exceeding 1% of the total remains studied. The author highlighted the absence of either threshing or adhered chaff remains in the assemblage, meaning that they had been completely processed, as at Can Sadurní. However, as far as we know, there is always a slight presence of weeds and cereal chaff in the Neolithic seed record on the Iberian Peninsula (Buxó 1997; Zapata et al. 2004). We believe the possibility that the Cova de l'Or remains could also have been offerings should not be ruled out. We have to bear in mind that the cereals were found together with Cardial ware, which had outstanding anthropomorphic decorations of people praying and musical instruments made of bird ulnae (Arias-Gago et al. 2001), and with a similar chronology to that of Can Sadurní (around 5500 B.C.). Therefore, these might be two examples of the same social practice. Unfortunately there are still many gaps in the research and interpretations cannot go any further.

As far as the rest of the archaeological sites in the northeastern Peninsula are concerned, only one sufficiently large concentration of cereals has been found, at the well-known lacustrine archaeological site of La Draga (Banyoles, Girona Province; 5300-5150 cal yrs B.C.; Tarrús 2008), where there is an enormous amount of carbonised seed material made up of naked wheat and a much smaller proportion of hulled barley (Buxó et al. 2000). This assemblage most probably goes back to a conflagration of the whole settlement together with the grain stores, resulting in a burnt layer.

The large amount of glume wheat found at Can Sadurní is, therefore, an isolated case to date in the Mediterranean part of the Iberian Peninsula, although there does not appear to be an established pattern for the area. We do not believe, on the other hand, that the concentrations of carbonised cereals reflect the economic importance of each type of cereal in the past. It is possible that when they were used as offerings, the composition corresponded to particular criteria established by the people concerned.

Conclusions

The seed assemblage at Can Sadurní appears to be the result of an intentional deposit of grains in pottery vessels that were subsequently burned, perhaps as part of some type of funerary ritual (Antolín et al. in press a). The seeds were found fully processed with no chaff remains and cleaned of all impurities. The amount of labour involved in such an offering, bearing in mind that it included different cereals, probably harvested and processed separately, adds more weight to the hypothesis that it was indeed an offering of great significance. The fact that another possible similar assemblage was found in Cova de l'Or (Beniarrés, Alacant Province) (Hopf 1966), also corresponding to the very beginning of the Neolithic in the Iberian peninsula, throws some light on a possible ritual of the first farmers of the area that would have taken place in caves and always involved cereals and Cardial ware pottery, among other artefacts. We hope future investigations can increase our knowledge of this first phase of occupation, which has still huge gaps.

On a methodological level, we would like to conclude by stating that the recording system presented here still has a long way to go. It is necessary to do more experimental work in order find causes of the state of grain assemblages as a whole, and especially how they were affected by each taphonomic factor, for example: what percentage of protruded caryopses should be expected when an intentional fire of 400°C heats an assemblage for 45 min? What density of grains attached to the spikelet and glumes are to be expected after dehusking when conditions of charring allow their preservation? Such questions, that we have now presented in very simplistic terms, and many others, should be our main aims of future research in order to understand both the conditions that created the studied assemblages as we recover them and their representativity.

The proposed methodology increases the possibilities for describing seed assemblages and, in short, brings us a more detailed knowledge of our subject of study, as well as allowing us to make interesting economic interpretations of the results. Thus, seed-by-seed description has to be done if we want to evaluate not only the presence of some taphonomic factors but also their intensity, which is absolutely essential so as to be able to state the representativity of an assemblage.

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References

Ache M (2008) Gestió, transformació i ús dels artefactes macrolítics. Una perspectiva diacrònica. Departament de Prehistòria, Universitat Autònoma de Barcelona. Unpubl master thesis

Alonso N (2008) Crops and agriculture during the Iron Age and late antiquity in Cerdanyola del Vallès (Catalonia, Spain). Veget Hist Archaeobot 17:75–84

Alonso N, Buxó R, Rovira N (2007) Recherches sur l'alimentation végétale et l'agriculture du site de Lattes-Port Ariane: étude des semences et fruits. Lattara 20:219–249

Antolín F (2008) Aproximació a l'estudi de la percepció i la interacció amb l'entorn vegetal en societats caçadores recol·lectores i agricultores ramaderes (10,000–4,000 cal ANE). Resultats de l'estudi arqueobotànic del jaciment arqueològic de la Cova de Can Sadurní (Begues, Baix Llobregat). Departament de Prehistòria, Universitat Autònoma de Barcelona. Treball de Recerca de Tercer Cicle inèdit. http://hdl.handle.net/2072/40656

Antolín F (in press a) Les propietats del registre carpològic: el punt de partida per a l'estudi de la seva representativitat arqueològica. Cypsela 18

Antolín F (in press b) La potencialitat del registre carpològic per a l'estudi de la percepció, el treball i el consum de recursos vegetals per part de les societats prehistòriques. Revista d'Arqueologia de Ponent 20

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). Andavira, Santiago de Compostela, pp 177–196

Antolín F, Ache M, Bergadà M, Blasco A, Buxó R, Edo M, Gibaja JF, Mensua C, Palomo A, Piqué R, Ruiz J, Saña M, Verdún E, Villalba MJ (in press a) Aproximació interdisciplinària a l'acció del foc en les inhumacions i aixovars del Neolític antic cardial de Can Sadurní (Begues, Baix Llobregat). Actes de les Jornades Internacionals de Prehistòria del Garraf. Begues, 5–7 de Desembre del 2008

Antolín F, Mensua C, Piqué R (in press b) The perception of the environment during the Mesolithic and the Early Neolithic in Can Sadurní (Begues, Barcelona). A view from the archaeobotanical data. In: Proceedings of the Fourth International Meeting of Anthracology, Brussels 8–13 September 2008. Oxford, BAR International Series

Arias-Gago A, Martí B, Martínez Valle R, Juan-Cabanilles J (2001) Los tubos de hueso de la cova de l'Or (Beniarrés, Alicante). Instrumentos musicales en el Neolítico antiguo de la Península Ibérica. Trabajos de Prehistoria 58:41–67

Blasco A (1993) Les ocupacions prehistòriques a la cova de Can Sadurní. Universitat de Barcelona, Unpubl Licenciature Thesis

Blasco A, Edo M, Millán M, Blanch M (1983) La Cova de Can Sadurní, una cruïlla de camins. Pyrenae 17(18):11–53

Blasco A, Edo M, Villalba MJ, Buxó R, Juan J, Saña M (1999) Del cardial al postcardial en la cueva de Can Sadurní (Begues, Barcelona). Primeros datos sobre su secuencia estratigráfia, paleoeconómica y ambiental. II Congrés de Neolític a la Península Ibèrica, SAGUNTUM-PLAV, Extra- 2:59–67

Blasco A, Edo M, Villalba MJ, Saña M (2005a) Primeros datos sobre la utilización sepulcral de la Cueva de Can Sadurní (Begues, Baix Llobregat) en el Neolítico Cardial. In: Arias Cabal P, Ontañón Peredo R, Garcá-Moncó Piñero C (eds) III Congreso del Neolítico en la Península Ibérica. Santander 5 a 8 de octubre de 2003. (Monografías del Instituto Internacional de Investigaciones Prehistóricas de Cantabria, 1) Santander, pp 625–633

Blasco A, Edo M, Villalba MJ (2005b) Cardial, epicardial y postcardial en Can Sadurní (Begues, Baix Llobregat). El largo fin del Neolítico Antiguo en Cataluña. In: Arias Cabal P, Ontañón Peredo R, Garcá-Moncó Piñero C (eds) III Congreso del Neolítico en la Península Ibérica. Santander 5 a 8 de octubre de 2003. (Monografías del Instituto Internacional de Investigaciones Prehistóricas de Cantabria, 1) Santander, pp 667–677

Boardman S, Jones G (1990) Experiments on the effects of charring on cereal plant components. J Archaeol Sci 17:1–11

Bojnansky V, Fargasova A (2007) Atlas of seeds and fruits of central and East-European flora. The Carpathian Mountains Region. Springer, Dordrecht

Bolós O, Vigo J, Masalles R, Ninot JM (2005) Flora manual dels Països Catalans, 3rd edn. Pòrtic, Barcelona

Bouby L, Fages G, Treffort JM (2005) Food storage in two Late Bronze Age caves of Southern France: palaeoethnobotanical and social implications. Veget Hist Archaeobot 14:313–328

Braadbaart F (2008) Carbonization and morphological changes in modern dehusked and husked Triticum dicoccum and Triticum aestivum grains. Veget Hist Archaeobot 17:155–166

Braadbaart F, van der Host J, Boon JJ, van Bergen F (2004) Laboratory simulations of the transformation of emmer wheat as a result of heating. J Therm Anal Calorim 77:957–973

Buxó R (1997) Arqueología de las plantas. La explotación económica de las semillas y frutos en el marco mediterráneo de la Península Ibérica, Crítica (Grijalbo), Barcelona

Buxó R, Rovira N, Saüch C (2000) Les restes vegetals de llavors i fruits. In: Bosch A, Chinchilla J, Tarrús J (eds) El poblat lacustre neolític de la Draga. Excavacions de 1990 a 1998. (Monografies del CASC, 2) Museu d'Arqueologia de Catalunya, Girona

Cappers RTJ, Bekker RM, Jans JEA (2006) Digitale zadenatlas van Nederland. Barkhuis, Groningen

Edo M, Millán M, Blasco A, Blanch M (1986) Resultats de les excavacions de la Cova de Can Sadurní (Begues, Baix Llobregat). Tribuna d'Arqueologia 1985–1986:33–41

Hall BM (2008) Differentiation of charred corn samples via processing methods: an ethno-archaeological and experimental approach. University of Wisconsin-La Crosse. Unpubl Senior Thesis. http://digital.library.wisc.edu/1793/37044

Hastorf CA (1988) The use of paleoethnobotanical data in prehistoric studies of crop production, processing, and consumption. In: Hastorf CA, Popper VS (eds) Current paleoethnobotany. Analytical methods and cultural interpretations of archaeological plant remains. University of Chicago Press, Chicago, pp 119–144

Hillman GC, Mason S, de Moulins D, Nesbitt M (1996) Identification of archaeological remains of wheat: the 1992 London workshop. Circaea 12:195–209

Hopf M (1966) *Triticum monococcum* L. y Triticum dicoccum Schübl, en el neolítico antiguo español. Archivo de Prehistoria Levantina 16:53–74

Hubbard RNLB, al Azm A (1990) Quantifying preservation and distortion in carbonized seeds; and investigating the history of *Friké* production. J Archaeol Sci 17:103–106

Hubbard RNLB, Clapham A (1992) Quantifying macroscopic plant remains. Rev Palaeobot Palynol 73:117–132

Jones G (1990) The application of present-day cereal processing studies to charred archaeobotanical remains. Circaea 6:91–96

Knörzer KH (1981) Auswertung von Großrestuntersuchungen für Aufklärung von Siedlungszusammenhängen. Zeitschrift für Archäologie 15:73–76

Margaritis E, Jones M (2008) Crop processing of *Olea europaea* L.: an experimental approach for the interpretation of archaeobotanical olive remains. Veget Hist Archaeobot 17:381–392

Meurers-Balke J, Lüning J (1992) Some aspects and experiments concerning the processing of glume wheats. In: Anderson PC (ed) Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques. CNRS, Monographie du CRA n°6, Paris, pp 341–362

Miller NF (1988) Ratios in paleoethnobotanical analysis. In: Hastorf CA, Popper VS (eds) Current paleoethnobotany. Analytical methods and cultural interpretations of archaeological plant remains. University of Chicago Press, Chicago, pp 72–85

Popper VS (1988) Selecting quantitative measurements in paleoethnobotany. In: Hastorf CA, Popper VS (eds) Current paleoethnobotany. Analytical methods and cultural interpretations of archaeological plant remains. University of Chicago Press, Chicago, pp 53–71

Renfrew JM (1973) Palaeoethnobotany. The prehistoric food plants of the Near East and Europe. Routledge, London

Schiffer MB (1983) Toward the identification of formation processes. Am Antiquity 48:675–706

Schoch WH, Pawlick B, Schweingruber FH (1988) Botanical macroremains. Haupt, Stuttgart

Tarrús J (2008) La Draga (Banyoles, Catalonia), an Early Neolithic lakeside village in Mediterranean Europe. Catalan Hist Rev 1:17–33

Valamoti SM (2002) Food remains from Bronze Age Archondiko and Mesimeriani Toumba in northern Greece? Veget Hist Archaeobot 11:17–22

Van der Veen M (1989) Charred grain assemblages from Roman-period corn driers in Britain. The Archaeological Journal 146:302–319

Van Zeist W (1970) Prehistoric and early historic food plants in the Netherlands. Palaeohistoria 14:41–173

Zapata L, Peña-Chocarro L, Pérez Jordà G, Stika H-P (2004) Early neolithic agriculture in the Iberian Peninsula. J World Prehist 18:283–325

Zohary D, Hopf M (2000) Domestication of plants in the Old World. 3rd edn. Oxford University Press, Oxford